



Effect of Tillage Techniques on Depth, Furrow Slice and Water Retention in Maugo Smallholder Rice Scheme in Kenya

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ABSTRACT

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This study was conducted with the aim of determining the influence of tillage techniques on depth, furrow slice and water retention in Maugo Smallholder Rice Scheme in Kenya. Treatments were arranged in randomized complete block design with four replicates. Four tillage treatments were used. The first one was conventional ox plough practiced by farmers where they first flood the field with water before ploughing. The other three treatments were ox plough, hand hoe and tractor ploughing all with no flooding before ploughing. Data collected included depth of ploughing and harrowing during land preparation. Furrow slices during ploughing and harrowing as well as water retention were recorded. Tractor ploughing had the highest mean depth of ploughing of 42.00 ± 0.81 cm followed by conventional ox ploughing with 17.75 ± 0.75 cm, ox ploughing 15.75 ± 0.62 cm and hand hoe ploughing had the lowest mean depth 15.50 ± 0.28 cm. Tractor ploughing had the largest mean furrow size of 62.00 ± 0.91 cm followed by conventional ox ploughing 32.25 ± 0.85 cm, ox ploughing 30.25 ± 0.85 cm while hand hoe ploughing had the smallest mean furrow slice of 16.5 ± 0.50 cm. Highest mean of retained water was recorded in week 4 in paddy rice fields prepared using conventional ox ploughing (10.5 cm), ox ploughing (10 cm), hand hoe ploughing (11.5 cm) and tractor ploughing (11.5 cm) while the lowest was recorded in week 15 for conventional plots. There were significant differences in mean depths during both ploughing and harrowing. Tractor ploughing mean depths were significantly different from the other treatments. The weekly mean water depths retained in the plots were more than 6 cm for the entire growing period of rice.

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Introduction

More than half of the earth's inhabitants consume rice (*Oriza sativa* L.) as their staple food (Prodhan and Qingyao, 2020). At moisture content of 12 percent, rice has 80 percent starch and 7 percent protein (Del Rosario et al., 1968). Total annual world production of rice in 2018 stood at 0.8 billion metric tons (FAO, 2020). Although area under rice farming is increasing in Kenya, its production is stagnating because of the challenges faced by smallholder farmers who contribute 63% food produced in the country (FAO, 2015).

Smallholder farmers in the study area have an average land size of 4 acres used for both homestead and farming purposes (GoK, 2013). Therefore, solving challenges faced by smallholder farmers will lead to increase in rice productivity consequently solving the problem of food insecurity in Kenya. This will also help reduce rice imports in Kenya which stood at 0.6 million tonnes in 2019 (Knoema, 2019). In fact, one of the "Big-Four" priorities of Kenyan president for the period 2017 to 2022 is

achievement of 100% food and nutrition security (World Food Programme, 2018). Rice production can be improved through proper land preparation and proper irrigation among other agronomic requirements for rice crop.

Tillage method is crucial in cultivation of crops (Sornpoon and Jayasuriya, 2013). This is because knowledge of tillage effect on soil physical properties is essential for plant growth. Irrigation is one of the most effective ways to develop smallholder agriculture and contribute to poverty reduction through increasing crop yield and income (Domenech, 2015). One of the Kenya's irrigation sector is the smallholder community irrigation schemes which are owned, operated and managed by the farmers through their irrigation water users' associations. They are developed on a cost-sharing basis between the government, communities and development partners. An example of smallholder irrigation scheme is Maugo in Homa Bay County in Kenya.

Land preparation techniques may influence water retention and yields of rice. No tillage is considered the best alternative to ploughing and harrowing due to its effect on soil properties but ploughing, harrowing and levelling increases rice yield and reduces weed density. Information on the effect of different land preparation techniques on water retention and rice yields in the smallholder irrigation schemes like Maugo Irrigation scheme is scanty. Therefore, this study aimed to study the effect of land preparation techniques on ploughing and harrowing depth as well as water retention. The information in this study will assist Kenya to make progress in achievement of Sustainable Development Goal number 2 on Zero hunger (United Nations, 2015).

Materials and Methods

Study Area

The study was conducted in Powo B sub-block (Latitude 0°23'S, Longitude 34°30' E and altitude 1020 metres above sea level) which is part of Maugo Irrigation Scheme. The experiments were done from July 2019 to January 2020 season. The study area falls under agro-ecological zone lower midland (LM3), with mean annual rainfall ranging from 740 mm to 1,200 mm. The rainfall has a high variability on duration and amount making up two fairly distinct rainy seasons (long rains peaking between April and May and the short rains peaking between November and December). The mean annual maximum temperature is 31°C, while the mean annual minimum temperature is 18°C. Relative humidity varies between 60% and 75% and potential evapotranspiration rates range from 1,800 to 2,000 mm per annum (GoK, 2013). Soils in the study area are clayey with more than 40% clay with a bulk density of 1.15 g/cm³ and penetration resistance of 2.0 bars (M'Marete, 1991).

