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Research Article

Effects of Integrated Nutrient Management and Water Harvesting Technique (Tied Ridges) on Growth Rate of Pearl Millet

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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 pearl millet growth rate. The study was carried out as an experiment was carried out 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}). Data collection for plant height and panicle length was measured using tape measure on five randomly selected plants on the net plot and mean was calculated. Data was subjective to analysis of variance (ANOVA) using IBM SPSS version 25. The results show that pearl millet in tied ridge treatments had the highest height of 198.15 cm compared to 169.12 cm from conventional tillage. The results show that there was a significant (P<0.05) different between tied ridges and conventional tillage. Height from tied ridges treatments was 14.7% higher than those from conventional tillage. Pearl millet height from plots with 10 tha^{-1} cattle manure (201.61 cm) was 12.6% higher than height from pearl millet in 0 tha-1 cattle manure (176.25 cm). Under inorganic fertiliser management it was 100 kg N ha-1 > 50 kg N ha^{-1} > 0 kg N ha^{-1}. Pearl millet height from 100 kg N ha^{-1} (202.22 cm) was 2.6% higher than height from 50 kg N ha^{-1} (196.87 cm) treatments and 15.7% greater than height from 0 kg N ha^{-1} (170.48 cm) treatments. Water harvesting techniques and soil amendments significantly (P < 0.05) affected pearl millet height. Pearl millet in tied ridge treatments had the highest panicle length of 22.25 cm compared to 20.70 cm from conventional tillage. The results show that integrated nutrient management and rainwater harvesting significantly increase plant height and panicle length. Farmers are recommended to use a combination of cattle manure and inorganic fertiliser to improve soil fertility to improve plant height and panicle length.

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

Pearl millet (*Pennisetum glaucum* L.) productivity in semi-arid areas is primarily limited by low and erratic rainfall [1]. The soils in these areas have prevailing light texture and are shallow with low moisture holding capacity [2]. 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 [1]. 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 [3,4]. By so reducing runoff through increased infiltration and storage of water in the soil profile, the onset and occurrence of severe water stress is delayed thereby buffering the crop against damage caused by water deficits during dry periods (Nyamadzawo., *et al.* 2013). High soil water potential under effective moisture conservation techniques also increases the plant nutrients uptake capacity and the ability of soils to supply nutrients [5]. Kinama., *et al*. (2005) noted that reduced soil evaporative losses under mulches can provide additional 20–25 mm soil moisture for crop transpiration.

The first effect of water deficit on pearl millet growth is reduced leaf and tillers number [6,7] and decreased shoot and height growth (Stone., *et al*. 2001; Soler., *et al*. 2007). This lowers pearl millet leaf area index development which compromises light interception, thus leading to less allocation of biomass to stem and grain [8,9]. A considerable reduction also occurs in the pearl millet stomatal conductance, leading to an interruption of CO2 assimilation. Under such conditions, the water reserves of the plants may be consumed leading to death of pearl millet plants (Sinclair, 2000). Wang., *et al*. [9] reported that phosphorous deficiency could be one of the earliest effects of mild to moderate levels of water stress with its uptake decreasing with decreasing soil moisture in pearl millet. A decrease in soil potassium uptake by pearl millet may also occur with increasing moisture stress [10]. Nagaz., *et al*. [8] however, observed an increase in uptake of potassium in pearl millet with increasing water stress indicating that K is absorbed preferably to N and P under water-stress conditions.

Consequently, evaluation of soil water harvesting techniques should be carried out together with nutrient inputs. Such studies are, however, rare in the Sahelian agro ecological zone of Mali. Considering the low inherent soil fertility of the soil in the Sahelian zone and the arid nature of climate, it is imperative for the smallholder millet farmers to combine manure, inorganic fertilizers and appropriate water harvesting techniques to increase grain yield. The objective was to determine the effects of integrated nutrient management and water harvesting technique (tied ridges) on growth rate of pearl millet.

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. 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.

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.

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.

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

Panicle length

Panicle length was measured using tape measure at maturity stage. Five (5) plants were randomly selected from each plot in the net plot area. The averages were recorded.

Plant height

Plant height was measured at maturity stage. In each plot, five (5) plants were randomly selected and the height measured with a tape measure. The averages were recorded.

