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The Use of *Zai* Pits and Integrated Nutrient Management as a Strategy in Improving Maize Grain Yield: A Case of Zvipani Area in Hurungwe

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Abstract

The objective of the study was to assess the effects of *Zai* Pits and Integrated nutrient management on maize productivity. The experiment was set up as randomised complete block design with eight treatments which were replicated three times. The treatments used were *Zai* pits with cattle manure, 30 kg N ha^{-1}; 60 kg N ha^{-1} with cattle manure and with no inputs (ZCM, ZN30, ZC60 and ZN0 respectively) and using conventional tillage with same treatments as control (CCM, CN30, CC60 and CN0) respectively. Maize variety ZS65 was planted on 28 November 2016. The following parameters, grain yield, stover yield and soil moisture content were measured. Grain yield from ZCM was recorded as the highest with 3.91t ha^{-1} followed by 3.79 t ha^{-1} from ZC60 which showed a significant difference ($p< 0.05$) from grain yield for CCM (3.42 t ha^{-1}) and CC60 (3.38 t ha^{-1}) respectively. Stover yield for ZCM (8.69 t ha^{-1}) was highest and significantly different ($p<0.05$) from all other treatments. Moisture content varies among treatments but was not significantly different from each other. Higher yields were recorded form *Zai* pit treatments with cattle manure. *Zai* pits can be beneficial to farmers if used in combination with cattle manure. *Zai* pits stores moisture for longer periods and this sustains maize plant during dry spell. It is recommended to use *Zai* pits as soil moisture conservation option if it is amended with soil fertility options. Farmers are also recommended not to use *Zai* pits without nutrient management options.

Keywords: Zai Pits, Integrated, Nutrient Management, Maize, Zvipani

JEL Classification: Q1, Q15, Q25

Paper Classification: Research Paper

Introduction

Maize production was in a declining trend in Zvipani area due to adoption of tobacco production by many farmers in the area. Most of the farmers reserved good land for tobacco production and grew maize on steep slopes and hilly land where the land is susceptible to erosion. Short growing season, drought and moisture stress are major limiting factors in maize production (Milkias, Tadese & Zeleke, 2018) in the Sub Saharan Africa. Water deficit in the area is because of high surface runoff, which is triggered by steep slopes where farmers grow maize (Kugedera, Kokerai & Chimbwanda, 2018). This is accompanied with high evaporation rates, unexpected droughts and poor rainfall distribution. High evaporation rates cause soil to quickly dry inducing moisture deficit leading to water stress to maize crops (Damiyal, Manggoel, Ali, Dalokom & Mashat, 20017). According to Washington, Harrison & Conway (2004) and Stige, Stave, Chan, Ciannelli, Pretorelli, Glantz, Herren & Stenseth (2006), climate change scenario in Africa is the major contributor to higher temperatures although rainfall varies from West Africa to Southern Africa, with the former receiving higher rainfall than the later. Climate variability leads to seasonal droughts, which mainly hits Zimbabwe together with other southern African countries. Climate change also increases soil erosion especially in steep sloped areas due to poor soil cover. Soil erosion is a global concern as it leads to loss of topsoil and nutrients (Frank, Martinson & Isaac, 2019) leading to a decline in maize productivity in the area. This caused many farmers to abandon their land due to high costs of rehabilitating the land (Mutekwa & Kusangaya, 2006).

