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Effects of integrated nutrient management and tied ridges on maize productivity in dry regions of Zimbabwe

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ABSTRACT

Low maize productivity in smallholder farming areas of Zimbabwe especially in semi-arid and arid areas are largely caused by moisture stress and inherent soil fertility. The aim of the study was to assess the effects of integrated nutrient management and tied ridges on maize productivity. The experiment was carried out in Mashava area which is to the south eastern part of Zimbabwe in Masvingo Province. Randomised Complete Block Design was used with three main treatments namely cattle manure, inorganic fertiliser and water harvesting techniques of tied ridges. Data collected was based on grain, stover yields and 1000 grain weight. Grain and stover yields were calculated after harvesting net plot. 1000 grain weight was measured by collecting 1000 grains from every treatment and was measured using digital scale. The results show that there was significant different ($p<0.001$) between the treatments with cattle manure and those with inorganic fertiliser only. An average grain yield of 3.05 t/ha was recorded for 100 kg N/ha + 5 tonnes cattle manure/ha ($TN_{100}C_5$) treatments during the 2017/2018 farming season which was lower than grain yield obtained during the 2018/2019 farming season for the same treatments (3.13 t/ha). The results show that there was a significant difference ($p<0.001$) on the effect of season and treatments on stover yields. Treatments with 50 kg N/ha + 5t/ha cattle manure recorded the highest stover yield of 5.29 t/ha for the 2018/2019 farming season. The findings show that 1000 grain weight was higher for the 2018/2019 farming season as compared to the weight obtained during the 2017/2018 farming season for all treatments. There was a significant difference ($p=0.02$) on the effects of season on 1000 grain weight. Treatments with cattle manure recorded higher 1000 grain weight compared to those without cattle manure. The use of cattle manure and tied ridges has the possibility of increasing grain, stover yields and 1000 grain weight. Farmers are recommended to use cattle manure at 5t/ha or more to improve soil fertility, structure, regulate pH and increase yields.

Keywords: *Cattle manure, integrated nutrient management, Maize stover, Tied ridges, Dry regions*

1. INTRODUCTION

Maize (*Zea mays* L.) production has been declining in dry regions of Zimbabwe due to climate change, increased droughts and long dry spells during the growing season (Motsi *et al*., 2019). Low rainfall received has also contributed to crop failure, decline in food security and increased food insecurity. Maize production has been declining in Zimbabwe to a point where only farmers in high rainfall areas only manage to produce food for their consumption and little for sale. The introduction of integrated nutrient management and water conservation has been successfully used by smallholder farmers to improve soil fertility and maize productivity (Mugwe, 2017). Maize is ranked first in Zimbabwe since it is the staple food for the majority of people in Southern Africa. The use of integrated nutrient management options and rainwater harvesting has been indicated as the only option to boost productivity in smallholder farming areas (Vanlauwe *et al*., 2010; Nyamadzawo *et al*., 2013; Mudatenguha *et al*., 2014). Soil fertility management options increase nutrient availability in the soil for crops (Mugendi *et al*., 2004; Vanlauwe *et al*., 2010) and this improves both plant growth and nutrient absorption. Rainwater harvesting techniques such as tied ridges; harvest and store water efficiently for use by crops (Milkias *et al*., 2018) which if amended with organic and inorganic fertiliser leads to increased crop yield. In Sub Saharan countries maize production has been low due to poor soil fertility, poor farming methods and low rainfall received (Kanonge *et al*., 2009; Motsi *et al*., 2019). Smallholder farmers are resource poor and unable to apply recommended rates of fertiliser. According to Morris *et al*. (2007) fertiliser application by smallholder farmers was 3.5 kg/ha which was too low compared to 300 kg/ha which is recommended. Most farmers in the smallholder farmers are harvesting low maize

yields of less than 1 tonne per hectare. Smallholder farmers in African countries who own cattle does not apply cattle manure and this has also contributed to poor yields (World Bank, 2006; SIMA, 2008). According to Kanonge *et al*. (2009) farmers can apply cattle manure to improve soil fertility and other soil physical properties. The objective of this study was to assess the effects of integrated nutrient management and tied ridges on maize productivity.

