ACTA SCIENTIFIC MICROBIOLOGY (ISSN: 2581-3226)

Volume 2 Issue 8 August 2019

Research Article

Effects of Integrated Nutrient Management and Water Harvesting Technique (Tied Ridges) on Grain and Stover Yields of Pearl Millet

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Received: June 13, 2019; **Published:** July 05, 2019

DOI: 10.31080/ASMI.2019.02.0297

Abstract

Low crop productivity has been caused by moisture stress and inherent soil fertility. The main objective of the study was to assess the effects of integrated nutrient management and rainwater harvesting on grain and stover yields. The study was carried out as an experiment in ward 26 of Gutu district as a complete randomised block design with two main factors of conventional tillage and tied ridges and sub-factors were inorganic fertiliser (0, 50, 100Kg N ha^{-1}) and cattle manure (0, 10t ha^{-1}). Grain yield was measured after threshing the panicle, winnowed and measured using digital scale. Stover yield was measured after cutting plant residues into smaller pieces and measure using digital scale. Data was subjective to analysis of variance (ANOVA) using IBM SPSS version 25. The results of straw and grain yields as affected by water harvesting techniques and soil amendments application showed that the yields from T+100KgN+10TC (1.59tha^{-1}) were higher than yields from C+100KgN+10TC (1.45 tha^{-1}) with 8.8%. Pearl millet grain yield significantly ($P < 0.001$) increased under tied ridge compared to conventional tillage. Application of manure at 10t ha^{-1} and inorganic fertiliser at 100 kg N ha^{-1} recorded the highest stover yield (4.31 ha^{-1} for tied ridges), while the lowest grain yield was obtained under no application of manure and mineral fertiliser (2.98 t ha^{-1}). The results show that integrated nutrient management and rainwater harvesting significantly increase plant height, panicle length, grain and stover yields. Farmers are recommended to use a combination of cattle manure and inorganic fertiliser to improve soil fertility, grain and stover yields.

Keywords: Integrated; Nutrient; Rainwater; Harvesting; Pearl Millet; South-Eastern

Introduction

Food insecurity and soil fertility depletion across much of sub-Saharan Africa in recent decades have led to the pursuit of alternative nutrient management strategies for restoring degraded soils and improving crop yields [1]. Most soils in Zimbabwe have low fertility status mainly as a result of nutrient mining. It is estimated that about 22.5 kg N ha^{-1}, 5.9 kg P ha^{-1} and 27.3 kg K ha^{-1} are lost annually from pearl millet production system [2]. Pearl millet (*Pennisetum glaucum L.*) is the most important rainfed crop in arid and marginal areas of Zimbabwe such as Buhera and Mwenezi. The grain yields of this cereal are low, usually below 514 kg ha^{-1} [3] due to poor rainfall distribution and inherently infertile soils. Poor distribution and scarcity of rainfall as well as low inherent soil fertility are some of the major constraints to cereals production in countries such as Zimbabwe [4], Mali, Botswana and some parts of Zambia. Tabo., *et al.* [5] reported that about 38% of rainfall is lost through runoff.

Pearl millet (*Pennisetum glaucum* L.) productivity in semi-arid areas is primarily limited by low and erratic rainfall [3]. The soils in these areas have prevailing light texture and are shallow with low moisture holding capacity [6]. As a result, rainfall in semi-arid areas is often accompanied by large amounts of surface runoff. This runoff can however, be trapped in situ and encouraged to infiltrate and become available to crops. One way of doing this is through adoption of in situ soil moisture conservation techniques. Such techniques include pot-holing, tied ridging, furrow sowing, earth and stone bunding, pit planting and mulch ripping [3]. These water harvesting techniques increase infiltration and soil water storage and decrease water losses by surface evaporation and thus lead to an increase in the amount of water retained in the soil for subsequent use by crops [4]. In rainfed fields, improvement may come from conserving rainwater in the root zone of crops, and managing the field and the crops to use water more efficiently. According to Bayu., *et al*. [7], improved water use with best fit soil fertility management practices are major pathways for improving crop productivity in smallholder farming systems. The application of inorganic inputs is recognized as a convenient way for rapidly restoring nutrient deficiencies in soils. For economic reasons, smallholder farmers cannot apply the recommended rates of mineral fertilizers [8]. The use of manure has therefore, become the best way to improve soil properties and increase grain yield of cereals [6], but the quantities of manure available to smallholder farmers are low [9]. To address the constraints using manure and mineral fertilizer, Fatondji [10] proposed the combined application of mineral and organic input as an appropriate strategy to improve soil fertility and increase crop yields. The objective of the study was to assess the effects of integrated nutrient management and rainwater harvesting on grain and stover yields.

