Original Research Article

Effects of Tied Ridges and Drought Tolerant Maize and Legume Varieties on Maize yields in Semi Arid Areas of Northern Tanzania

ABSTRACT

This paper is based on research findings and field experience of maize and legume crops using integrated technologies in Mwanga and Same Districts, Kilimanjaro region, Tanzania. Field experiments were conducted over the period of two years (2013-2014) to investigate the effects of tied ridges, drought tolerant maize and legumes on maize grain yield. The experiment was arranged in randomised complete block design (RCBD) with three replications. The data collected included maize plant height, biomass yield and grain yields. The data were coded into different variables and subjected to analysis of variance (ANOVA) using the STATISTICA computer package and the treatments mean separation test were done using Fischer Least Significance Difference (LSD).

Results obtained from both Same and Mwanga district showed that tied ridges and cropping systems had significant ($P \leq 0.001$) effect on maize plant height, biomass and grain yield in both cropping seasons. Further, the results showed significant interactive ($P \leq 0.05$) effect between tied ridges and cropping systems on maize plant height and biomass yield for Mwanga and Same Districts in both seasons although no significant interactive effects observed for maize grain yield. The results further showed that maize yields increased from 0.65 to 1.26 t/ha and 0.4 to 1.5 t/ha for Mwanga and Same Districts, respectively.

On average, the highest yield increment of more than 60% due to tied ridges and drought tolerant maize and legume varieties were obtained from the two districts in both seasons over the control. Therefore, use of tie ridges, drought tolerant maize varieties and legumes as a package has significant effect on maize grain yield in semi arid areas of northern Tanzania and can be extrapolated to other areas with similar climatic conditions.

Keywords: *Tied ridges, soil, Water conservation, Soil nutrient, Mixed cropping*

1. INTRODUCTION

In Tanzania, the majority of the populations derive their livelihood from agriculture. Smallholder agriculture accounts for 75% of agricultural production of which the majority is rainfed farming [1]. Rainfed agriculture is dramatically hampered by drought and is linked directly or indirectly to climate change. This leads to low crops yield and severe food shortages in drought prone areas attributed to a large population growth and therefore necessitates the need to improve the productivity in rainfed agriculture.

Maize (*Zea mays*) is the third most important cereal crop and contributes to 36% in the total grain production of the world [2]. In Sub Sahara Africa (SSA), maize is a staple food for an estimated 50% of the population [3], where 95% of the maize produced constitutes a significant part of the daily diet [4]. Likewise, maize is the most important staple food consumed and marketed in Tanzania [5]. It is estimated that the annual per capital consumption of maize in Tanzania is around 73 kg [6]. The potential maize production in Tanzania is 4 t ha^{-1} [6]. However, this quantity has not been attained because of drought, lack of improved seeds and low soil fertility levels [7].

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Intercropping system is a type of mixed cropping and defined as the agricultural practice of cultivating two or more crops in the same space at the same time [8]. This is a common practice in SSA, and it is mostly practiced by smallholder farmers [8]. In Tanzania, pigeon pea and dolichos lablab are often intercropped with maize and play an important role in production, consumption, and cash income in the household. They are cash crops with a high potential to enhance productivity per unit area due to its complementarities with maize. Pigeon pea and dolichos lablab are intercropped with maize to maximize land use, spreading economic risk and improving soil productivity through nitrogen fixation [4]. Despite their economic significance, the productivity of maize-pigeon pea, maize-dolichos lablab intercrops in Tanzania is very low due to inadequate availability of soil moisture for plant growth[30].

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Off all the factors, soil-moisture deficiency is primary factor limiting maize crop production in drought prone areas of northern Tanzania. However, there have been attempts to optimize maize crop yield by planting maize in association with legumes in northern Tanzania, but still crop failures due to water stress are observed [9]. These problems are mainly attributed to the inadequate efforts and absence of technologies proved to conserve the soil and water resources [10]. A study by Xavery et al [11] indicated that, intercropping drought tolerant maize varieties and legumes coupled with tied ridges have beneficial effect for conserving soil and moisture and also increases in grain yield. This practice is particularly effective in areas where the rainfall intensity is low to medium and the soils are freely drained and on gentle slopes. Past studies reported that, the use of tied ridges, as in-situ soil and water conservation technique, is known to be beneficial for increasing crop yields [12], reducing runoff and holding rain water on the soil, and thus giving it time to infiltrate [13].