2. MATERIALS AND METHODS

Study area

The study was carried out in south eastern part of Zimbabwe as an on-farm station experiment located in Masvingo district between 20º 2′ 43″ S and 30º 40′ 29″ E. The area is characterised by sandy loam soils which are deep and moderately fertile soils. The area is characterised with *Terminalia-Combretum* species associated with few Mopane trees on the river banks of Shashe River. The area lies on the meandering section of Shashe River. The area receives 450-500 mm of rainfall per annum on average and temperatures ranges from 18 º C minimum and 32 ºC maximum. This area is mainly composed of small scale commercial farms and few smallholder farmers in the adjacent of the ward.

Experimental Design and Treatments

Randomised Complete Block Design was used with three main treatments namely cattle manure, inorganic fertiliser and water harvesting techniques. Cattle manure was applied at a rate of 0 and 5 t/ha, inorganic fertiliser at a rate of 0 kg N/ha, 50 kg N/ ha and 100 kg N /ha and tied ridges as rain water harvesting technique. Tied ridges were spaced 2 metres in width and ridges were 35 cm in height. Cross ties were placed at 10 m intervals at a height of 25 cm to prevent damages caused by flowing water. Maize plants were spaced at 0.9 m between rows and 0.3 m within the row to achieve a plant population of 37 037 plants/ ha. Plots used were measuring 10 m by 7 m and a net plot of 4.5 m by 4.5 m was marked in each experimental plot. The treatments were replicated three times.

Land preparation

The trials were established on a farmer field during the short rain season (December 2017 to March 2018 and December 2018 to March 2019) and a short season variety SC 303.Land was ploughed using ox-drawn plough to a depth of 36 cm. Ridges were made using the plough and ties were placed using hand hoe. Cattle manure was applied at before planting in opened farrows using ox-drawn plough. Fertilisers 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 twice using hand hoe weeding.

Table 1. Experimental treatments used

No.	N kg/ha	Cattle manure (t/ha)	Rainwater harvesting	Treatment combinations
1	0	0	Tied Ridge	TN_0C_0
2	0	5	Tied Ridge	TN_0C_5
3	50	0	Tied Ridge	$TN_{50}C_0$
4	50	5	Tied Ridge	$TN_{50}C_5$
5	100	0	Tied Ridge	$TN_{100}C_0$
6	100	5	Tied Ridge	$TN_{100}C_5$

Data collection

Harvesting was done using hand hoe to cut maize in the net plot and a sharp knife was used to remove husks. All cobs from each plot/ treatment were collected and separately placed in different sacks which were well labelled.

Grain and stover yield

Grain and stover yields were measured from plants harvested from the net plots, 120 days after planting. Ears and stover were sun dried for 7 days; ears were threshed and weighed at 12 % moisture content. Grain yield was then converted from kilogrammes per net area to tonnes per hectare (t/ha).

$$\text{Grain yield (kgha}^{-1}) = \frac{Yield\ in\ the\ treatment \times 10000}{Harvest\ area}$$

Where harvest area = 20.25 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^{-1}.

$$\text{Stover yield (kgha}^{-1}) = \frac{Yield\ in\ the\ treatment \times 10000}{Harvest\ area}$$

Where harvest area = 20.25 m^2 and 10000 m^2 is equivalent to area of one hectare.

Data analysis

Data was processed using Microsoft excel and analysed for analysis of variance (ANOVA) using IBM SPSS version 25. Means were separated using least significant different (LSD) at 0.05 to identify means which were significantly different. Results were presented using tables, figures and texts. Figures were generated using IBM SPSS version 25 using calculated mean grain, stover and 1000 grain weight.

3. RESULTS AND DISCUSSION

Effects of integrated nutrient management and tied ridges on grain yields

The results show that there was a significant difference ($p<0.001$) between the treatments. Highest grain yield was recorded from treatments with 100 kg N/ha + 5 t/ha cattle manure for both seasons. An average grain yield of 3.05 t/ha was recorded for $TN_{100}C_5$ treatments during the 2017/2018 farming season which was lower than grain yield obtained during the 2018/2019 farming season for the same treatments which was 3.13 t/ha (Table 2). The results coincides with findings by Muna-Mucheru *et al*., (2007)

who reported an increase in grain yields of maize after using cattle manure as organic fertiliser. Treatments with sole 100 kg N/ha ($TN_{100}C_0$) recorded lower grain yield (1.93 t/ha) compared to $TN_{100}C_5$ treatments which recorded 36.7 % higher during the 2017/2018 farming season. The results coincides with findings by Milkias *et al*., (2018) who indicated that tied ridges are efficient in storing water and increase yield if added nutrient sources.