Methodology

Study area

The experiment was up in the experimental plot at a Farm in ward 26 of Gutu district, Masvingo Province, Zimbabwe. Located within the latitude 20° 28' 43" S and longitude 30° 40' 33" 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 characterised with high temperatures ranging from 17-32°C. The soils of the experimental site were sandy loam soils as indicated in Table 1. The area is characterised with sandy loam soils which if added nutrient amendments can promote crop productivity. The soils are dominated with *Brachstegia spiciformis* and *Terminalia sericea* species. Maize productivity fails to produce maximum yields in the area hence farmers opted to try small grains such as pearl millet and sorghum to boost food security.

Soil parameters	0 – 20 cm depth
pH (1:1 H_2O)	5.65 ± 0.15
Organic C (%)	0.30 ± 0.012
Total N (%)	0.025 ± 0.003
Available P (mg kg-1)	4.06 ± 0.66
Exchangeable bases (cmol$_c$ kg^{-1})	
K	0.18 ± 0.05
Ca	1.13 ± 0.14
Mg	0.68 ± 0.14
Na	0.11 ± 0.03
CEC (cmol$_c$ kg^{-1})	2.50 ± 0.51
Bulk density (g cm^{-3})	1.55 ± 0.02
Sand %	76.02 ± 0.66
Silt %	20.72 ± 0.50
Clay %	4.22 ± 0.31
Texture	Sandy loam

Table 1: Initial soil physical and chemical characteristics of the experimental site.

Experimental designs and treatments

The Complete Randomized Block Design was used in the experiment with two main treatments: conventional tillage (C) and tied ridges (T) as main factors with inorganic fertiliser and cattle manure as sub-factors (Table 2). Different rates of inorganic fertiliser (0, 50 and 100 kgha^{-1} N) and cattle manure (0 and 10 tha^{-1}) was applied. The ridges were made to be of 0.3m in height and the ties were at a height of 0.20m. A total of 12 (4m by 2m) plots were prepared and planted according to the described treatments. There were four rows of sorghum in each plot planted at a 0.90 m row spacing and 15cm plant spacing. Pearl millet seeds were planted at a 50 mm soil depth. Cattle manure was evenly applied for all treatments indicated addition of manure before ploughing.

Cattle manure and mineral fertiliser acquisition

Cattle manure was obtained from a local farmer. Manure consisted of faecal matter, urine and orts was collected from the kraal after accumulating from July to June. The kraal had no roof consequently; manure was exposed to the weather and lost nutrients through leaching, denitrification and volatilization leading to reduced quality. Triple super phosphate (TSP) and ammonium nitrate fertiliser were bought form GMB Gutu.

Treatment No.	Rainwater harvesting	N in Kg /ha	Cattle manure in t/ha	Treatment combination
T1	Conventional	0	0	C+0KgN+0TC
T2	Conventional	0	10	C+0KgN+10TC
T3	Conventional	50	0	C+50KgN+0TC
T4	Conventional	50	10	C+50KgN+10TC
T5	Conventional	100	0	C+100KgN+0TC
T6	Conventional	100	10	C+100KgN+10TC
T7	Tied ridges	0	0	T+0KgN+0TC
T8	Tied ridges	0	10	T+0KgN+10TC
T9	Tied ridges	50	0	T+50KgN+0TC
T10	Tied ridges	50	10	T+50KgN+10TC
T11	Tied ridges	100	0	T+100KgN+0TC
T12	Tied ridges	100	10	T+100KgN+10TC

Table 2: Main treatments and their sub-treatments.