The use of irrigation was once used as an option to supplement rainfall during dry spell but due to poor development of irrigation in Zimbabwe, the programme failed leading farmers with no option but to abandon the land. The introduction of several *insitu* rainwater harvesting technologies such as *Zai* pits has the potential to increase land utilisation and maize production (Frank *et al*., 2019) if well adopted by farmers. *Insitu* rainwater harvesting technologies are much simpler, well affordable and can be easily adopted by smallholder farmers who are resource poor (Mudatenguha, Anena, Kiptum & Mashingaidze, 2014). *Insitu* rainwater harvesting technique of *Zai* pits has the capacity to improve rainfall capture, reduce runoff and evaporation together with improving crop productivity (Evet & Tolk, 2009; Frank *et al*., 2019). Digging which is done during construction of *Zai* pits breaks soil pans increasing the potential of soil to store more moisture caused by increased infiltration; increased aeration and harvested water (Kaboré & Reij, 2004; Kimaru, 2017). Integrating *Zai* pits with lime and cattle manure as mulch improves soil structure and crop nutrient availability (Kimaru, 2017). This increases crop nutrient uptake from soil reserves (Kar, Bindroo, Ghosh & Majumder, 2013; Kokerai and Kugedera, 2019). *Zai* pits were shown to increase grain yields 2-69 times compared to conventional tillage system (Fatondji, Martius, Bielders, Vlek, Bationo & Gérard, 2006; Kimaru, 2017; Frank *et al*., 2019). Due to increased water storage in the plant root zone, reduced surface runoff (Nyamadzawo, Wuta, Nyamangara & Gumbo, 2013) and increased crop nutrient uptake, *Zai* pits have greater potential of increasing maize yields (Mwangi, Moebe, Wanjekenche, Onyango, Ngeny & Osore, 2010; Frank *et al*., 2019).

In Zimbabwe maize is regarded as one of the most important cereal crop together with other cereals such as sorghum and wheat (Motsi, Kugedera & Kokerai, 2019. In Zvipani, maize is ranked second to tobacco since most farmers grow tobacco for income generation and maize to produce green mealies. Maize production had declined rapidly in Zvipani area due to adoption of tobacco farming which is used as the major source of income for smallholder farmers. They usually buy maize for sadza from nearby farmers in Magunje and Karoi. There is no information about the use of *Zai* pits to increase maize productivity in Zvipani. The objective of the study was to assess the effects of *Zai* pits and cattle manure on soil moisture, grain and stover yields of maize in Zvipani area in Hurungwe.

Review of literature

Maize production

Maize is ranked first and a major cereal crop in Zimbabwe and is the staple food (Motsi *et al*., 2019). It is the most important cereal crop grown in all Zimbabwe regions although it performs badly in other regions such as region IV and V. It is ranked first in Zimbabwe and third in the world after rice and wheat (Kihanda, Warren & Micheni, 2006; Motsi *et al*., 2019).). Maize production has been noted to be increasing from region 1 where it was grown most to region 4 and 5 (semi-arid areas) where production was very low due to unreliable rainfall receive in the regions (Kanonge, Nezomba, Chikowo, Mtambanengwe & Mapfumo, 2009) due to favourable temperatures for maize production under irrigation. Maize production has increased rapidly in semi-arid areas in the south-eastern regions of Zimbabwe under irrigation (Motsi *et al*., 2019). Rainfed maize production in semi-arid regions is under intense risk due to long mid-season drought caused by unreliable rainfall (Dagnaw, Bagegnehu & Abiy, 2018). According to Kanonge *et al*. (2009) maize grain yield decreased by 60.3 % in 2011 from 508 000 tonnes to 200 000 tonnes as a result of soil moisture stress caused by unreliable low rainfall in arid and semi-arid regions.

It is widely grown in all regions in Zimbabwe but higher production is witnessed in natural region 1 and 2 where rainfall is high, and soils are fertile. Maize production declined from natural region 3 to 5 due to low rainfall received in these areas. Low maize productivity in natural region 4 and 5 is caused by a decline in soil moisture and fertility of the soil which hinders growth rate (Motsi *et al*., 2019). Maize productivity has been at its declining phase in Zimbabwe especially in Hurungwe where farmers prefer tobacco due to high price in market. Farmers allocated maize production on hilly and slope areas where soil is easily eroded. This causes inherent soil fertility as a result of increased soil erosion. Farmers in Hurungwe are now trying to adopt maize production back but poor soil fertility and slope of the land affects the production. The use of integrated nutrient management tied ridges and zai pits can improve maize production (Dagnaw *et* al., 2018). Same observations were also made on sorghum production as reported by Gamachu, Tadele, Eshetu &Ayana (2019) where the use of insitu water harvesting increased sorghum grain yields

