



Effect of Integrating Tied ridging, Fertilizers and Cropping Systems on Maize Performance' in Arid and Semi-Arid Lands of Eastern Kenya

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ABSTRACT

The main cause of food insecurity in the semi-arid parts of Eastern Kenya is decline in soil fertility, unsuitable cropping systems, low and unreliable rainfall. This has led to low food productivity. An experiment was carried out in semi-arid parts of Eastern Kenya during short rains 2014 and long rains 2015 to determine the effect of tied ridges, fertilizers and cropping systems on growth parameters, yields and yield components of maize. The experiment was a 2 x 4 x 2 factorial laid in a randomized complete block design. The results showed that, interaction between tied-ridges x fertilizers x cropping systems had a significant effect ($P < 0.05$) on plant height, number of leaves/plant, leaf length, leaf width and leaf area. Treatment combinations with maize mono crop resulted to increased vegetative growth compared to treatment combinations of maize cow pea intercrop. During the short rains 2014, treatment combinations of flat bed planting, farm yard manure 5t/ha + 20kgN/ha in maize mono crop recorded the highest value for vegetative growth. However, during the long rains 2015, treatment combinations of tied-ridging with 20kgN/ha in maize mono crop had increased vegetative growth. The interaction between tied ridging x fertilizers x cropping system was significant ($P < 0.05$) on ears weight, biomass and grain yields. The highest value for grain yield was registered by tied ridging with farm yard manure 5t/ha in maize mono crop and tied ridging plus 20kgN/ha in maize mono crop (0.15t/ha); an increase of 650% above the control treatment. Variations in seasonal rainfall affects the effectiveness of soil and water management practices. From this study, farmers in semi-arid regions of Eastern Kenya could adopt farm yard manure 5t/ha or 20kgN/ha with maize mono crop under tied ridging in order to improve maize yields in seasons when the rain fall amount is below average.

Key words: Tied ridges, fertilizers, cropping systems, yield components

INTRODUCTION

Some of the challenges facing the world in the 21st century, are food insecurity, poverty, water scarcity, complex issues emanating from global warming and climate change (Leonard *et al.*, 2010). Climate change and variability has resulted in problems such as reduced rainfall; in addition to frequent droughts (Leonard *et al.*, 2010). Reduced farm productivity in Kenya is due to low adoption of improved agricultural technologies. This is mainly associated with high poverty levels among the small scale farmers leading to inability to afford appropriate inputs. Though maize is the most important food crop in semi-arid parts of Eastern Kenya, unreliable rainfall and declining soil fertility have contributed to its poor production.

Fertilizer use and adoption of soil conservation technologies is minimal in Eastern Kenya due to the high costs which are beyond the reach of most small scale farmers. Integrated soil fertility and water conservation methods involving use of water conservation technologies, appropriate cropping systems, inorganic and organic fertilizers are some of the options in addressing water scarcity and declining soil fertility; to ensure agronomic efficiency of applied



inputs. Maize production in Eastern Kenya is less than 0.5t/ha for small scale farmers which is only 1/3 of the expected potential. Poverty levels are high resulting in limited use of nutrient inputs and water conservation technologies (NEMA, 2013). Few studies in Eastern parts of Kenya have focused on the integration of different soil and water management practices. Therefore, there is need to integrate different soil and water management practices in order to improve maize yields.

MATERIALS AND METHODS

An experiment was carried out during short rains 2014 and long rains 2015 at Kenya Agricultural and Livestock Research Organization (KALRO) Katumani in Eastern Kenya. The experiment was a factorial component of 2 x 4 x 2 in each that was used to create treatment combinations tested as an integrated component. The treatments were: flat bed planting, tied ridging, farm yard manure 0t/ha, farm yard manure 5t/ha, 20kg nitrogen/ha and farm yard manure 5t/ha + 20kg nitrogen/ha, maize mono crop and maize cow pea intercrop. The experiment was laid out in a randomized complete block design (RCBD) with plot sizes of 5.4 m X 3.6m replicated four times. The tied ridges were imposed during land preparation. The spacing of the ridges was 90cm tied at 2.5m interval. The ridges were 20cm high and ties (cross ties) 20 cm high. The maize variety planted was KVD1 (a short duration seed with maturity between 85 to 100 days) recommended for dry areas. The maize seeds were sown 3 seeds per hole then thinned to 2 seeds at a spacing of 90cm x 30cm. The cowpea variety planted was K80. Two seeds were sown per hill at a spacing of 30 cm in between the maize rows in the plots. Triple Super Phosphate (TSP) at a rate of 60kg/ha was put in the planting holes. In plots where farm yard manure was a treatment, it was applied 3 weeks before planting. Calcium ammonium nitrate (CAN) was applied as a top dress at a rate of 20kg/ ha in plots where it was a treatment when the soil was moist. Other agronomic procedures in maize production were appropriately followed after planting.

