Research Application Summary

Effect of different tillage methods on soil moisture dynamics in maize-bean cropping systems in semi arid Mwala district, Kenya

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Abstract

Water is an important factor affecting plant growth especially in semi arid areas. A study to determine the effects of tillage and cropping systems on soil surface roughness, moisture storage and maize and bean yields was conducted in semi arid Mwala District, Kenya. Five tillage systems: mouldboard (MB), mouldboard and harrowing (MBH), ox-ploughing (OX), hand hoe and tied-ridges (HTR) and hand hoe only (H) and, three cropping systems; sole maize, sole bean and maize-bean intercrop, were investigated in a split-plot design with four replicates. Soil moisture varied significantly ($p<0.05$) among the tillage methods at 2 and 4 weeks after planting (WAP). Groundcover was significantly different ($p<0.05$) among the cropping systems at 4 WAP and both tillage and cropping system at 6 WAP with the highest being observed in the maize-bean intercrop. Maize plant height was significantly different ($p<0.05$) among the tillage methods, with the highest height (78 -180 cm) in the MBH plots across the different WAPs. Preliminary results demonstrate that tillage methods influence the level of soil moisture conservation and crop growth in the semi arid areas of Kenya where most of the soils are prone to crusting and formation of hardpans.

Key words: Cropping systems, semi arid areas, soil moisture, tillage systems

Résumé

L’eau est un facteur important qui affecte la croissance des plantes en particulier dans les régions semi-arides. Une étude visant à déterminer les effets du labour et des systèmes de culture sur la rugosité de la surface du sol, le stockage de l’humidité et les rendements du maïs et des haricots a été menée dans les régions semi arides du District de Mwala au Kenya. Cinq systèmes de labour du sol: le versoir (MB), le versoir et l’hersage (MBH), le labour par les vaches (OX), la houe manuelle et les billons attachés (HTR) et la houe manuelle seulement (H) et, trois systèmes de culture : le maïs seul, les haricots seuls et la culture intercalaire maïs-haricots, ont été étudiés dans un dispositif des parcelles fractionnées avec quatre répétitions. L'humidité du sol a varié significativement (p <0,05) entre les méthodes de labour du sol à 2 et 4 semaines après la plantation (WAP). La couverture du sol était significativement différente (p <0,05) entre les systèmes de culture à 4 semaines après la plantation et ensemble le labour et le système de culture à 6 semaines après la plantation avec les plus importants étant observés dans la culture intercalaire maïs-haricot. La hauteur de la plante de maïs a été significativement différente (p <0,05) entre les méthodes de labour du sol, avec la plus grande hauteur (78 -180cm) dans les parcelles de versoir et d'hersage à travers les différentes semaines après la plantation. Les résultats préliminaires montrent que les méthodes de labour du sol influent sur le niveau de conservation de l'humidité du sol et la croissance des cultures dans les zones semi-arides du Kenya, où la plupart des sols sont sujets à la formation de croûtes.

Mots clés: Systèmes de culture, régions semi-arides, humidité du sol, systèmes de labour

Background

Soil moisture content in the root zone during the crop growing period affects crop growth, development and the overall land productivity especially in semi arid areas. Dry spells adversely affect maize production in at least three out of four seasons in the semi-arid areas of Kenya and Tanzania (Barron *et al.*, 2003). In such areas, supplemental water to mitigate the dry spells is one of the critical challenges in crop production. Water conservation is thus a key issue and technologies that use rainwater more efficiently are therefore needed.

Conservation tillage practices and *in-situ* rainwater harvesting technologies offer good prospects for increased infiltration and storage of rainwater within soils, which is subsequently available for plant uptake during dry periods (McHugh *et al.,* 2007). The *in-situ* rainwater conservation tillage techniques include open and tied ridging, subsoiling, ripping, half moon, flat beds and no till (Manyatsi *et al.*, 2011) and offers an entry point for efforts to increase maize yields especially in the semi-arid regions of eastern Kenya.