Zai pit

Zai pit is an *insitu* rainwater harvesting technique used for soil maintenance, water preservation and soil erosion control. It is a hole dug in the ground but in different sizes depending on the innovation of the farmer. Most of the farmers dig *zai* pits just after harvesting when the soil is moist, to reduce cost and labour. *Zai* pits are believed to originate from Burkina Faso (Danjuma & Mohammed, 2015; Kimaru, 2017; Frank *et al*., 2019) although many farmers apply them in different countries. In Zimbabwe non-governmental organisations (NGOs) are promoting *zai* pits in areas such as Chivi (Gumbo, Snelder, Wuta, & Nyagumbo, 2012), Mwenezi and Buhera. In countries like Mali, Niger and Cameroon farmers use zai pits to improve sorghum, pearl millet and maize productivity. In Niger, smallholder farmers use *zai* pitting system to improve pearl millet productivity (Fatondji, Martius, Bielders, Koala, Vlek & Zougmoré, 2009) and maize production in South Africa (Magombeyi & Taigbeu, 2008), Ethiopia (Amede, Tarawali & Peden, 2011) and in Rwanda to improve maize production (Mudatenguha *et al*., 2014) and sorghum in Zimbabwe (Kugedera & Kokerai, 2019). This system is one of the best methods of storing water and improving crop productivity in most semi-arid and arid region in Africa (Thierfelder & Wall, 2009; Kimaru, 2017; Frank *et al*., 2019; Kugedera and Kokerai, 2019). According to Kathuli & Itabari (2015) and Kimaru (2017) zai pits are dug using the following dimensions, 0.6 m long by 0.6 m wide by 0.6 m deep. In dry areas smallholder farmers plant five (5) maize seeds in each zai pit and nine (9) seeds in each zai pit in wet areas to increase grain yields (Mati, 2005; Kugedera & Kokerai, 2019). These pits can be used for a period of up to 3 years. Smallholder farmers dig and space zai pits at 0.6 m to 0.8 m and are dug in alternate to capture runoff. After digging zai pits, farmers mix soil with mineral fertiliser and organic matter then half fills the pit and place seeds. According to Saha, Mzingirwa & Mangale (2007), Milkias *et al*. (2018) and Frank *et al*. (2019) zai pit technology has been regarded as a rainwater harvesting technique for improving maize production. The technology has been used in Zimbabwe to improve sorghum production as planting pits (Kugedera *et al.*, 2018). In Zimbabwe they are mainly used by poor resource farmers in natural region 4 and 5 to improve soil moisture conservation, preserve water, for soil maintenance and improving maize and sorghum grain yields.

Integrated nutrient management options

Integrated nutrient management options are methods used by farmers to integrate nutrient sources as a way of maximising nutrient availability to crops and to improve oil fertility. The smallholder farmers are resource poor and they are usually located in areas where soil fertility is very poor which negatively affects crop productivity. These options also improve soil properties such as cation exchange capacity, pH and water retention (Mati, 2005; Motsi *et al.*, 2019). The smallholder farmers mainly integrate inorganic and organic fertilisers as integrated nutrient management options (Mugwe, Mugendi, Mucheru-Muna, Odee & Mairura, 2009b; Mugwe, 2017). The use of inorganic fertiliser supplies nitrogen which is one of the most limited macro-nutrient in soil and organic fertilisers such as cattle manure supplies both macro and micro-nutrients which are not found in inorganic fertilisers such as ammonium nitrate (Fuad, Tamado, Jamal, Habte, & Taye, 2017). Cattle manure used as organic fertiliser decomposes slowly releasing nutrients into the soil (Mati, 2005; Mugwe, 2017). Cattle manure is rich in potassium and phosphorous with low nitrogen content as a result of variations in how farmers keep their animals. Cattle manure has been widely used by smallholder farmers, but they failed to utilise it due to lack of knowledge because cattle manure takes time to fully decompose (Barry, Olaleye, Zougmoré & Fatondji, 2009; Damiyal *et al.*, 2017). The use of inorganic fertiliser adds value to cattle manure in terms of nitrogen content and this boosts nitrogen availability in the soil. The use of organic and inorganic fertilisers are the only ways of improving soil fertility and boosting maize grain yield in marginal areas especially farmers in communal areas who are not able to buy large quantities of chemical fertilisers.