However, the majority of farmers in drought prone areas of northern Tanzania do not use available rain water efficiently through tied ridges nor drought tolerant maize and legume varieties hence there is high food insecurity caused by frequent crop failure due to drought [14]. Despite the fact that droughts occur frequently, farmers still grow maize in association with legumes as the only options to reduce food insecurity. Therefore, there is a need to determine the extent of which the tied ridges affect the yield of drought tolerant maize in association with legumes in drought prone areas of northern Tanzania. This will help to provide the base for improving crop productivity and can be extrapolated to other drought prone areas with similar climatic conditions.

2. MATERIALS AND METHODS

2.1 Location of the sites

Same district is located at 4°15'S and 37°55'E while Mwanga district is located at 3°45'S and 37°40'E. The districts experience 500 – 600 mm of rainfall per annum in the low lands and between 800 – 1250 mm in the highlands. There are two distinct rainy seasons, short (*vuli*) from October to December and long (*masika*) from March to May. The districts experience some strong and dry winds blowing normally from the East to the West.

2.2 Experimental sites

Selection of experimental sites involved reconnaissance survey of the study sites, historical background information of the farming systems was collected through discussion with farmers and extension workers as to how long the land had been in use, grain yield obtained in past seasons, types and rates of fertilizers which had been used and finally the soil samples were collected for quantification of initial soil fertility status for each site.
Soil samples were collected from the selected experimental sites at Mwanga (Kwakoa) and Same (Kavambugu) districts. Soils were sampled from 0-20 cm depth (optimum rooting depth for maize/legume plants) at randomly in ten points of each experimental site mixed thoroughly to constitute the composite soil sample. About 500 g of the composite soil sample collected was air dried, ground to pass through a 2 mm sieve and be analysed for soil pH, nitrogen (N), phosphorus (P), potassium (K) and physical soil properties.

The soil pH was measured electrometrically in 1:2.5 (weight/volume) soil: water suspensions in accordance with the procedure described by Thomas [15]. Total nitrogen was determined by the Kjeldah method as described by Okalebo et al. [16]. Available phosphorus was determined by the Olsen method in accordance with the procedure described by Juo [17] while K was determined by flame photometer. Particle size distribution was determined by the hydrometer method as described by Gee and Bauder [18] and textural classes of the soils were determined by the United States Department of Agriculture procedure [19].

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2.3 Experimental design and treatments

The research experiment was conducted for the period of two years (2013-2014) at the two selected districts. The experiment was conducted using a randomised complete block design with three replications. The following planting systems were the plot treatments:

1. Situka M1-Flat bed planting (control) (CP1)
2. Situka M1 + Pigeon pea - Flat bed planting (CP2)
3. Situka M1 + Dolichos lablab - Flat bed planting (CP3)
4. Situka M1-On ridge planting (CP4)
5. Situka M1+Pigeon pea-On ridge planting (CP5)
6. Situka M1+Dolichos lablab-On ridge planting (CP6)

Each plot size was 5 m by 5 m (25 m^2). Plots were prepared by minimum tillage using hand hoe. Rows were spaced at 0.9 m ridged to a height of 0.3~0.4 m with the furrows tied in the middle along the length of the ridges. Six rows were sown per plot at a spacing of 0.3 m between plants and 0.9 m between rows. Phosphorus fertilizer namely diammonium phosphate was applied at the rate of 20P kg ha^{-1} during sowing. Phosphorus fertilizer was placed 0.05 m below the seed at sowing to avoid direct contact of fertilizer and seed. According to treatments considered, the ends of the ridges were either closed or left open and the maize seeds were planted on top of ridges while the pigeon pea and dolichos lablab were planted in the furrow between ridges. Urea was used as a source of nitrogen and was applied at the rate of 60N kg ha^{-1} after sowing when the maize plants were 40~50 cm height and was placed at 0.05-0.1 m deep in the soil and 0.07-0.1 m to the side of the plant. Maize (var Situka-M1) were sown at 20 kg seed ha^{-1} with two seeds per hole thinned out to one after emergence. Legumes (pigeon pea and dolichos lablab) were sown at 4 kg seed ha^{-1} each with three seeds per hole thinned out to two after emergence.