Tillage Treatments

There were four tillage treatments that were replicated four times and arranged in a randomized complete block design (Picture 1). The first tillage treatment (conventional) was ox ploughing using Victory Ox Plough practiced normally by farmers where they first flood their fields to a depth of 20 cm before ploughing. The second treatment was ox ploughing with Victory Ox Plough and no flooding. The third treatment was hand hoe ploughing. The last treatment was using a 75 horse power tractor Massey Ferguson (MF 375) with a three bottomed disc plough. The last three treatments were ploughed without flooding. Secondary tillage in form of harrowing was done manually by using hand hoe. This resulted in a total of 16 experimental plots each with an area of 90 m². There was an alley of one meter between plots and two meters between replications.

Data Collected and Analysis

Data collected included depth during ploughing and harrowing. Size of furrow slice during ploughing and harrowing was measured. The depth of water entering and leaving the plots were measured to determine the weekly water retained in each plot. Water retained was not measured in week 7 because of the problem of heavy rain that resulted in inaccessibility of the experimental site.

Mean depths during ploughing and harrowing were calculated as well as mean sizes of furrow sizes during ploughing and harrowing. One-way Analysis of Variance (ANOVA) at 0.05 level of significance was done using Microsoft Excel® data analysis tool for both depths and furrow slices during ploughing and harrowing. Also, in Microsoft Excel, t-test with two samples assuming unequal variance was used. Spearman's Rank-order correlation between different treatments was done to gauge the relationship between weekly water retention in the paddy rice field.



(a)



(b)



(c)

Picture 1. Ox ploughing (a), hand hoe ploughing (b) and tractor ploughing (c)

Results and Discussion

Depths of Ploughing and Harrowing

Tractor ploughing had the highest mean depth of ploughing of 42.00 ± 0.81 cm followed by conventional-ox ploughing with 17.75 ± 0.75 cm, ox ploughing 15.75 ± 0.62 cm and hand hoe ploughing had the lowest mean depth 15.50 ± 0.28 cm. The depth of tractor ploughing was twice the 20 cm observed by Kareem and Sven, (2015). It was also one and half times the 30 cm reported by (Tnau Agritech, 2016). Results show that when the ground is wet, the ox plough goes deeper because of wetting of the field.

During harrowing, hand hoe ploughing had the greatest mean depth of 14.50 ± 0.05 cm followed by that of tractor ploughing 13.75 ± 1.03 cm while conventional- ox ploughing had mean depth of 11.55 ± 0.26 cm, and ox-ploughing had the least mean depth of 11.25 ± 0.75 cm as shown in Figure 1. Hand hoe depth was deeper because of its shallower depth of harrowing. Also, hand hoe cannot go deeper than the size of the hoe so larger ploughing depths

cannot be reached by use of hoe. There was a significant difference in mean depths during both ploughing and harrowing as shown in Table 1 at $\alpha = 0.05$. There was no significant difference between conventional ox plough and the ox plough and also no significant difference between ox plough and hand hoe ploughing. However, there was a significant difference in depth between tractor ploughing and all the other methods during ploughing.

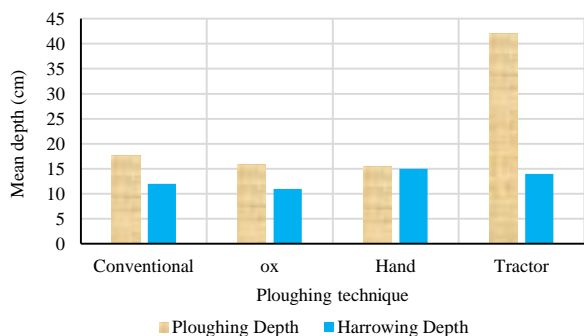


Figure 1. Mean ploughing depths for different ploughing techniques

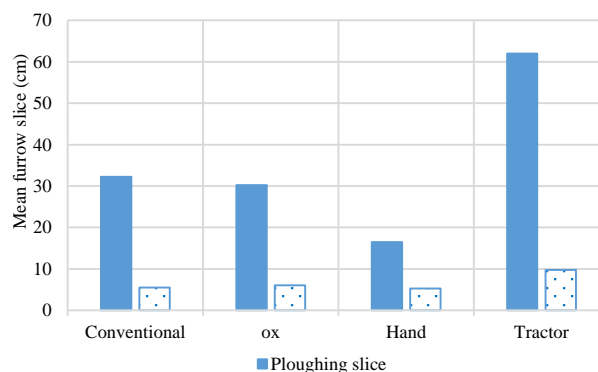


Figure 2. Mean furrow slice for different ploughing techniques

Table 1. Analysis of Variance for depths and furrow slices during ploughing and harrowing