Effects of *zai* pits on crop production

The use of Zai pits were reported to increase soil moisture and nutrient availability in the plant root zone. Increasing soil moisture reduces moisture stress and promotes crop growth. The use of Zai pits by farmer can increase soil water retention and maize growth rates (Mudatenguha *et al.*, 2014; Frank *et al.*, 2019). Application of cattle manure and chemical fertilisers increases the nutrient availability in the plant root zone allowing the plants to absorb a lot of nutrients leading to increased cell development. Water stored in zai pits delays the onset and occurrence of water stress (Nyamadzawo *et al.*, 2013; Kokerai and Kugedera, 2019) buffering the damage caused by water stress. Zai pits capture the runoff and increase water availability in the plant root zone reducing crop damage caused by erratic rainfall distribution and dry spells. Zai pits increase water infiltration and reduce runoff of water thereby increasing water uptake by plants (Drechsel, Quansah & Penning de Vries, 2005; Kimaru, 2017). Zai pits has the capacity to increase maize grain yields in the high failure areas in Zimbabwe and Africa at large (Fatondji *et al.*, 2009; Kugedera *et al.*, 2018; Frank *et al.*, 2019). Zai pitting technology can significantly increase the maize grain yields and stover in highly degraded areas which were mostly abandoned by farmers (Kaboré & Reij, 2004). It has been reported that Zai pit technology has the ability to increase grain and stover yields of most cereal crops grown in areas with soils which previously degraded due to unreliable rainfall causing mid-season droughts (Fatondji *et al.*, 2006; Gamachu *et* al., 2019). Report by Kaboré & Reij (2004) indicated that zai pit technology increased the sorghum grain production by 310 kg ha^{-1} compared to treatments with no zai pit technology. In Niger, sorghum grain yields reached a maximum of 969 kg ha^{-1} under zai pitting technology in one year than areas without zai pit technology (Kaboré & Reij, 2004; Gamachu, Beyisa & Tadale, 2018). Zai pit technology increased sorghum grain in Chivi, Zimbabwe compared to conventional tillage (Kugedera *et al*., 2018).

Effects of zai pits and integrated nutrient management on crop production

Zai pits and integrated nutrient management in Niger have been reported to increase the crop production compared to conventional tillage with amendments (Kaboré & Reij, 2004; Kimaru, 2017). The use of integrated nutrient management increases soil fertility by restoring leach and absorbing nutrients by the plants in arable lands. The use of zai pits and integrated nutrient management increases the nutrient availability in the plant root zone thereby promoting crop production (Kugedera *et al*., 2018). Integrated nutrient management is the only solution to restore soil fertility and improve the soil quality as a means of increasing cereal production in smallholder farming areas of Zimbabwe and Africa at large (Motsi *et al*., 2019). The combination of integrated nutrient management and zai pits can be one of the best options of improving the crop production since zai pits harvests a lot of water, reduces surface runoff, increases nutrient availability in the plant root zone leading to increased plant growth rate (Kimaru, 2017; Mugwe, 2017. Imbalanced nutrient application which leads to low nitrogen and phosphorous in the soil can be reduced by integrated application of mineral fertiliser and organic manure to boost nitrogen and phosphorous content in the soil (Ghosh, Dayal, Bandyopadyay & Mohanty, 2006; Milkias *et al*., 2018; Frank *et al*., 2019). Cattle manure added in zai pits improves availability of nutrients in the plant root zone, water holding capacity, regulating pH and improving soil structure leading to reduced leaching of nutrients (Tekle & Wedajo, 2015; Frank *et al*., 2019**)**. This promotes crop production by producing quality grains which are heavier due to the presence of more nutrients absorbed from the soil due to increased availability of plant nutrients (Motsi *et al*., 2019). In areas where zai pits were used as soil and water conservation integrated with organic manure increased crop production but crop production did not increase in areas where only zai pits were used without integrated nutrient management (Kokerai & Kugedera, 2019).