Although conservation tillage is highly advocated, there is strong evidence that soils prone to surface crusting and sealing, characteristic of semi arid areas, would benefit from conventional tillage once every 2-3 years (Unger *et al.*,1991). Conventional tillage practices modify the soil structure by changing its physical properties such as soil moisture retention which leads to a favourable environment for crop growth and nutrient use (Rashidi *et al.*, 2010).

Assessment of maize performance under some of these selected tillage systems, is therefore, important in identification and selection of the socially accepted and economically viable measures that will contribute towards optimization of maize-bean production especially in semi-arid areas where maize and beans are important crops.

Literature Summary

The semi-arid areas of Eastern Kenya, including Mwala District, are characterized by low, erratic and poorly distributed bimodal rainfall that makes crop production difficult under rain fed conditions. The major constraints to arable agriculture in the semi-arid areas are severe soil erosion, low soil fertility, soil crusting and low soil moisture. Of these, soil moisture is the most critical as it directly affects crop production in these areas (Mutune *et al.*, 2011).

Availability of soil moisture depends on environmental and management factors such as rainfall, temperature regimes, soil properties, soil surface cover and soil moisture storage capacity. High risk of crop failure due to drought and dry spells leads to reluctance by smallholder farmers to invest on cropland, which suggests that drought and dry spell mitigation through better on-farm rainwater management could be the key to improved crop production in the current farming systems of semi arid areas (Rockstrom, 2003).

Enhancement of soil moisture storage can be achieved by employing tillage practices that enhance rainwater infiltration and suppress subsequent evaporation. In order to enhance soil moisture, there is need to maintain soil surface conditions necessary for rapid infiltration and the removal of soil profile layers that restrict water penetration through sustainable tillage and cropping systems.

Maize is the most important agricultural commodity and main staple food in Kenya and is grown by 90 % of farm households and provides about 40 % of the population’s food requirements (Makokha *et al.*, 2001). Traditionally in East Africa, maize is intercropped with legumes such as cowpeas, beans, groundnuts, pigeon peas and green grams. Cereal-legume intercropping plays an important role in situations of limited water resources.

Associated benefits of intercropping include improved soil structure and associated soil physical characteristics, increase in soil organic matter (SOM) and improving soil nutrient and moisture contents of the soil (Dahmardeh *et al.,* 2010).

Study Description

This study is being conducted in Mbiuni Location, Mwala District, Kenya (1˚15'S, 37˚ 25'E). Five tillage systems; mouldboard (MB), mouldboard and harrowing (MBH), ox-ploughing (OX), hand hoe and tied ridges (HTR) and hand hoe only (H) and, three cropping systems namely, sole maize, sole bean and maize-bean intercrop were investigated in a split-plot design with four replications. Disturbed soil samples were taken from the 0-15 and 15-30 cm depth to determine soil moisture using the gravimetric method (Okalebo *et al.*, 2002). Ground cover assessment was observed using the String and Dot method (Laflen *et al.,* 1981). Maize height was also monitored to relate to the soil moisture content in the soil during the growing period.

Research Application

The study is still underway with beans about to be harvested. Soil moisture content decreased over time in the growing season. The changes in profile water content could thus be attributed to a combination of rainfall, soil evaporation, transpiration or crop water uptake. The trend observed at both depths shows some significant differences ($p<0.05$) that occurred among the tillage methods especially at 2 and 4 WAPs (Table 1).

Both maize and bean cover measurements were taken at 4 and 6 WAP. Treatments with Maize-Beans were able to build a surface cover of about > 20 % at 4 WAP and > 30 % at 6 WAP. This could be attributed to the higher plant population in the intercrop plots than in the sole cropped plots. The highest cover was recorded in the MB and MBH plots which are under conventional tillage. Groundcover was significantly different ($p<0.05$) for tillage and cropping systems (Table 2). The maize plant heights obtained in the different treatments were greatly influenced by the tillage method used and the soil moisture available to the crop (Gicheru *et al.,* 2005). Tractor ploughed (MB and MBH) and Ox-plough (OX) had taller (2-10 cm) plants than those in the H and HTR plots as the WAPs progressed (Table 3). The height difference could be attributed to the greater plough depth (average of 25 cm) resulting in soil surface roughness which enhances greater infiltration.