Data Collection and Analysis

The data collected included: rainfall data, maize growth parameters (plant height, number of leaves /plant, leaf width, leaf length and leaf area), yield and yield components (cobs weight (t/ha), ears weight (t/ha), number of ears/ha, stover yield (t/ha), grain yield (t/ha), biomass yield (t/ha) and harvest index. At maturity, maize was harvested from a net plot measuring 3.4m x 1.6m. The rainfall data was recorded on daily basis using a rain gauge installed at Katumani Research Station meteorological department. The monthly averages were then computed. The total amount of rainfall received for each season was also calculated. The rainfall amounts varied among the two seasons under study. Both the short rains 2014 and long rains 2015 seasons had poorly distributed rainfall. In both seasons, the most critical months for rapid crop growth had very little rainfall. The total amount of rainfall received during the SR 2014 was 221.6mm while LR 2015 received a total of 146.1mm.

The collected data was subjected to analysis of variance using Genstart 15th Edition and the means were separated using LSD at $p < 0.05$.

RESULTS AND DISCUSSION

Effect of Tied Ridges, Fertilizers and Cropping Systems on Maize Growth Parameters

The interaction between tied ridging x fertilizers x cropping systems had a significant effect ($P < 0.05$) on plant height, number of leaves/plant, leaf length, leaf width and leaf area (Table I). Treatment combinations with maize mono crop increased vegetative growth compared to treatment combinations with maize cow pea intercrop in both seasons. During the short rains



2014, treatment combination of flat bed planting, farm yard manure 5t/ha + 20kgN/ha in maize mono crop (W1xF4xC1) recorded the highest values for vegetative growth while the lowest values were observed from treatment combination with maize cow pea intercrop without fertilizer under tied ridging (W2xF1xC2). However, during the long rains 2015, maize mono crop with 20kgN/ha under tied ridging (W2xF3xC1) had the highest values for vegetative growth while the lowest values were recorded by treatment combination of maize cow pea intercrop with 20kgN/ha under flat bed planting (W1xF3xC2). In both seasons, the highest plant height was 1.72m which was an increase of 16.22% above the control (W1xF1xC1). Treatment combinations with flat bed planting in maize mono crop increased vegetative growth more than treatment combinations of tied ridging in maize mono crop during short rains 2014. Contrary, during the long rains 2015, treatment combinations with tied ridging had increased vegetative growth compared to treatment combinations of flat bed planting in maize mono crop. In addition, the vegetative growth was higher during the short rains 2014 compared to long rains 2015. This could be attributed to the increased soil moisture content during the short rains 2014 resulting from the slightly higher rainfall received during the short rains 2014 compared to the low amount of rain fall received during the long rains 2015. Therefore, the differences observed in vegetative growth during short rains 2014 and long rains 2015 between treatment combinations with tied ridging and those with flat bed planting could be related to the differences in rain fall amount. Similar findings were observed by Khurshid *et al.*, (2006).

Application of farm yard manure 5t/ha and 20kgN/ha enhanced vegetative growth resulting to differences in treatment combinations with fertilizer application compared to treatment combinations where fertilizers were not applied. In addition, farm yard manure and nitrogen fertilizer improved the nutrient levels in the soil. Nitrogen plays a key role in vegetative growth because it's involved in protein synthesis which promotes plant growth (Hassan *et al.*, 2010). The improved soil moisture in flat bed planting led to increased vegetative growth during the short rains 2015. The maize mono crop had reduced plant density which in turn lowered competition for growth resources hence better vegetative growth (Karuma *et al.*, 2014). During the long rains 2015 when the rainfall amount was low, treatment combination with tied ridging, 20kgN/ha in maize mono crop (W2xF3xC1) recorded the highest values for vegetative growth. This is probably because tied ridges were able to effectively conserve the little rain water which was available. Similarly, application of 20kgN/ha resulted to higher vegetative growth. This could be explained by the fact that, nitrogen was readily absorbed and taken up by the plant. However, treatment combinations with application of farm yard manure 5t/ha whether under tied ridges or flat bed planting resulted in reduced vegetative growth during long rains 2015. This could be associated with the fact that, the amount of moisture in the soil was not enough for farm yard manure mineralization to take place. Therefore, the effect of farm yard manure was not realized.