Planting and fertilisation

Pearl millet variety, PV3 was used as the test crop. The planting was done on 25 November 2018. Land preparation was done by hand using hoes, loosening a layer of up to 0-20cm depth. Planting holes were prepared where the soil and cattle manure were mixed. Plot size was 4.5 m x 4.5 m with spacing of 75 cm between the rows and 30 cm within the rows. Two seeds were planted per hole and thinned to one 14 days after emergence. At planting, TSP was applied and incorporated in the planting holes while ammonium nitrate was top dressed in two splits; one at three weeks and another at six weeks after emergence. Fertilisers were pre-weighed for each plot before going to the field and applied using dollop cups to ensure uniform distribution to all plots. The trial was maintained weed free during the entire study period.

Data collection

Grain and stover yield

Plants in the area reserved (net plot) for final harvest were harvested after 150 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 one week. After threshing of ears of each treatment, grain was weighed at 12% moisture content and converted into grain yield (kg ha^{-1}).

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

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^{-1}.

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

Where harvest area = 9 m^2 and 10000 is equivalent to area of one hectare. The final yield was converted to tonnes per hectare (tha^{-1}).

Statistical analysis

Data was analyzed using the IBM SPSS statistics version 25 analysis software (IBM, 2017). Variation among treatments was determined using the descriptive statistics and the means were separated using the least significant difference (LSD).

Results

Effects of integrated nutrient management and water harvesting technique (tied ridges) on grain and stover yields of pearl millet

The results of straw and grain yields as affected by water harvesting techniques and soil amendments application showed that the yields from T+100KgN+10TC (1.59tha^{-1}) were higher than yields from C+100KgN+10TC (1.45 tha^{-1}) with 8.8%. Pearl millet grain yield significantly (P < 0.001) increased under tied ridge compared to conventional tillage. On the other hand, combination of cattle manure and inorganic fertiliser at maximum rates (100Kg N and 10TC) increased the grain yield by 55.9% for conventional tillage and by 46.5% for tied ridges over the treatments without amendments. Combined application of manure and mineral fertilizer significantly (P < 0.001) increased the millet grain yield (Table 3) without considering rainwater harvesting techniques.

Application of manure at 10t ha^{-1} and inorganic fertiliser fertilizer at 100 kg N ha^{-1} recorded the highest stover yield (4.31 ha^{-1} for tied ridges), while the lowest grain yield was obtained under no application of manure and mineral fertilizer (2.98 t ha^{-1}). These results were higher than those from conventional tillage with highest of 4.18t ha^{-1} and lowest of 2.75 t ha^{-1} under same treatments. However, the interactive effect of water harvesting techniques and soil amendments (manure and inorganic fertiliser) was significant (P < 0.05) (Table 3). An increase in both cattle manure and inorganic fertilisers at different rates significantly (P<0.05) increase pearl millet grain and stover yield. An increase of inorganic fertiliser from 0KgN ha^{-1} to 50KgN ha^{-1} increased grain yields by 33.3% for conventional tillage and 31.45% for tied ridge treatments. Stover yields were increased by 14.1% for conventional tillage treatments and by 15.1% for tied ridge treatments

Treatment combinations	Grain yields (tha^{-1})	Stover Yields (tha^{-1})
C+0KgN+0TC	0.64^{h}	2.75^{h}
C+0KgN+10TC	0.91^{f}	3.14^{g}
C+50KgN+0TC	0.96^{f}	3.20^{fg}
C+50KgN+10TC	1.15^{de}	3.48^{e}
C+100KgN+0TC	1.22^{d}	3.72^{d}
C+100KgN+10TC	1.45^{b}	4.18^{b}
T+0KgN+0TC	0.85^{f}	2.98^{h}
T+0KgN+10TC	1.24^{d}	3.28^{f}
T+50KgN+0TC	1.30^{c}	3.51^{e}
T+50KgN+10TC	1.47^{b}	3.87^{c}
T+100KgN+0TC	1.38^{c}	3.84^{c}
T+100KgN+10TC	1.59^{a}	4.31^{a}

Table 3: Effects of integrated nutrient management and water harvesting technique (tied ridges) on grain and stover yield of pearl millet**.**

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

The results are illustrated in Figure 1 which shows a greater comparison of all treatments for both grain and stover yields and also indicates that as quantities of cattle manure and inorganic fertilisers increases, grain and stover yields increase significantly (P<0.05).