Plate 1: Land preparation, construction of tied ridges and planting

Plate 2: Maize planted on tied ridges

2.4 Data collected and analysis

At the beginning a reconnaissance survey was conducted in the case study areas and the status of average maize production was obtained (Data not reported in this report). The data collected on each treatment included; plant height, biomass and grains yield of maize**.** The plant height was measured using tape measure from ground level to the growing tip of the longest plant leaves and average data were recorded in cm per ten plants in each treatment plot at maturity. Biomass yield estimation involved ten maize plants above ground portions selected randomly at harvesting and sun dried for three days and then oven dried to constant weights at 70^{o}C. After oven drying samples were weighed and data recorded as dry matter in kg/ha. Grain yield was determined by drying the seeds from each yield sample to a constant weight at 60^{0}C in an oven, weighing the sample with an electronic scale and then calculating grain yield in kg/ha at 13% Moisture content. The data collected were coded into different variables and subjected to analysis of variance (ANOVA) using the STATISTICA computer package and the treatments mean separation test were done using Fischer Least Significance Difference (LSD).

3. RESULTS AND DISCUSSION

3.1 Characterization of the Soils at the Two Experimental Sites

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The physical and chemical properties of the soils from the two experimental sites at Mwanga and Same districts are as presented in Table 1 below.

Table 1: Some of the Chemical and Physical Properties of the Composite Soil Samples from the Experimental Sites

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Soil Parameters	Mwanga (Kwakoa)	Same (Kavambugu)	Mean	Rating[1]
pH (water)	5.30	5.10	5.20	Mild acidic
Total nitrogen (%)	0.04	0.05	0.05	Low
Extractable P (Olsen, mg kg^{-1})	7.10	9.20	8.15	Medium
Exchangeable K (cmol kg^{-1})	0.63	0.71	0.67	Medium
Particle size distribution				
Sand (%)	71.00	73.00	72.00	
Silt (%)	22.00	19.00	21.50	
Clay (%)	7.00	8.00	7.50	
Textural class	SL	SL	-	

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Note: SL= Sand loamy

Soil parameters rating was done according to Landon [20].

3.2 Soils' Textural Classes

The soil textural classes of the soils were sandy loam for site 1 and 2, respectively (Table 1). It has been reported that soils with high sand contents are not suitable for maize production because of their low capacities to retain plant nutrients and soil water [21]. The high sand contents in these soils would further allows fast percolation of water through the soils; hence do not encourage water ponding in the fields. It has also been reported that maize plants perform well in fine to medium textured soils [20]. Based on the textural classes of the soils in Same and Mwanga, the soils are moderate suitable for maize production given that, the other maize plant growth factors are optimal through organic amendments which include use of farm yard manure, mulching and compost are important.

3.3 Soil pH

The soils' pH values for the two sites were 5.2 (mild acidic soil reaction) (Table 1). The optimum soil pH for maize plants is 6.0 to 6.8 [20]. The observed soil pH value might not favour the formation of diphosphate ions (HPO_4^{2-}), and also will not increases the activity of Ca^{2+} which reacts with HPO_4^{2-} to form insoluble calcium diphosphate and hydroxy-apatite. However, it has been reported that cultivation of maize is even possible in soils with pH of 5.0 although yield levels will not be that much high because of low exchangeable bases and P fixation by Al and

Mn [21]. Based on the soil pH hence the soil reaction (mild acidic), the soils of Mwanga and Same districts are suitable for maize cultivation.

3.4 Total nitrogen

The mean percentage total nitrogen in the soils was 0.05% (Table 1). This value is rated as very low [20], hence the soils are deficient in nitrogen for plant growth. Pillai [22] reported that N requirement is categorized as low, medium and high when the percentage total nitrogen values are less than 0.1%, 0.1 – 0.2% and >0.2%, respectively. The low total nitrogen might have been caused by limited use of organic soil amendments, N uptake by plants, leaching, denitrification, sparse vegetation and burning of the crop residues and use of the crop residues as an animal feed. Therefore, for high maize production in the Mwanga and Same districts, nitrogen in the form of fertilizers and manures has to be applied to the soils to supplement the deficient levels of N in the soils. However, total nitrogen in soils is not a good index of nitrogen availability as the N in soils occur in complex organic compounds that have to be biochemically transformed to NH_4^+ and NO_3^- that can be taken up by plants.