In addition, plants usually take up nutrients in ionic form. This means that, the low soil moisture content during the long rains 2015 was not adequate to dissolve the plant nutrients. The limited up take of nutrients contributed to reduced vegetative growth in treatment combinations with farm yard manure (Zang *et al.*, 2010) during the long rains 2015. The increased plant density in treatment combinations with maize cowpeas intercrops resulted to competition for growth resources reducing vegetative growth. During the long rains 2015, the lowest values were recorded by treatment combinations of flat bed planting with 20kgN/ha in maize cowpeas intercrop (W1xF3xC2). This could be attributed to the fact that the soils were too dry even for nitrogen fertilizer to be dissolved hence; limiting its uptake by the crop. This



resulted to treatment combinations with flat bed planting to have reduced vegetative growth because of low soil moisture content (Karuma *et al.*, 2014).

In both short rains 2014 and long rains 2015, treatment combinations where 20kgN/ha was applied registered increased vegetative growth. This could be due to the fact that, application of nitrogen fertilizer to crops facilitates development of leaf area and lateral stem as a result of increased physiological indices. When nitrogen is applied to crops, it improves plant growth by increasing plant height and stem diameter at the end of the vegetative growth. In addition, nitrogen promotes plant growth, enhances leaf expansion and development (Okpara, 2000). The increased leaf area in treatment combinations with addition of nitrogen fertilizer agrees with the findings of Adeleke and Haruna (2012) who reported significant response of maize leaf as a result of nitrogen application. The increased leaf area shows the important role played by nitrogen in promoting vegetative growth because nitrogen enhances cell division and is required in protein synthesis. The rate of growth, development processes and final leaf size are negatively affected by higher temperatures as well as inadequate rainfall (Birch *et al.*, 2003) hence, the differences in leaf area during short rains 2014 and long rains 2015. In addition, Asim *et al.*, (2012) observed differences due to season, plant population and N fertilizer application on leaf area of plants.

Leaf area is determined by plant population and soil fertility (Okpara, 2000). This could be the reason why treatment combinations with maize mono crop, FYM 5t/ha, 20kgN/ha, FYM 5t/ha + 20kgN/ha had significantly higher values for the growth parameters compared to treatment combinations without farm yard manure in maize cowpeas intercrop. The increased vegetative growth during the short rains 2014 could be due to the high amount of rainfall received. When plants have adequate water, the cells become turgid resulting to higher meristematic activity of maize. This leads to more foliage development, higher photosynthetic rate and finally improved plant growth (Arnon 1975 as cited by Hassan *et al.*, 2012).

The reduced vegetative growth in treatment combinations with tied ridging during the short rain 2014 could be associated with the reduced soil moisture content. This may have been as a result of inversion and mixing of the top soil as the tied ridges were being constructed which may have reduced the fertility of the top soil. Also, some water may have ponded in the plots with tied ridges at the beginning of the rain season which could have negatively affected the germination as well as the growth of the crops. These findings agree with Khurshid *et al.*, (2006) who reported that, taller plants were found in plots with flat bed planting compared to those planted in tied – ridges during seasons of high rainfall. There was increased plant height during short rains 2014 compared to long rain 2015. Increased plant height is important in that, height is related to the final grain yield as the stem of maize can conserve as a reservoir of labile non- structural carbohydrates which are mobilized as sugars and in turn translocated to the filling grains during the post flowering period. The stems also play an important role in maintaining the rate of grain filling against longer term effects of persistent post flowering stress like drought (Edmeades and Lafitte, 1993, as cited by Karuma *et al.*, 2014; Sebetha *et al.*, (2015).