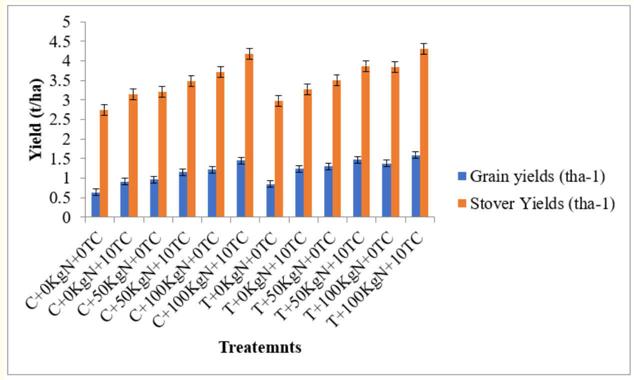

Figure 1: Effects of integrated nutrient management and water harvesting technique (tied ridges) on growth rate of pearl millet.

The results in Table 4 show that interaction of rainwater harvesting, cattle manure and inorganic fertiliser produced the highest grain yield of 1.45t ha^{-1} and application of cattle manure in sole gave the highest stover yield of 3.98 t ha^{-1} compared to 3.96 t ha^{-1} from the interaction of rainwater harvesting, cattle manure and inorganic fertiliser. Application of 100kgN ha^{-1} gave the highest grain yield when applied in sole compared to other forms of fertiliser levels applied in sole. The use of tied ridges without any amendment gave the highest grain and stover yields compared to conventional tillage without amendments. The results show that any form of interaction increases both grain and stover yields compared to sole treatments.

Treatments	Grain Yield	Stover Yield
Water harvesting techniques (A)		
Conventional tillage	0.64	2.38
Tied ridge	0.85	2.52
Fpr	0.03	
Cattle manure (tha^{-1}) (B)		
C0	0.59	2.72
C10	0.98	3.98
Fpr	< 0.001	
Inorganic fertiliser (kgha^{-1}) (C)		
0 N	0.62	2.94
50 N	0.99	3.60
100N	1.05	3.74
Fpr	< 0.001	
Int A x B	1.12	3.15**
Int A x C	1.20	3.21
Int B x C	1.28	3.09**
Int A x B x C	1.45	3.96

Table 4: Effects of integrated nutrient management and water harvesting technique (tied ridges) on grain and stover yields of pearl millet.

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

Int: Interaction, **: not significant at F probability 5 %.

Discussion

Effects of integrated nutrient management and water harvesting techniques on grain and stover yields of pearl millet

The results show that pearl millet grain and stover yields were significantly increased by addition of cattle manure and inorganic fertiliser at different rates. These results concur with results by Qui., *et al*. [11] who reported that addition of cattle manure increases soil fertility, physical and chemical properties of the soil which in turn increase crop growth leading to increased crop yields. Grain and stover yields were increased by 8-20% and 14-16% respectively by adding different rates of cattle and inorganic fertiliser. The results concur with results by Bayu., *et al*. [12] in Kokerai and Kugedera [1] who reported that cattle manure and inorganic fertiliser increase sorghum grain and stover yields by 8-21% and 14-21% respectively. These ranges are also familiar to the ranges in this study. Addition of cattle manure increases microbial population which causes decomposition and allows smooth flow of nutrients leading to higher growth rate, high nutrient uptake by both plant and grain of pearl millet; thus leading to higher yields.

Kouyaté., *et al*. [13] reported that tied ridges integrated with nutrient management has the potential to increase sorghum grain yields to 1.81 t ha^{-1} and Fatondji [10] also reported that rainwater harvesting amended with cattle manure has the potential to increase pearl millet and sorghum grain yields up to 1.10 t ha^{-1} or more depending on application rates. This coincides with results from this study which showed that pearl millet grain yields can be increased up to 1.59t ha^{-1} if tied ridges are amended with 10t cattle manure and 100KgN ha^{-1}. The use of tied ridges and integrated nutrient management has proved to increase pearl millet production significantly than conventional tillage under integrated nutrient management. This concurred with results by Ngetich., *et al*. [14] and Kugedera., *et al*. [4] who reported that the use of tied ridges and planting pits under integrated nutrient management increases sorghum yields that conventional tillage under integrated nutrient management [15,16].