3.5 Extractable phosphorus

The mean extractable Phosphorus in the soils was 8.15 mg P kg^{-1} soil (Table 1). The soils' extractable phosphorus values would be rated as medium [20]. Pillai [22] reported that the P requirement for maize is low, medium and high when the available P values are less than 5, 5-10 and greater than 10 mg P kg^{-1}, respectively. Maize being a high P demanding crop, the observed soil available phosphorus values would not satisfy the phosphate demand or requirement by the maize crop; hence response by maize to phosphate application to these soils as inorganic or organic fertilizers would be expected. The amounts of P to be added should aim at raising the P availability status to the critical P concentration range of 15 – 20 mg P kg^{-1} soil [23].

3.6 Potassium (K)

The exchangeable K in the soils (Table 1) is rated as medium (> 0.67 mg K kg^{-1} soil) according to Landon [20]. However, exchangeable K levels in soils are of limited value in predicting crop response to K as there is no direct relationship between soil K value and its availability to plants [20]. It has been reported that soils with large amounts of available K lose some of the K through fixation and those with low amounts have their exchangeable K increased through transformation of the non-available K to available/exchangeable forms under field conditions [22]. The availability of K uptake is thus controlled by the physico-chemical equilibrium between the soil solution K, exchangeable K and fixed K in the soils [22]. Thus, the soil K value (0.67 $mgkg^{-1}$ soil) of Mwanga and Same soils are sufficient for maize production.

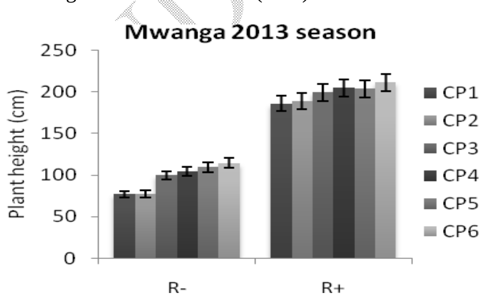
3.7 Effects of tied ridges and cropping systems on maize plant height

The average plant height increased significantly ($P \leq 0.05$) with tied ridges and cropping systems within the different treatments (Table 2). There was interactive effect between tied ridges and cropping system ($P \leq 0.05$) on maize plant height. Plant height increased progressively and was influenced by the tied ridges and the cropping system in each season. The sole maize flat planting (control) maintained shorter plants with 40% height increase due to tied ridges and cropping systems in other treatments. The average trend of plant height observed across tied ridges was CP6 > CP5 > CP4 > CP3 > CP2 > CP1. The shorter plant height noted due to cropping systems can be attributed to competition for soil moisture, nutrients and solar radiation in crop mixtures. A study by Anne et al [24] found a mean increase in maize plant height of 11.28 % and 9.59 % due to use of ridges and cropping systems. Further studies by Manyatsi et al [25] and Anne et al [24] indicated that; conservation tillage practices such as tied ridging; sub soiling and ripping have the potential of soil moisture retention and mitigation of intra-seasonal dry spells. This comprehends the current study which gives more than 40 % increases in plant height due to use of tied ridges in different cropping systems. The significant differences in the growth of maize among the different cropping systems show the sensitivity to the effects of maize to tied ridges.

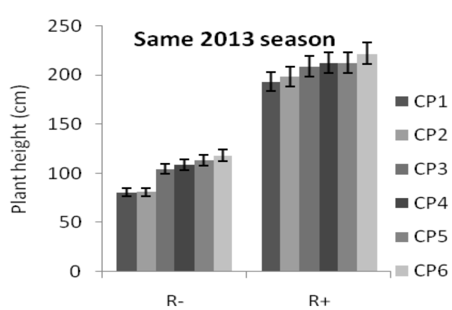
Table 2: Effect of tied ridges and cropping systems on maize plant height in two cropping seasons

Treatments	Cropping season 2013		Cropping season 2014	
	Plant height (cm)		Plant height (cm)	
	Mwanga	Same	Mwanga	Same
Ridges				
R-	97.2±3.7b	101.1±3.7b	104.3±3.9b	107.8±3.9b
R+	199.2±2.3a	207.9±2.5a	213.8±2.5a	221.6±2.7a
Cropping systems				
CP1	131.6±24.4b	136.9±25.2b	141.3±26.3c	146.0±26.9c
CP2	133.2±24.9b	139.7±26.2b	142.9±26.7c	148.9±27.9c
CP3	149.7±22.3ab	156.6±23.3ab	160.8±24.0b	167.2±24.9b
CP4	155.0±22.6ab	160.9±23.3ab	166.2±24.2ab	171.4±24.8b
CP5	156.8±21.2a	162.8±22.2a	168.4±22.8ab	173.8±23.7ab
CP6	162.9±21.7a	170.0±23.3a	174.8±23.2a	181.1±24.8a
2-Way ANOVA (F-statistic)				
Ridges	6154.4***	5678.2***	5181.8***	4826.1***
Cropping systems	66.3***	58. 8***	55.6***	49.8***
Ridges x Cropping systems	4.5**	3.8*	3.8*	3.2*