	Significance ($\alpha = 0.05$)	Ploughing		Harrowing	
		Calculated F	Critical F	Calculated F	Critical F
Ploughing depth	Significant ($P = <0.05$)	388	3.5	5.3	3.5
Furrow slice	Significant ($P = <0.05$)	577	3.5	8.0	3.5

Furrow Slice Sizes

Tractor ploughing had the largest mean furrow size of 62.00 ± 0.91 cm followed by conventional- ox ploughing 32.25 ± 0.85 cm, ox ploughing 30.25 ± 0.85 cm while hand hoe ploughing had the smallest mean furrow slice of 16.5 ± 0.50 cm. Tractor furrow slice was twice 30 cm observed by (Tnau Agritech, 2019) The mean size of furrow slice after harrowing was high in tractor ploughing 9.75 ± 1.03 cm followed by that of ox-ploughing 6.00 ± 0.40 cm then conventional ox plough 5.50 ± 0.90 cm while hand hoe ploughing had the least size of 5.25 ± 0.48 cm as portrayed in Figure 2. There was a significant difference in mean furrow slices during both ploughing and harrowing as shown in Table 1 with significant difference observed between tractor ploughing and all the other techniques.

Water Retention

The water retention during weeks 1, 2, 3, 4, 5, 10, 12 and 14 in the paddy rice fields for the four ploughing techniques did not differ significantly as represented in Table 2, however, in weeks 6, 8, 9, 11, 13 and 15 they differed significantly. Highest mean water retention was observed in tractor treatment whereas the least was observed in the conventional one using ox plough. It is worth to note that the water retention for tractor ploughing was close to that of hand hoe ploughing. This means that the extra depth during tractor ploughing did not contribute much in water retention. Highest mean of retained water was recorded in week 4 in paddy rice fields prepared using conventional- ox ploughing (10.5 cm), ox ploughing (10 cm), hand hoe ploughing (11.5 cm) and tractor ploughing

(11.5 cm) while the lowest was recorded in week 15. The highest water retention in week 4 was attributed to rainfall received during that week. It is interesting to note that water retention increased in those weeks when rainfall was experienced for example in weeks 3, 9 and 11. Water retention decreased whenever there was no rainfall. Therefore, the water retention fluctuated according to rainfall. Higher moisture retention for tractor ploughed field was similar to that observed in Ghana by Bashagaluke et al., (2019) who reported higher soil moisture content in tractor ploughing when compared to other techniques.

Based on Spearman’s rank-order correlation; conventional- ox ploughing was positively correlated with ox ploughing ($r = 0.93$), hand hoe ploughing ($r = 0.91$) and tractor ploughing ($r = 0.83$). Looking at the average depths it was found out that the mean depths were more than 6 cm for the entire growing period with tractor ploughing having higher depths.

Conclusion

There was enough evidence that tractor ploughing results in deep ploughing depths and big furrow slices during ploughing and harrowing. Highest water retention was observed in both hand hoe and tractor ploughed plots. There was strong correlation between the weekly amount of water between different treatments. The greatest correlation occurred between conventional ox plough (with water) and ox plough (without water).

Table 2 ANOVA of weekly water retained (cm) in different ploughing techniques

	Conventional- Ox Ploughing	Ox Ploughing	Hand hoe Ploughing	Tractor Ploughing	F-Ratio	Critical F
Week 1	8.50±0.27	8.25±0.20	8.83±0.34	8.38±0.05	1.06	3.49
Week 2	6.70±0.45	6.95±0.41	7.18±0.36	8.03±0.41	1.99	3.49
Week 3	8.35±0.21	7.28±0.26	7.70±0.20	7.40±0.76	1.25	3.49
Week 4	10.50±0.65	10.00±0.00	11.50±0.65	11.50±0.29	2.45	3.49
Week 5	9.25±0.85	10.25±1.18	9.50±0.29	11.00±0.71	0.92	3.49
Week 6	4.20±0.51	4.35±0.49	5.30±0.27	6.28±0.47	4.62	3.49
Week 8	3.68±0.32	3.73±0.26	4.75±0.19	6.23±0.38	16.27	3.49
Week 9	7.80±0.31	8.20±0.43	7.75±0.31	3.88±.50	26.26	3.49
Week 10	5.25±0.49	5.33±0.50	6.75±0.23	5.68±0.09	3.41	3.49
Week 11	8.25±0.37	7.63±0.11	7.85±0.28	9.03±0.31	4.76	3.49
Week 12	4.65±0.13	5.35±1.29	7.88±0.80	7.13±0.72	3.18	3.49
Week 13	3.88±0.10	3.90±0.19	5.33±0.13	7.15±0.23	84.26	3.49
Week 14	3.58±0.28	4.05±0.15	3.28±0.10	4.08±0.43	2.00	3.49
Week 15	1.60±0.93	4.15±0.54	3.85±0.50	3.75±0.25	3.75	3.49
Average	6.160±0.71	6.39±0.61	6.96±0.61	7.11±0.64		

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