Conclusions

Rainwater harvesting of tied ridges integrated with soil fertility management of cattle manure and inorganic fertiliser at maximum rates was the best techniques and it can be easily adopted by poor resources farmers so that they increase their yields. If managed well tied ridge treatments are the best soil and water conservation option to increase grain yield as compared to tied ridges and conventional tillage. Conventional tillage treatments had the least grain yield compared to planting pits and tied ridges. What farmers need most is high grain yield for their consumption, that's the value farmers gives to these technologies.

Recommendations

The following recommendations were made following finding of the study;

1. Cattle manure and mineral fertiliser are reliable to enhance soil fertility and increase pear millet growth rate, grain and stover yields. Tied ridges are the best way of conserving soil moisture in semi-arid and arid environments where water is a priority compared to conventional tillage.
2. To enhance pearl millet grain yields tied ridges can be used as well as conventional tillage when the farmer have limited labour to construct tied ridges.

Bibliography

1. Kokerai LK and Kugedera AT. "Review: Role of Insitu Rainwater Harvesting and Integrated Soil Fertility Management on Small Grain Productivity". *International Journal of Agriculture and Agribusiness* 2.2 (2019).: 249-259.

2. Food and Agriculture Organization of the United Nations (FAO). The state of food and agriculture. FAO Series No 36. FAO, Rome (2005).

3. Akram, A., *et al*. "Growth, yield and nutrient uptake of sorghum in response to integrated phosphorus and potassium management". *Pakistan Journal of Botany* 39.4 (2007): 1083-1087.

4. Kugedera AT., *et al*. "Effects of insitu rainwater harvesting and integrated nutrient management options on sorghum production". *Global Scientific Journals* 6.12 (2018): 415-427.

5. Tabo R., *et al*. "Improving cereal productivity and farmers' income using a strategic application of fertilizers in West Africa" (2007): 201-208.

6. Palm C., *et al*. "Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database". *Agriculture, Ecosystems and Environment* 83.1 (2001): 27-42.

7. Bayu W., *et al*. "Effects of farmyard manure and inorganic fertilizers on sorghum growth, yield, and nitrogen use in a semiarid area of Ethiopia". *Journal of plant nutrition* 29.2 (2006): 391-407.

8. Adamou A., *et al*. "Improving soil fertility through the use of organic and inorganic plant nutrient and crop rotation in Niger" (2007): 589-598.

9. Mafongoya PL., *et al*. "Appropriate technologies to replenish soil fertility in southern Africa". *Nutrient Cycling in Agroecosystems* 76 (2006): 137-151.

10. Fatondji D. Organic amendment decomposition, nutrient release and nutrient uptake by millet (Pennisetum glaucum L. R. Br) in a traditional land rehabilitation technique (zai) in the Sahel, 2002. PhD dissertation. Ecology and development Series No. 1 2002. Eds: Paul L. Vlek, Manfred Denich, Christopher Martius, Nick van de Giesen (2002).

11. Qiu SL., *et al*. "Effects of fertilization regimes on tea yields, soil fertility, and soil microbial diversity". *Chilean Journal of Agricultural Research* 74.3 (2014): 333-339.

12. Bayu W., *et al*. "The role of manure in sustainable soil fertility management in Sub-Saharan Africa". *Journal of Sustainable Agriculture* 25 (2005): 113-136.

13. Kouyaté Z., *et al*. "Influence of crop management systems on soil properties and sorghum yields in the Sahelian zone of Mali". *African Journal of Agricultural Research* 7.37 (2012): 5217-5223.

14. Ngetich FK., *et al*. "The potential of organic and inorganic nutrient sources in Sub-Saharan African crop farming systems". Soil fertility improvement and integrated nutrient management-a global perspective (2011): 135.

15. Patel HH., *et al*. "Response of Rabi sorghum [Sorghum bicolor (L.) Moench] to land configuration and nutrient management". *BIOINFOLET-A Quarterly Journal of Life Sciences* 10.2 (2013): 387-389.

16. Wang FX., *et al*. "Effects of drip irrigation frequency on soil wetting pattern and potato growth in North China Plain". *Agricultural Water Management* 79 (2006): 248-264.

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