Control treatments (TN_0C_0) recorded the lowest grain yield for both season which were an average of 1.20 t/ha and 1.24 t/ha for the 2017/2018 and 2018/2019 farming seasons respectively. On average control grain yields were 60.7 % and 60.4 % less than yield from $TN_{100}C_5$ treatments for the 2017/2018 and 2018/2019 farming seasons respectively. The findings also indicated that there was significant difference ($p = 0.022$) between grain yields obtained from different seasons regardless of treatments. Treatments with 5 t/ha cattle manure and 50 kg N/ha recorded second highest yields for both farming seasons as indicated in Table 2 and Figure 1. The results are also in agreement with findings by Muna-Mucheru *et al.,* (2007) who reported that the use of cattle manure increases nutrient availability hence promote plant growth and increase yields. Same sentiments were further affirmed by Motsi *et al.,* (2019) who indicated that addition of 5 t/ha cattle manure amended with inorganic fertiliser increases both grain yields of maize. The results also show that there was no significant difference on the effects of interaction of season and treatments on grain yields with $p = 0.434$. The findings also show that grain yields for the 2018/2019 farming season was higher than grain yields for the 2017/2018 farming season except for grain yields from $TN_{100}C_0$ treatments which recorded higher grain yields in the 2017/2018 farming season than grain for the 2018/2019 farming season (Figure 1).

Effects of integrated nutrient management and tied ridges on stover yields

Treatments which recorded higher grain yields also recorded higher stover yields. Treatments with 100 kg N/ha and 5t/ha cattle manure ($TN_{100}C_5$) recorded the highest stover yields of 5.16 t/ha and 5.17t/ha for the 2017/2018 and 2018/2019 farming seasons respectively. The findings also show that addition of cattle manure to 100 kg N/ha increased stover yields due to accumulation of nutrients in the stover. These results coincide with report by Kanonge *et al.,* (2009) who reported that the use of organic and inorganic minerals has a significant effect on maize grain and stover. This was also supported by Bationo *et al*., (2004) and Kokerai and Kugedera (2019) who reported an increase in sorghum stover yield in all treatments; were 5 t/ha cattle manure was used. Control (TN_0C_0) treatments recorded lowest stover yields for both seasons. Results in Table 3 show that control treatments recorded 4.36 t/ha and 4.46 t/ha of stover for the 2017/2018 and 2018/2019 farming seasons respectively. This coincides with results by Kugedera *et al*., (2018) who reported that insitu rainwater harvesting without amendments showed no significant effect on both grain and stover yields of sorghum.

The results show that there was a significant difference ($p<0.001$) on the effect of season and treatments (Table 3) on stover yields. Treatments with 50 kg N/ha + 5t/ha cattle manure recorded the highest stover yield of 5.29 t/ha for the 2018/2019 farming season. Higher stover yields were also correlated to higher grain yields. Tied ridges harvest rainwater and this facilitates absorption of nutrients, promote plant growth and increase both stover and grain yields. Cattle manure also supplies all the required nutrients which promotes plant growth, improves plant health and quality leading to higher yields for both grain and stover yields. The results concurs with findings by Nyamangara *et al*., (2005) who reported that cattle manure improves soil structure hence more effective to increase crop productivity and this was further affirmed by Nyamangara *et al*. (2005) and Tirol-Padre *et al*. (2007) who reported that organic amendments have significant effects on soil parameter leading to improved wheat straw. Mudatenguha *et al*. (2014) also reported that the use of insitu rainwater harvesting amended with organic and inorganic fertiliser increase grain and stover yields. Results from this study also agree with findings by Vanlauwe *et al*. (2010) who reported the integrated soil fertility management improves crop productivity.