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 growth rate of pearl millet

Millet height during 2018/2019 cropping season are presented in Table 3. The results show that millet height was significantly affected by water harvesting techniques as well as by integrated nutrient management. The following trend was observed under water harvesting techniques: tied ridge > convention tillage. Pearl millet in tied ridge treatments had the highest height of 198.15 cm compared to 169.12 cm from conventional tillage. The results show that there was a significant (P<0.05) different between tied ridges and conventional tillage (Table 3). Height from tied ridges treatments was 14.7% higher than those from conventional tillage. The trend under cattle manure management options was C 10t ha^{-1} > C 0 t ha^{-1}.

Pearl millet height from plots with 10 tha-1 cattle manure (201.61 cm) was 12.6% higher than height from pearl millet in 0 tha^{-1} cattle manure (176.25 cm). Under inorganic fertiliser management it was 100 kg N ha^{-1} > 50 kg N ha^{-1} > 0 kg N ha^{-1}. Pearl millet height from 100 kg N ha^{-1} (202.22 cm) was 2.6% higher than height from 50 kg N ha^{-1} (196.87 cm) treatments and 15.7% greater than height from 0 kg N ha^{-1} (170.48 cm) treatments. Water harvesting techniques and soil amendments significantly (P < 0.05) affected pearl millet height. The effects of water harvesting and soil amendments on pearl millet show that there was no significant different (P>0.05). The combined use of water harvesting techniques and manure application significantly (P < 0.05) increased plant height at maturity stage.

Treatments	Plant height (cm)
	Maturity Stage
Water harvesting techniques (A)	
Conventional tillage	169.12^{bc}
Tied ridge	198.15^{a}
Fpr	0.03
Cattle manure (tha^{-1}) (B)	
C0	176.25^{b}
C10	201.61^{a}
Fpr	< 0.001
Inorganic fertiliser (kgha^{-1}) (C)	
0 N	170.48
50 N	196.87^{a}
100N	202.22^{a}
Fpr	< 0.001
Int A x B	195.12**
Int A x C	199.87**
Int B x C	197.8**
Int A x B x C	203.05**

Table 3: Effects of water harvesting technique (tied ridges) and soil amendments on pearl millet height.

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

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

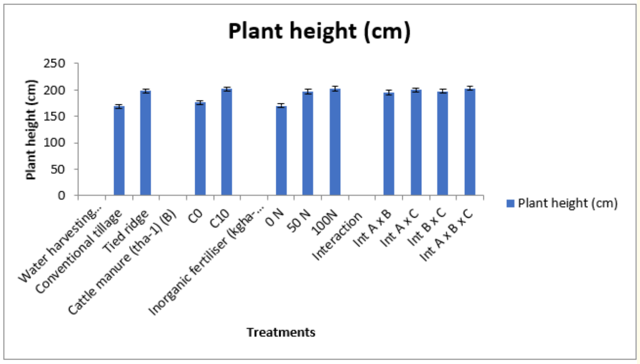

Figure 1: Effects of water harvesting technique (tied ridges) and soil amendments on pearl millet height.

Effects of integrated nutrient management and water harvesting technique (tied ridges) on panicle length of pearl millet

Panicle lengths obtained during the cropping season are presented in Table 4. The results show that panicle length was significantly affected by water harvesting techniques as well as by integrated nutrient management. The following trend was observed under water harvesting techniques: tied ridge > convention tillage as shown in Table 4. Pearl millet in tied ridge treatments had the highest panicle length of 22.25 cm compared to 20.70 cm from conventional tillage. The results show that there was a significant (P<0.05) different between panicle length from tied ridges and conventional tillage (Table 4). Panicle length from tied ridges treatments was 7.0% higher than those from conventional tillage. The trend under cattle manure management options was C 10t ha^{-1} > C 0 t ha^{-1}.

Pearl millet panicle length from plots with 10 tha^{-1} cattle manure (23.65 cm) was 16.4% higher than height from pearl millet in 0 tha^{-1} cattle manure (19.78 cm). Under inorganic fertiliser management it was 100 kg N ha^{-1} > 50 kg N ha^{-1} > 0 kg N ha^{-1}. Panicle length from 100 kg N ha^{-1} (23.70 cm) was 7.7% higher than height from 50 kg N ha^{-1} (21.87 cm) treatments and 17.9% greater than height from 0 kg N ha^{-1} (19.45 cm) treatments. Water harvesting techniques and integrated nutrient management significantly (P < 0.05) affected pearl millet panicle length. The combined use of water harvesting techniques and integrated nutrient management significantly ($P < 0.05$) increased panicle length at maturity stage. An increase in quantities of cattle manure and inorganic fertiliser combined with rainwater harvesting increased panicle length significantly ($P<0.05$) higher than rainwater harvesting, cattle manure and inorganic fertiliser in sole application (Table 4).