Effects of integrated nutrient management on soil quality and maize productivity

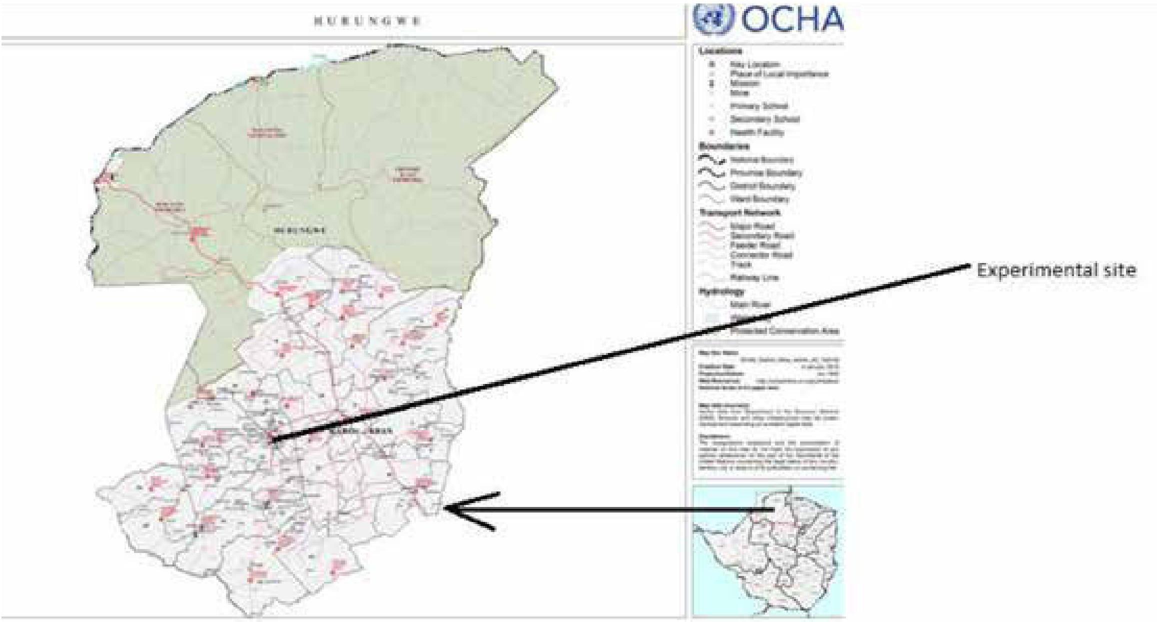
The addition of organic and inorganic fertilisers has the capacity of increasing nitrogen content in the soil and improves soil fertility (Mugwe, 2017). Cattle manure has been reported to improve exchangeable calcium and magnesium in the soil thereby increasing soil cation exchange capacity (CEC) (Kokerai & Kugedera, 2019). It is known that cattle manure improves soil structure by increasing organic matter content in the soil, improving water holding capacity, reducing leaching and regulating soil pH (Motsi *et al*., 2019). The addition of mineral fertiliser increases nitrogen content thus boosting available nitrogen in the soil which later increases plant growth leading to increased maize grain yields (Mati, 2005; Damiyal *et al*., 2017; Kokerai & Kugedera, 2019). Cattle manure also increases microbial activity in the soil due to the increased proportion of decomposable material (Kimaru, 2017; Mugwe, 2017). The organic matter content of the soil regulates soil temperature hence promoting activities of soil organisms which helps decomposition of cattle manure (Kugedera *et al*., 2018).