Table I Effect of tied ridges, fertilizers and cropping systems on Maize growth parameters

Treatments	Short Rains 2014					Long Rains 2015				
	Plant height (m)	No. of leaves/plant	Leaf length (m)	Leaf width (m)	Leaf area (m ²)	Plant height (m)	No. of leaves/plant	Leaf length (m)	Leaf width (m)	Leaf area (m ²)
W1xF4xC1	1.72a	12.76a	0.67a	0.080ab	4.66a	1.27bcd	11.60ab	0.7	0.07bcd	4.36bcd
W2xF4xC1	1.67ab	12.55abc	0.65abc	0.078abc	4.34abc	1.37abc	11.61ab	0.72	0.08ab	4.77ab
W1xF3xC1	1.67ab	12.54abc	0.66ab	0.082a	4.71a	1.24bcd	10.88bcdef	0.71	0.07bcd	4.34bcd
W1xF2xC1	1.65abc	12.79a	0.64abc	0.077abcd	4.27abc	1.31abc	11.22abc	0.65	0.07bcd	4.10bcde
W2xF2xC1	1.62abcd	12.64abc	0.62abcd	0.074bcde	4.00abcde	1.42ab	11.65a	0.66	0.08ab	4.48abc
W2xF2xC2	1.58abcde	12.50abcd	0.61bcde	0.074bcde	3.95bcdef	1.17cde	10.34ef	0.7	0.07bcd	4.33bcd
W2xF4xC2	1.52bcdef	12.31abcde	0.60cde	0.069defg	3.63cdefg	1.08def	10.29f	0.66	0.06cde	3.80cde
W1xF4xC2	1.51bcdef	12.67ab	0.64abc	0.074bcde	4.11abcd	1.04ef	10.29f	0.66	0.07bcd	3.60de
W2xF3xC1	1.51bcdef	12.13abcde	0.58def	0.072cdef	3.63cdefg	1.49a	11.77a	0.71	0.09a	5.27a
W2xF1xC1	1.49cdefg	12.19abcde	0.56ef	0.069defg	3.39defg	1.31abc	11.44ab	0.65	0.07bcd	4.28bcd
W1xF1xC1	1.48defg	11.98cde	0.57def	0.068efg	3.42defg	1.19cde	11.12abcd	0.63	0.07bcd	3.73cde
W2xF3xC2	1.44efg	12.02bcde	0.57def	0.065fg	3.23fg	1.18cde	11.18abc	0.7	0.07bcd	4.35bcd
W1xF2xC2	1.39fg	12.34abcde	0.59cdef	0.069defg	3.52defg	1.03ef	10.42def	0.65	0.06de	3.63cde
W1xF1xC2	1.38fg	11.79e	0.58def	0.065fg	3.30efg	1.03ef	10.40def	0.65	0.06de	3.61de
W1xF3xC2	1.37fg	12.05bcde	0.59cdef	0.068efg	3.51defg	0.94f	10.57cdef	0.65	0.05e	3.39e
W2xF1xC2	1.33g	11.83de	0.54f	0.064g	3.00g	1.05ef	11.07abcde	0.66	0.07bcd	3.99bcde
P value	< 0.001	0.035	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.39	< 0.001	0.002
s.e.d	0.085	0.341	0.03	0.004	0.365	0.085	0.3742	0.039	0.0053	0.4355

*Means with the same letter in each column are not significantly different at $P < 0.0$

* W1: Flat bed planting, W2: Tied ridges, F1: Farm yard manure 0t /ha, F2: Farm yard manure 5t/ha, F3: 20kg nitrogen fertilizer /ha, F4: Farm yard manure 5t/ha + 20kg nitrogen fertilizer /ha, C1: Maize mono crop, C2: Maize – cowpea intercrop



Table 2 Yield components of maize under tied ridges, fertilizers and cropping systems