Treatments	**Panicle length (cm)**
Water harvesting (A)	
Conventional tillage	20.70^{b}
Tied ridge	22.25^{a}
Organic fertiliser (cattle manure) (tha^{-1}) (B)	
0	19.78^{b}
10	23.65^{a}
Inorganic fertiliser (KgNha^{-1}) (c)	
0	19.45^{c}
50	21.87^{b}
10	23.70^{a}
Interaction of ABC	
C+10C	21.92^{d}
C+50N	22.01^{e}
C+50N+10C	22.84^{bc}
C+100N	22.98^{bc}
C+100N+10C	23.15^{ab}
T+10C	22.42^{de}
T+50N	22.47^{de}
T+50N+10C	22.89^{bc}
T+100N	23.25^{ab}
T+100N+10C	23.92^{a}
Mean ± SE	**22.79 ± 0.05**

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

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

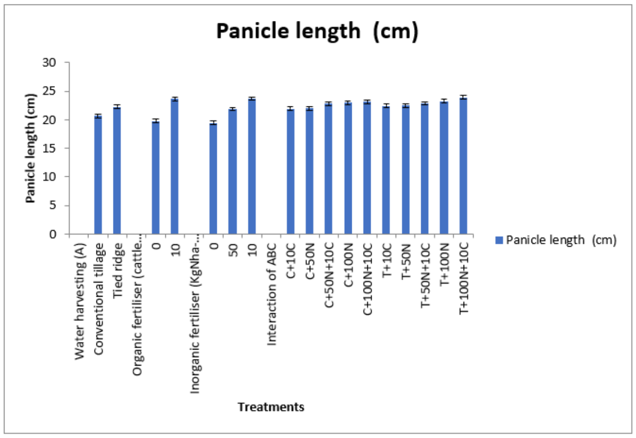

Figure 1: Effects of integrated nutrient management and water harvesting technique (tied ridges) on panicle length of pearl millet.

Discussion

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

Millet grown under water harvesting techniques (tied ridge) gave the highest height values compared to the conventional tillage. The highest plant height values obtained with water harvesting techniques could be attributed to the increase in soil water content in these water harvesting techniques structures which led to better root development thereby increasing millet growth. The results obtained in the current study corroborate with those reported by Kouyaté., *et al.* [11] who reported that tied ridge increased sorghum height than ripping. The results also confirm those reported by Fatondji [12] who showed that zai increased millet growth in terms of height as compared to planting in flat. The lowest plant height recorded under conventional tillage could be due to low moisture availability which limited nutrient absorption by plant roots hence hindering growth.

Application of cattle manure during sowing period improved early development of pearl millet root which induced rapid growth of crop. Ayoola and Adeniyan (2006) reported that application of poultry manure and P fertilisers influenced plant growth and yield by providing more nutrients. This concurred with the results of this study where all treatments applied cattle manure recorded increase in peal millet plant height. The combination of cattle manure and inorganic fertiliser gave the best result in terms of pearl millet growth because of the quantity of nutrients made available to the soil- crop system during the growing stage. Ammonium nitrate fertiliser made nutrients directly available to the crop, while the cattle manure released the nutrient slowly during the cropping period. The beneficial effects of combined organic manure and inorganic fertilisers on cereal growth have previously been highlighted [2]. Panicle height was also reported to highest where rainwater harvesting and integrated nutrient management option of cattle manure and inorganic fertilisers were used. A comination of these with tied ridges gave highest values of panicle length compared to their combination to conventional tillage. These results coincide with results by Kouyaté., *et al*. [11] who reported that addition of organic manure and inorganic manure increases panicle length under different water harvesting techniques [13-16].

Conclusions and Recommendation

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 pearl millet growth rates. If managed well tied ridge treatments are the best soil and water conservation option to increase growth rate of pearl millet compared to conventional tillage. 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. It recommended that farmers can adopt the use of tied ridges in areas with clay soils not sand soils. Tied ridges are more effective on clay soils and farmers are recommended to use cattle manure integrated with little mineral fertiliser to increase growth rate of pearl millet.

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