Methods and Materials

Study Area

The experiment was carried out at Zvipani area (16.9844° South and 29.2257° East) at a farm owned by Zvikonyaukwa Jesse in Hurungwe at an elevation of 1051 m. The area is 45 km from Magunje town. The area is characterised with sandy loam soils. On average it receives 550 to 600 mm per annum and temperature ranges from 16 °C to 32°C similar to Chivi (Kugedera, 2016).

Fig 1: Map showing Location of Zvipani in Hurungwe (Source: Google)



Experimental Design

Zai pits treatments (planting pits with not amendments (ZN0), planting pits with cattle manure (ZCM), planting pits with cattle manure + 60kg N/ha (ZC60) and planting pits with 30 kg N/ha (ZN30)) were compared with planting maize on flat land which was used as the control experiment. Randomised complete block design with three replications was used in the experiment. Experimental plots were planted on 28 November 2016. Land preparation was done using ox-drawn plough up to 30 cm deep. *Zai* pits were done using a hoe to a depth of 30 cm and 20 cm diameter. The plots were measured 4.5 m x 3.5 m in size with 2 m wide pathways within the block from each plot to prevent inter plot effect. A short season open pollinated variety ZS65 was used in this experiment and planted using a spacing of 0.9 m x 0.3 m to achieve a plant population of 37037 plants per hectare. Cattle manure was applied in ZCM treatments; compound D was applied in ZN30 as basal dressing before planting two seeds in each *Zai* pit. Furrows were opened using ox-drawn plough and maize seeds placed at a spacing of 0.9 m x 0.3 m. Cattle manure and compound D were also applied as basal dressing. Thinning was done three weeks after emergency and one plant was left per hole. Mulching was done using *Hyparrhenia hirta* grass to achieve 100% cover (Kugedera, 2016,).

Data collection

During the study soil samples from experimental plots were collected from six places within the experimental plots randomly using an auger. The per cent moisture was determined using gravimetric moisture method. The soil samples collected were weighed using weighing balance and oven dried at 105 °C for 48 hours and reweighed until constant mass was obtained. Maize grains were harvested from net plots measuring 4.5 m x 2 m after physiological maturity. The grain yield was measured using digital scale and grain moisture meter was used to measure grain moisture content (Mudatenguha *et al*., 2014,).

Data processing and statistical analysis

The data was processed using Microsoft excel and analysed for analysis of variance using IBM SPSS version 25. Means which were significantly different were separated using least significant different (LSD) after F-test was used.

Results

The results show that grain yield was higher from treatments of *Zai* pits integrated with cattle manure as nutrient source where yield of maize grain was 3.91t ha^{-1}. This indicates that the results were significantly different from others ($p < 0.05$). The grain yield from treatments where mineral fertiliser was integrated with cattle manure showed a decline in grain yield with 3.1% compared to control. These results were also similar to the results by Mudatenguha *et al*. (2014). There was a significant difference between grain yield from a combination of *Zai* pits + 30 kg/ha AN (ZN30) and conventional tillage +30 kg/ha AN (CN30) ($p <0.05$) where ZN30 produced 2.89 t/ha and CN30 yielded 2.15 t ha^{-1}. An increase in fertiliser combination for the treatments showed that maize grains significantly increased at harvesting. This was indicated by an increase grain yields from 2.89 t ha^{-1} for ZN30 to 3.79 t $ha^{-1}$for ZN60 and, an increase from CN30 treatment form 2.15 t $ha^{-1}$to 3.38 t $ha^{-1}$for CN60 treatments. The results show that an increase in mineral fertiliser by 100 % increased maize grain yield by 31.1 %. The results also show that there was no significant difference for grain yield obtained from ZN0 and CN0 as indicated by the same superscript, although maize grain yield from ZN0 was 16 % greater than the grain yield obtained from CN0. Grain yield from ZCM treatments was 63.7 % greater than the grain yield from CN0 and 56.8 % greater than yields from ZN0 treatments. The use of *Zai pits* integrated with cattle manure also increased yields by 56.8 % as compared to pits without amendments. The integration of cattle manure with conventional tillage also increased grain yields by 58.5 % as compared to the conventional tillage without amendments. The results also indicate that an increase in mineral fertiliser by 100 % increased maize grain yields by 36.4 %. The results are summarised in Table 1 .