R-: Without Ridge, R+; With Ridge, Cropping System 1, 2, 3, 4, 5 and 6 refers to maize planted on flat bed, maize-pigeon pea intercrops on flat bed, maize-dolichos lablab intercrops on flat bed, maize planted on ridges, maize-pigeon pea intercrops on raised ridges, maize-dolichos lablab intercrops on raised ridges. Values presented are means ± SE, *; **; *** = significant at$P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ respectively, ns = not significant. Means followed by dissimilar letter in a column are significantly different from each other at $P \leq 0.05$ according to Fischer Least Significance Difference (LSD).



(a)



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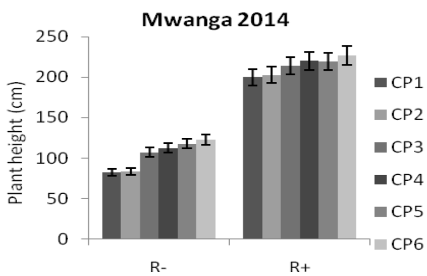

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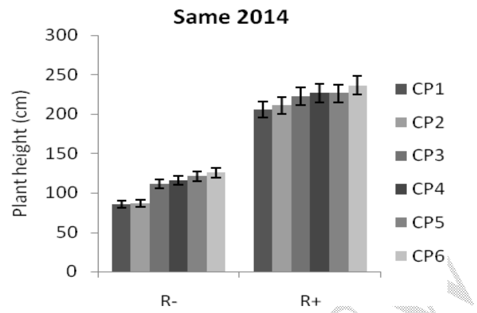

(d)

Figure 1(a-d): Interactive effects of *Ridges* and cropping systems on maize plant height for Mwanga and Same in 2013 1nd 2014 cropping seasons: (R-: Without Ridges, R+: With Ridges, CP1: Cropping system 1, CP2: Cropping system 2, CP3: Cropping system 3, CP4: Cropping system 4, CP5: Cropping system 5, CP6: Cropping system 6)

3.8 Effects of tied ridges and cropping systems on maize biomass yields

Biomass yield was significantly affected ($P \leq 0.05$) by tied ridges and cropping systems (Table 3). There was significant interactive effect between tied ridges and cropping systems ($P \leq 0.05$) in both seasons. This interaction shows that the average maize biomass yield obtained were differentially influenced by the tied ridges within a cropping system. Higher biomass yields were obtained in all tied ridges plots compared to cropping systems on flat planting. Generally, in the case of tied ridges treatments with lablab and pigeon pea cropping systems, a significantly higher biomass yield was obtained compared to the control. This was followed by flat planting but intercropping dolichos lablab and pigeon pea, resulted in yield increases of 37% and 34% over the control, respectively. A study by Pendke [26] in semi-arid areas, reported that tied ridging increased biomass yields by an average of 11 % as compared with yields under the flat bed planting. These biomass yields differed significantly among the different cropping systems within the two seasons. Under both seasons, planting maize alone on the flat without ridges and intercropping systems end biomass yield decreases of about 40% and 35% over the control, respectively. Statistically significant biomass yield differences were also found due to intercropping systems without ridges and intercropping systems with ridges as well as in comparison with sole maize planted on flat (control). McCartney *et al* [27] reported that tied ridging in Tanzania gave higher maize biomass yields not only in low but in high rainfall years as well.