These results indicated that cattle manure can significantly cause a positive effect on stover yields because it supplies both macro and micronutrients (Wuta and Nyamugafata, 2012). Cattle manure also improves soil structure, water retention and regulate soil pH to improve crop growth and nutrient absorption by plants (Tirol-Padre *et al*., 2007; Motsi *et al*., 2019). Generally, the 2018/2019 farming season had higher stover yields compared to the 2017/2018 farming season (Figure 2) and these results were significantly different ($p<0.001$). The findings also show that $TN_{50}C_0$treatments recorded lower stover yields to all other treatments except the control treatments only for both seasons and the yields were 8.9 % less than the highest stover yield for the 2017/2018 farming season and 7.8 % less than the highest stover yield for the 2018/2019 farming season. The results also indicated that the interaction of season and treatments had no significant effects on stover yields ($p=0.141$). All treatments with no cattle manure recorded low stover yields compared to treatments with cattle manure irregardless of the season.

Effects of integrated nutrient management and tied ridges on 1000 grain weight

The results show that control treatments recorded low 1000 grain weight compared to the rest of the treatments. The lowest 1000 grain weight recorded was 320.7 g during the 2017/2018 farming season and 338 g for the 2018/2019 farming season. Highest 1000 grain weight was recorded from $TN_{100}C_5$ treatments which had average of 390 g and 389.3 g for the 2017/2018 and the 2018/2019 farming seasons respectively. The findings also reveal that addition of cattle manure increase weight of grains irregardless of seasons and treatments. These results coincides with results by Motsi *et al*., (2019) who reported that 1000 grain weight is positively correlated to grain yield where all treatments with higher grain yields recorded higher 1000 grain weight. The results also show that there was significant different ($p=0.002$) on the effects of season on 1000 grain weight (Table 4). Results also indicate that there was significant different ($p <0.001$) on the effects of treatments on 1000 grain weight. The interaction of season and treatments had a significant difference ($p=0.005$) on 1000 grain weight.

Results show that $TN_{50}C_5$ treatments recorded 1000 grain weight which was not different which were 373 grams and 373.3 grams for the 2017/2018 and 2018/2019 farming seasons respectively. Findings from the study show that 1000 grain weight was highest from grains harvested in the 2018/2019 farming season for all other treatments except for $TN_{100}C_0$ treatments which recorded 368 grams during the 2017/2018 farming season which was 2.4 % higher than weight recorded during the 2018/2019 farming season (Figure 3).

Table 2. Effects of integrated nutrient management and tied ridges on grain yields

Treatment combinations	Mean Grain yield (t/ha)	
	Farming Seasons	
	2017/2018	2018/2019
TN_0C_0	1.20	1.24
TN_0C_5	1.62	1.72
$TN_{50}C_0$	1.56	1.64
$TN_{50}C_5$	2.11	2.13
$TN_{100}C_0$	1.93	1.90
$TN_{100}C_5$	3.05	3.13
SEM	0.261	0.263
P-value	<0.001	<0.001

TN_0C_0 = tied ridges with no inputs; TN_0C_5 = tied ridges amended with 5 tonnes cattle manure per ha; $TN_{50}C_0$ = tied ridges amended with 50 kg N/ha; $TN_{50}C_5$ = tied ridges amended with 50 kg N/ha + 5t/ha cattle manure; $TN_{100}C_0$ = tied ridges amended with 100 kg N/ha; $TN_{100}C_5$=tied ridges amended with 100 kg N/ha + 5t/ha cattle manure.