Table 1: Grain, Stover yield and moisture content from the experimental plots

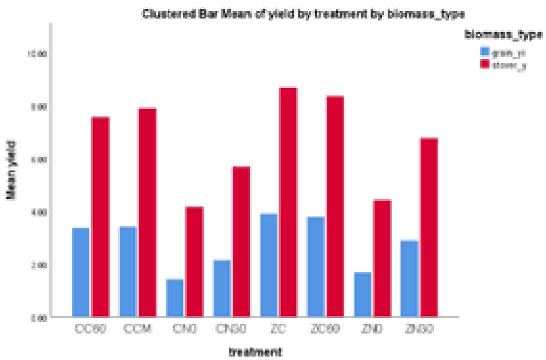
Treatment	*Grain yield (t/ha)*	*Stover yields (t/ha)*	*Moisture (m^3m^{-3})*
ZN0	*1.69^e*	*4.42^f*	*0.21*
ZN30	*2*	*6.75^d*	*0.23*
ZCM	*3.91^a*	*8.69^a*	*0.22*
ZC60	*3.79^{ab}*	*8.35^b*	*0.21*
CN0	*1.42^e*	*4.15^{fg}*	*0.23*
CN30	*2.15^d*	*5.69^e*	*0.21*
CCM	*3.42^b*	*7.90^{bc}*	*0.20*
CC60	3.38^b	7.56^c	0.22

ZCM = planting pits with cattle manure; ZN30 = planting pits with 30 kg N/ha; ZC60 = Zai pits amended with cattle manure + 60 kg N/ha; PN0= planting pits with no amendments; CCM = conventional tillage with cattle manure; CN30 = conventional tillage with 30 kg N/ha; CC60= conventional tillage cattle manure + 60 kg N/ha and CN0= conventional tillage with no amendments.

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

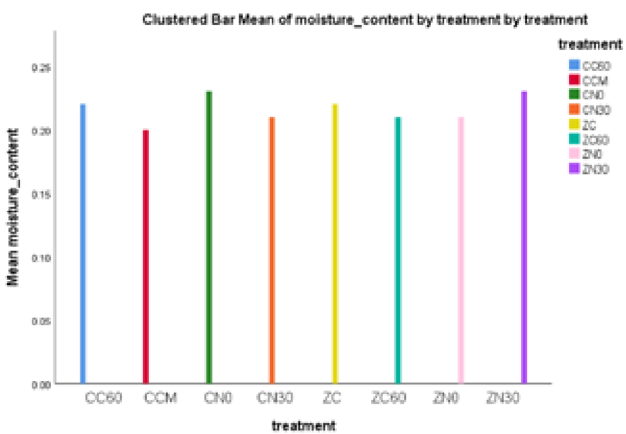
Maize stover yields were higher from ZCM treatment compared to any other treatment and this shows that the results were significantly different from others at $p < 0.05$. ZCM treatment yielded 8.69 t/ha of stover compared to 7.90 t/ha from CCM treatment. Stover yield increased from ZN0, ZN30 and CN0, CN30 treatments to higher yield for ZN60 and CN60 treatments. This shows that stover yields significantly increased compared to other treatments at $p < 0.05$. Maize stover yields from ZCM treatments was 3.91 % greater than Stover yields from ZC60 treatments; 22.3 % greater than Stover yields from ZC30 treatments and 49.1 % greater than Stover yield from ZN0 treatments. An increase in mineral fertiliser applied integrated with *zai* pits increased maize Stover yields with 19.2 %. Stover yield from CCM (7.90 t ha^{-1}) was not significantly different from Stover yields obtained from CC60 (7.56 t ha^{-1}) treatments as indicated by same superscript shown in Table 1 . The results indicate that an increase in mineral fertiliser by 100 % integrated with conventional tillage increased maize Stover yields by 24.7 %. In general maize Stover yields were higher from *zai* pits treatments regardless of the amendments used. On average the results show that Stover yield was higher than grain yield from all treatments as shown on Fig 2 .