Table 3: Effect of tied ridges and cropping systems on maize biomass yield in two cropping seasons

Treatments	Cropping season 2013		Cropping season 2014	
	Biomass yield (kg)		Biomass yield (kg)	
	Mwanga	Same	Mwanga	Same
Ridges				
R-	1225.6±58.3b	1237.5±58.9b	1331.8±63.5b	1335.0±63.6b
R+	2316.7±38.7a	2339.5±39.1a	2517.8±42.5a	2523.6±42.5a
Cropping systems				

CP1	1480.9±263.7de	1494.7±266.1de	1610.8±288.9de	1615.4±289.9de
CP2	1508.8±276.4d	1523.6±279.2d	1637.4±298.1d	1641.3±298.7d
CP3	1859.6±234.1c	1879.7±236.8c	2030.1±256.1c	2032.9±256.7c
4CP	1913.8±240.8b	1931.9±243.1b	2071.9±261.1b	2077.5±261.8b
CP5	1916.6±227.8ab	1934.7±230.0ab	2089.7±248.9ab	2095.3±249.6ab
CP6	1947.1±223.4a	1966.4±225.6a	2108.8±241.9a	2113.6±242.4a
2-Way ANOVA (F-statistic)				
Ridges	8316.4***	8250.6***	5036.9***	5051.9***
Cropping systems	217.4***	215.9***	131.3***	131.4***
Ridges x Cropping systems	10.5***	10.4***	6.2***	6.3***

R-: Without Ridge, R+; With Ridge, Cropping System 1, 2, 3, 4, 5 and 6 refers to maize planted on flat bed, maize-pigeon pea intercrops on flat bed, maize-dolichos lablab intercrops on flat bed, maize planted on ridges, maize-pigeon pea intercrops on raised ridges, maize-dolichos lablab intercrops on raised ridges. Values presented are means ± SE, *; **; *** = significant at$P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ respectively, ns = not significant. Means followed by dissimilar letter in a column are significantly different from each other at $P \leq 0.05$ according to Fischer Least Significance Difference (LSD).

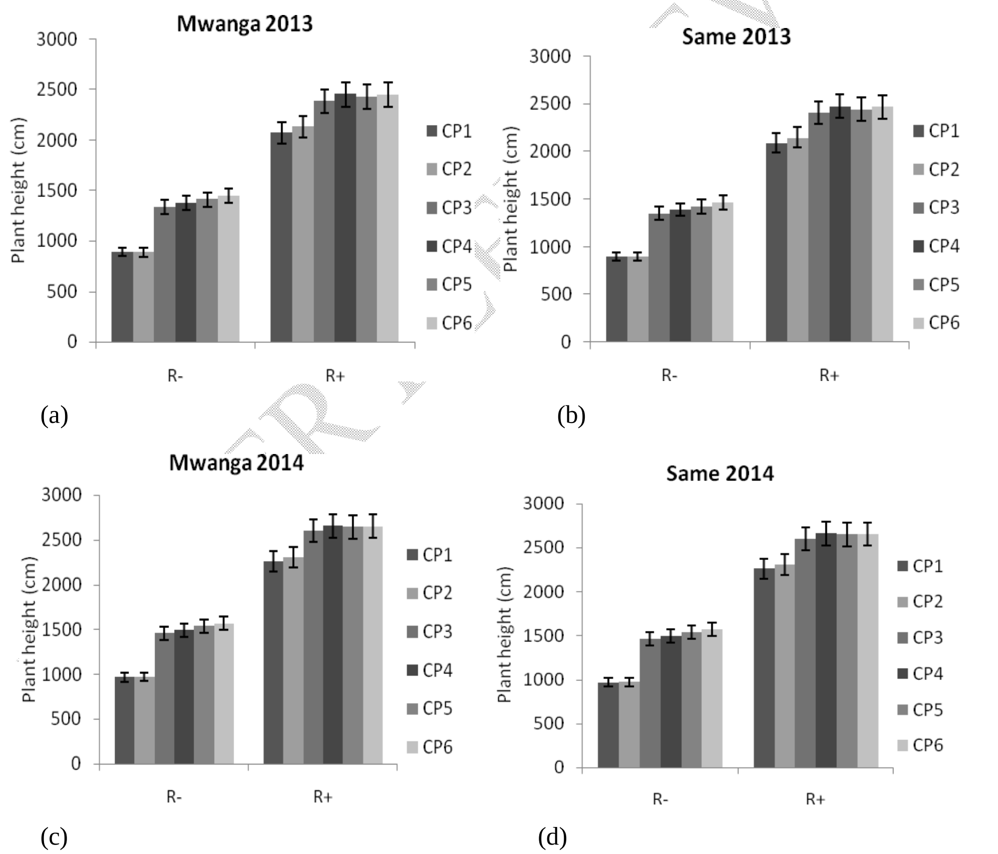

Figure 2(a-d): Interactive effects of *Ridges* and cropping systems on maize plant height for Mwanga and Same in 2013 1nd 2014 cropping seasons: (R-: Without *Ridges*, R+: With *Ridges*, CP1: Cropping system 1, CP2: Cropping system 2, CP3: Cropping system 3, CP4: Cropping system 4, CP5: Cropping system 5, CP6: Cropping system 6)