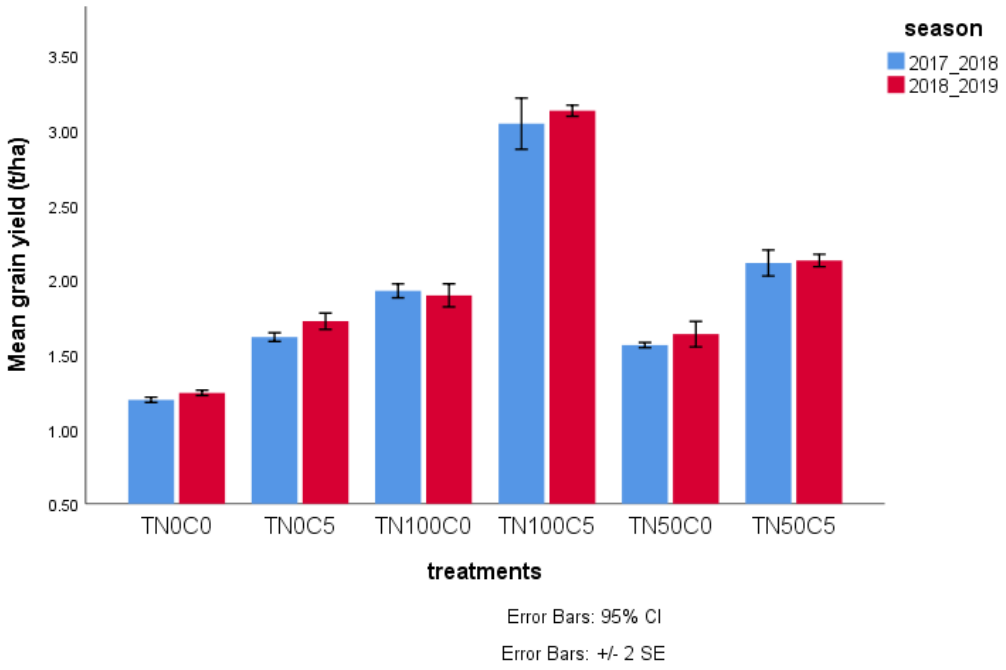

Figure 1. Effects of integrated nutrient management and tied ridges on grain yields

Table 3. Effects of integrated nutrient management and tied ridges on stover yields

Treatment combinations	Mean Stover yield (t/ha)	
	Farming Seasons	
	2017/2018	2018/2019
TN_0C_0	4.36	4.46
TN_0C_5	4.73	4.96
$TN_{50}C_0$	4.70	4.88
$TN_{50}C_5$	5.16	5.29
$TN_{100}C_0$	4.94	4.99
$TN_{100}C_5$	5.16	5.17
SEM	0.126	0.117
P-value	<0.001	<0.001

TN_0C_0 = tied ridges with no inputs; TN_0C_5 = tied ridges amended with 5 tonnes cattle manure per ha; $TN_{50}C_0$ = tied ridges amended with 50 kg N/ha; $TN_{50}C_5$ = tied ridges amended with 50 kg N/ha + 5t/ha cattle manure; $TN_{100}C_0$ = tied ridges amended with 100 kg N/ha; $TN_{100}C_5$=tied ridges amended with 100 kg N/ha + 5t/ha cattle manure.

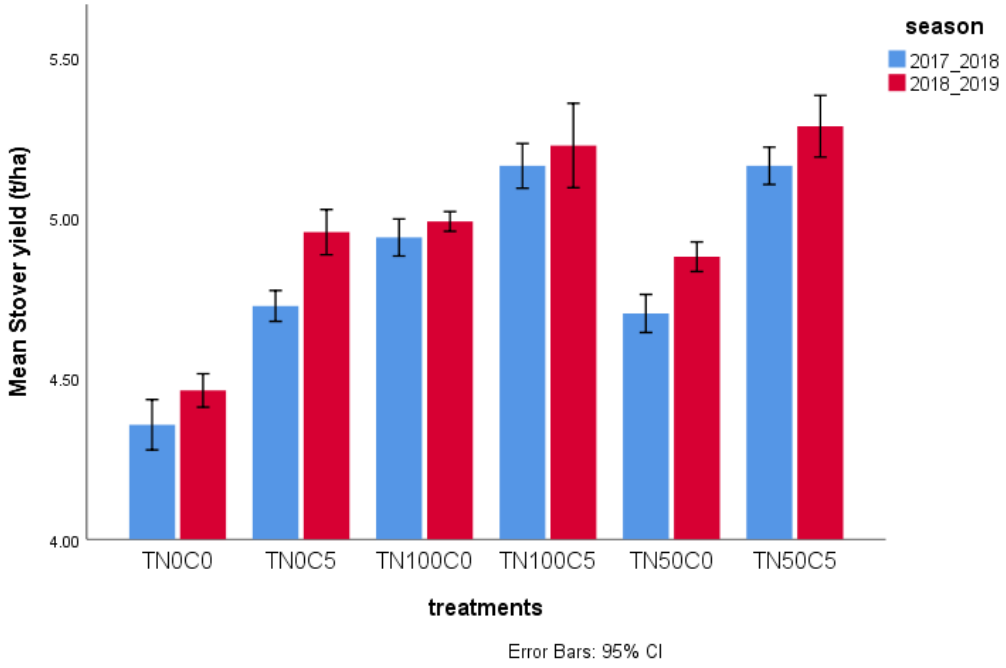

Figure 2. Effects of integrated nutrient management and tied ridges on stover yields

Table 4. Effects of integrated nutrient management and tied ridges on 1000 grain weight