Fig 2: Yield of grain and stover from all treatments



Soil moisture content results indicate that there was no significant difference between all treatments regardless of the amendments used. Soil moisture content results were highest for ZN30 and CN30 treatments. Soil moisture content varies between 0.20 and 0.23 m^3m^{-3} (Table 1 and Fig 3).

Fig 3: Soil moisture content for all treatments during the growing season



Discussion

Study results indicated that *Zai* pits can be beneficial to farmers if well adopted as indicated by an increase in grain yield from *Zai* pits treatments. The results show significant increase in yield from *Zai* pits treatments and these results coincide with results from Kihara, Bationo, Waswa & Okeyo (2009), Mudatenguha *et al.* (2014) and Kimaru (2017). Results from treatments amended with cattle manure were higher caused by increased water retention and improved soil fertility. This coincides with results by Fatondji *et al*. (2009) who found that grain yield was higher from *Zai* pits and conventional tillage amended with cattle manure than those not amended. This also concurred with findings by Mugwe (2017) who reported that the use of cattle manure increases grain yields of sorghum and maize. *Zai* pits amended with N fertiliser and cattle manure showed significant increase in grain yield as well as Stover yields. The results also concurred with findings by Wall & Thierfelder (2009) in Mozambique and in Niger (Fatondji *et al*., 2009). These results were also further affirmed by Damiyal *et al.* (2017) who reported significant increase in maize grain after using cattle manure as a source of nutrients. The results also indicated an insignificant increase in grain yield in CCM and CC60 treatments. This was due to the insignificant content in nutrients and moisture content between the treatments. On an average, the results indicated that more yields were received from *Zai* pits treatments due to availability of nutrients in the root zone area and higher moisture content in these treatments (Munodawafa & Zhou, 2008). Zai pits treatments increased infiltration of water and stores water for more periods compared to conventional tillage (Roose, Kaboré & Guenat, 1999). Higher Stover yield was because of high nutrient and moisture content in amended treatments, which increased plant growth. There is high correlation to yield of grain and stover as indicated by increased stover yield due to increase grain yield. Insignificant difference between moisture content of treatments was due to same depth used for land preparation although *zai* pits were prepared using hoe.

Conclusion

On average, basing on the results of the study *Zai* pits integrated with cattle manure increased maize grain and stover yields due to moisture and nutrient conservation. Moisture retention caused by cattle manure was a significant cause of higher grain and stover yield in ZC and CCM treatments. The use of *Zai* pits can be a good strategy to increase grain yield for food and stover yield for animal feeds. Amending zai pits and conventional tillage with cattle manure can be a great sustainable strategy for resource poor smallholder farmers. Use of N fertiliser only affected soil pH and this may reduce grain and stover yield as well as reducing moisture content due to the high water loss as soils become poor in structure (Patel, Patel, Patel, Patel & Desai, 2013).

Recommendations

Smallholder farmers are recommended to use *zai* pits integrated with cattle manure as this increased both maize grain and stover yields. Farmers in most rural communities of Zimbabwe are resource poor so they are not much recommended to use mineral fertiliser as a sole application due to high costs and it causes soil acidity with increased use which leads to decreased maize grain and stover yields. Smallholder farmers are also recommended to prepare *zai* pits when soil is moist just after harvesting to reduce labour costs and to save time for other farming activities. Farmers are also recommended to construct *zai* pits where they were constructed during previous season as a way of increasing utilisation of cattle manure as it decomposes slowly. This also saves manure for other arable lands. Farmers are also recommended to plant 2-3 seeds per hole as this increases grain and stover yields.

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