Treatments	Short Rains 2014							Long Rains 2015						
	Cobs weight (t/ha)	Ears weight (t/ha)	No. of ears/ha	Stover yield (t/ha)	Grain yield (t/ha)	Biomass yield (t/ha)	Harvest index	Cobs weight (t/ha)	Ears weight (t/ha)	No. of ears/ha	Stover yield (t/ha)	Grain yield (t/ha)	Biomass yield (t/ha)	Harvest index
W2xF4xC1	0.23	1.53ab	1.84	1.11ab	1.23ab	1.50a	0.09	0.046ab	0.19a	7.81a	0.95ab	0.14ab	3.73a	0.04ab
W2xF2xC1	0.29	1.59a	1.79	1.20a	1.30a	1.44a	0.09	0.041abc	0.19a	7.58a	0.76bcde	0.15a	3.45ab	0.04ab
W2xF3xC1	0.26	1.26bcd	1.72	0.78efg	1.00bcd	1.23ab	0.08	0.52a	0.21a	7.35a	1.07a	0.15a	3.41ab	0.05a
W1xF4xC1	0.26	1.36abc	1.84	0.10abcde	1.10abc	1.31ab	0.08	0.029bcd	0.14ab	6.20ab	0.89abc	0.11abc	2.63bc	0.04ab
W1xF2xC1	0.27	1.46abc	1.82	1.17a	1.15abc	1.46a	0.07	0.014de	0.07bcd	4.57abc	0.74bcdef	0.06cde	2.52c	0.02bcd
W2xF3xC2	0.18	0.87fgh	1.61	1.09abc	0.68fg	0.80d	0.08	0.028bcd	0.016d	7.35a	0.78bcd	0.09abcd	2.28cd	0.04ab
W1xF3xC1	0.23	1.16cdef	1.62	0.85defg	0.93cde	1.09bc	0.09	0.012de	0.061bcd	3.44bcd	0.75bcde	0.05cde	2.02cde	0.02bcd
W2xF2xC2	0.21	1.01defg	1.59	1.05abcd	0.81def	0.91cd	0.09	0.011de	0.050bcd	2.75bcd	0.71cdefgh	0.04de	1.89cdef	0.02bcd
W2xF4xC2	0.19	0.92efgh	1.49	0.87defg	0.76def	0.79d	0.12	0.011de	0.047cd	2.29cd	0.64defgh	0.04de	1.84cdef	0.01cd
W2xF1xC1	0.21	1.17cde	1.75	0.71fg	0.96cde	1.14bc	0.08	0.021cde	0.092bcd	4.13abcd	0.65defgh	0.07bcde	1.82cdef	0.03abc
W1xF2xC2	0.21	0.10defg	1.65	0.92bcdef	0.79def	0.92cd	0.08	0.004e	0.019d	1.14cd	0.59defgh	0.01e	1.62def	0.00cd
W2xF1xC2	0.16	0.72gh	1.61	0.71fg	0.56fg	0.69d	0.08	0.002e	0.010d	1.83cd	0.54fgh	0.00e	1.39ef	0.00cd
W1xF1xC1	0.45	0.90efgh	1.75	0.88cdefg	0.72efg	0.90efgh	0.08	0.005e	0.026d	1.37cd	0.59defgh	0.02e	1.38ef	0.01cd
W1xF1xC2	0.13	0.65h	1.68	0.69g	0.52g	0.65h	0.08	0.004e	0.020d	1.83cd	0.57efgh	0.02e	1.22ef	0.01cd
W1xF3xC2	0.13	0.62h	1.7	0.79efg	0.49g	0.62h	0.08	0.003e	0.015d	0.91cd	0.51gh	0.01e	1.14f	0.01cd
W1xF4xC2	0.16	0.78h	1.42	0.74fg	0.62fg	0.70d	0.08	0.00e	0.002d	0.45d	0.46h	0.00e	1.09f	0.00d
P value	0.982	< 0.001	0.13	< 0.001	< 0.001	< 0.001	0.266	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
s.e.d	0.201	0.152	1.409	0.111	0.123	0.152	0.010	0.011	0.049	1.858	0.102	0.0369	0.444	0.011

*Means with the same letter in each column are not significantly different at $P < 0.05$

*W1: Flat bed planting, W2: Tied ridges, F1: Farm yard manure 0t/ha, F2: Farm yard manure 5t/ha, F3: 20kg nitrogen fertilizer/ha, F4: Farm yard manure 5t/ha + 20kg nitrogen fertilizer/ha, C1: Maize mono crop, C2: Maize – cowpea intercrop.



Innocent, (2014) who observed increased yields emanating from farm yard manure application.