3.9 Effects of tied ridges and cropping systems on maize grain yields

The mean grain yields of the maize crop as influenced by tied ridges and cropping systems are presented in Table 4. Increases in grain yields were observed in plots with tied ridges and intercropping systems of maize-dolichos lablab and maize pigeon pea, respectively (Table 4). Grain yields increased due to tied ridges were significantly ($P \leq 0.05$) different from the flat planting. The highest yield was obtained from maize planted on the tied ridges with lablab intercropping systems and had an increase of about 55% over the control. Planting maize on the ridges with combination with pigeon pea intercropping systems gave the next highest grain yield increases of 37% over the control. Grain yield from on-ridge planting of maize alone was only higher than the control with increases of 23%. Pendke [26] reported that tied ridging increased maize grain yields by an average of 23 % as compared with yields under the flat bed planting. Further study by Anne et al [24] observed lower soil moisture and lower maize grain yields in flat planting compared to the tie ridges in western slopes of Mt Kenya during drier seasons. This was attributed to no runoff impounded and higher evaporation losses from soil due to increased soil surface area under tie-ridging. However, higher maize of 55 % in the tied ridging plots and bean yields in tied ridging have been reported by Miriti et al [28] in the semi-arid highlands area of Central Kenya. Further study by Gebrekidan and Uloro [29] in Alemaya, Eastern Ethiopia Highlands, found maize yield increments of 15 to 50 % due to tied ridges, a contrast to findings of this study.

Table 4: Effect of tied ridges and cropping systems on maize grain yield in two cropping seasons

Treatments	Cropping season 2013		Cropping season 2014	
	Grain yield (kg)		Grain yield (kg)	
	Mwanga	Same	Mwanga	Same
Ridges				
R-	513.4±28.9b	626.3±35.3b	535.2±127.9b	654.9±36.9b
R+	1340.6±26.2a	1635.6±32.0a	1397.6±116.1a	1710.0±33.5a
Cropping systems				
CP1	768.6±186.1d	937.7±227.1d	801.4±194.1d	980.5±237.5e
CP2	781.8±191.6d	953.7±233.7d	814.9±199.6d	997.1±244.3e
CP3	952.9±181.7c	1162.5±221.6c	993.6±189.4c	1215.6±231.7d
CP4	1004.2±191.5b	1225.1±233.7b	1046.7±199.7b	1263.8±236.3c
CP5	1005.1±177.8b	1226.3±216.9b	1048.1±185.4b	1299.2±234.9b
CP6	1049.4±182.8a	1280.3±223.1a	1093.9±190.6a	1338.4±233.2a
2-Way ANOVA (F-statistic)				
Ridges	8056.3***	8054.9***	7875.9***	7677.0***
Cropping systems	115.9***	115.9***	113.3***	111.1***
Ridges x Cropping systems	1.2ns	1.2ns	1.2ns	0.5ns

R-: Without Ridge, R+; With Ridge, Cropping System 1, 2, 3, 4, 5 and 6 refers to maize planted on flat bed, maize-pigeon pea intercrops on flat bed, maize-dolichos lablab intercrops on flat bed, maize planted on ridges, maize-pigeon pea intercrops on raised ridges, maize-dolichos lablab intercrops on raised ridges. Values presented are means ± SE, *; **; *** = significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ respectively, ns = not significant. Means followed by dissimilar letter in a column are significantly different from each other at P≤0.05 according to Fischer Least Significance Difference (LSD).

4. CONCLUSION

The current study found tied ridges with cropping systems to be very efficient and have influenced substantial yield increase of maize crop which automatically improves the food security to smallholder farmers and is one among promising ways of upgrading rainfed agriculture in drought prone areas. In rainfed agricultural systems, the problem of dry weather and drought can be mitigated by conserving and wisely using as much of the tied ridges and cropping systems as possible. Since rainfall is often unreliable and prevalence of harsh conditions, we recommend that these technologies should go as a package for improving maize productivity in drought prone areas of Tanzania. ….

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