Treatment combinations	Mean 1000 grain weight (grams) for different farming seasons	
	2017/2018	2018/2019
TN_0C_0	320.7	338.0
TN_0C_5	339.3	365.3
$TN_{50}C_0$	340.3	364.3
$TN_{50}C_5$	373.0	373.3
$TN_{100}C_0$	368.0	359.3
$TN_{100}C_5$	390.0	389.3
SEM	10.6	6.88
P-value	0.002	0.002

TN_0C_0 = tied ridges with no inputs; TN_0C_5 = tied ridges amended with 5 tonnes cattle manure per ha; $TN_{50}C_0$ = tied ridges amended with 50 kg N/ha; $TN_{50}C_5$ = tied ridges amended with 50 kg N/ha + 5t/ha cattle manure; $TN_{100}C_0$ = tied ridges amended with 100 kg N/ha; $TN_{100}C_5$=tied ridges amended with 100 kg N/ha + 5t/ha cattle manure.

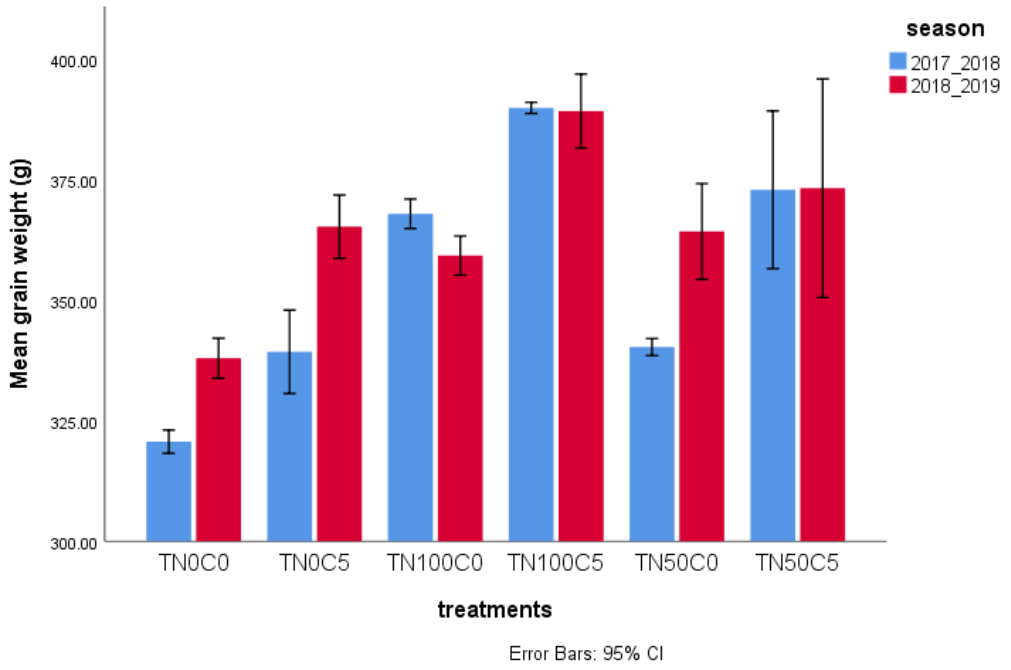

Figure 3. Effects of integrated nutrient management and tied ridges on 1000 grain weight

4. CONCLUSIONS

Integrated nutrient management and tied ridges had significant effect on grain, stover and 1000 grain weight. Integrated nutrient management options where cattle manure was used at 5t/ha and 100 kg N/ha positively influenced grain, stover and 1000 grain weight. The results had shown that cattle manure largely improves soil fertility, regulate soil pH, improve soil structure and water retention which promotes plant growth and quality yields. Cattle manure supply both macro and micro-nutrients which are needed by plants to support growth and initiation of fertilisation. Availability of nutrients from cattle manure improves grain filling. The use of inorganic fertiliser supplies a lot of nitrogen which is the most limiting nutrient and this promote chlorophyll formation leading to increased photosynthesis which facilitates high quality yields. The use of inorganic fertiliser in large quantities negatively affects soil pH since inorganic fertilisers are manufactured using acidic chemical compounds. Therefore farmers are recommended to use a lot of cattle manure since it is readily available at low cost compared to inorganic fertiliser which is expensive for resource poor farmers.

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