During long rains 2015, treatment combinations with maize mono crop under tied ridges had significantly higher values for all the yield and yield components compared to those with maize cowpeas intercrop under flat bed. Treatment combinations with tied ridging, 20kgN/ha in maize mono crop (W2xF3xC1) and tied ridging with farm yard manure 5t/ha in maize mono crop (W2xF2xC1) recorded the highest value for grain yield (0.15t/ha); an increase of 650% higher than the control treatment (W1xF1xC1) (Table 2). The lowest value for grain yield was registered by treatment combination with flat bed, FYM 5t/ha + 20kgN/ha in maize cowpeas intercrop (W1xF4xC2) which had no grains. The highest value for the stover yield was observed from treatment combination with tied ridging, 20kgN/ha in maize mono crop (W2xF3xC1) (1.07t/ha); an increase of 81.36% higher than the control treatment. The treatment with tied ridging, FYM 5t/ha in maize mono crop (W2xF2xC1) recorded significantly higher values for all the yield and yield components during the long rains 2015 compared to tied ridging with FYM 5t/ha in maize cowpeas intercrop (W2xF2xC2). This showed that, maize mono crop with an addition of FYM 5t/ha under tied ridging increased the yields more than maize cowpeas inter crop with FYM 5t/ha under tied ridging (Table 2). The significant increase in yields could be probably due to the low plant density in maize mono crop compared to that in maize cowpeas intercrop.

The increased plant density in treatment combinations with maize cowpeas intercrop may have led to competition for growth resources which were not sufficient hence the reduced yields. Similar observations were made by Kurasu et al., (2015) who also reported low yields as a result of increased plant density. Treatment combination with tied ridging, 20kgN/ha in maize mono crop (W2xF3xC1) had significantly higher means for all the yields in comparison to flat bed with 20kgN/ha in maize cowpeas intercrop (W1xF3xC2). This meant that, maize mono crop with 20kgN/ha under tied ridging led to more increased yields than maize cowpeas intercrop with 20kgN/ha under flat bed (Table 2). These differences could be attributed to increased soil moisture content in the tied ridges as opposed to flat bed. Similarly, treatment combination with tied ridging, FYM 5t/ha + 20kgN/ha in maize mono crop (W2xF4xC1) recorded significantly higher yields than flat bed, FYM 5t/ha + 20kgN/ha in maize cowpea intercrop (W1xF4xC2). This meant that, treatment combination with maize mono crop, FYM 5t/ha + 20kg4/ha under tied ridging led to more increased yields compared to treatment combination of maize cowpeas intercrop, FYM 5t/ha + 20kgN/ha under flat bed. Also, treatment combination of tied ridging plus farm yard manure 5t/ha in maize mono crop (W2xF2xC1) registered significantly higher yields than treatment combination of flat bed without FYM in maize mono crop (W1xF1xC1). This showed that, treatment combination of maize mono crop with FYM 5t/ha under tied ridging resulted to more increased yields compared to maize mono crop without farm yard manure under flat bed LR 2015 (Table II). Treatment combinations with application of FYM 5t/ha increased the yield compared to treatment combinations without fertilizers inputs. This points out the important role played by farm yard manure in improving crop yields because it increases the level of nutrients in the soil for plant use ((Adigbo *et al.*, 2013). These findings agree with the work done by Marschner *et al.*, (2011) who reported increased crop yields due to application of farm yard manure.



CONCLUSION AND RECOMMENDATIONS

The combination of tied ridges, flat bed, farm yard manure, nitrogen fertilizer, maize mono crop and maize cow pea intercrop resulted to increased maize vegetative growth and yield components. The use of tied ridging was more effective in promoting vegetative growth during the long rains 2015 when the rainfall was low, whereas flat bed planting was more effective during the short rains 2014 when the amount of rainfall received was slightly higher. Therefore, in order to promote vegetative growth, there is need to apply nitrogen fertilizers in addition to conserving soil moisture. From the findings in this study, it may therefore be concluded that, in maize production, soil moisture conservation, fertilizer input application and cropping systems are key aspects to be considered in order to improve maize yields. The use of maize mono crop under tied ridges when the rainfall was below average improved the yields. Therefore, from the findings of this study, it may be recommended that, during the seasons of low rainfall, farmers in the study area may consider adopting maize mono crop with application of 20kgN/ha under tied ridging. Also, use of tied ridging in the study area could be restricted only to seasons of low rainfall because they are less effective in seasons with high rainfall. In addition, it is important to integrate various soil and water management practices since adopting a single technology does not exploit its potential. Variations in seasonal rainfall should be put into consideration when recommending soil and water management practices in semi-arid areas. .

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