Conclusion and Recommendations

The study is in the initial stages of data collection (Long rains, 2012) but there are indications that moisture distribution within

Table 1. Effect of tillage and cropping systems on soil moisture content (long rains, 2012).

Tillage	Cropping system	Before planting		2 WAP		4 WAP	
		0 - 15 cm	15-30 cm	0 - 15 cm	15 -30 cm	0 - 15 cm	15-30 cm
Hand hoe (H)	bean	13.33	12.21	18.89	18.04	11.45	13.69
	maize			16.8	18.25	10.52	12.43
	maize + bean			21.42	21.59	10.04	12.76
Hand hoe +tied ridges (HTR)	bean	14.65	13.16	18.81	19.11	13.04	15.7
	maize			17.62	20.28	12.68	14.09
	maize + bean			17.89	19.9	12.86	15.51
Mouldboard (MB)	bean	14.29	12.3	16.69	16.89	8.96	12.07
	maize			17.36	15.25	11.42	12.9
	maize + bean			15.71	17.92	11.21	10.92
Mouldboard +harrowing (MBH)	bean	14.88	13.81	18.48	19.26	13.09	15.6
	maize			20.38	18.83	13.69	15.52
	maize + bean			18.66	17.88	12.3	12.39
Ox-plough	bean	15.28	12.81	19.66	20.04	12.09	13.68
	maize			17.22	19.49	10.23	12.56
	maize + bean			16.86	18.66	12.71	14.71
LSD (5 %)	tillage (T)	3.161	2.288	2.825	2.478*	1.844*	2.030*
	cropping sys (C)			1.585	1.626	1.297	1.512
	T × C			3.892	3.729	2.899	3.314
CV %		13.4	3	15.4	15.1	16	16.7

* = significant at $p < 0.05$; WAP = weeks after planting.

the rooting zone can be manipulated by modifications of the soil surface conditions through tillage systems and ground cover. If this is true, the results from this study will assist in instituting the good soil moisture conservation practices that will help mitigate the associated climatic risks while improving both the crop yields, soil properties and also the potential replicability to other semi arid areas in Sub-Saharan Africa.

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Table 2. Effect of tillage and cropping systems on groundcover (long rains, 2012).

Tillage	Cropping system	Groundcover (%)	
		4 WAP	6 WAP
Hand hoe (H)	bean	15.9	20.4
	maize	26.8	36.0
	maize + bean	27.7	47.9
Hand hoe +tied ridges (HTR)	bean	20.4	23.5
	maize	20.7	32.9
	maize + bean	23.5	36.0
Mouldboard (MB)	bean	21.3	35.7
	maize	20.6	39.6
	maize + bean	29.3	53.4
Mouldboard +harrowing (MBH)	bean	25.3	43.9
	maize	21.2	40.6
	maize + bean	27.9	59.1
Ox-plough	bean	18.6	30.8
	maize	20.3	39.6
	maize + bean	26.2	42.4
LSD (5 %)	tillage (T)	3.22	7.38*
	cropping sys (C)	3.36*	6.69*
	T × C	6.77	13.88
CV %		10.5	9.3

* = significant at $p < 0.05$.

Table 3. Effect of tillage and cropping systems on maize plant height (cm) (long rains, 2012).

Tillage	Cropping system	Maize plant height (cm)		
		4 WAP	6 WAP	9 WAP
Hand hoe (H)	Maize	69.3	136.3	175.8
	Maize + bean	76.5	145.2	172.0
Hand hoe +tied ridges (HTR)	Maize	71.2	138.4	163.1
	Maize + bean	64.4	113.5	152.3
Mouldboard (MB)	Maize	68.7	144.8	176.3
	Maize + bean	80.6	149.6	176.2
Mouldboard +harrowing (MBH)	Maize	78.6	151.0	183.9
	Maize + bean	79.1	153.2	180.6
Ox-plough	Maize	74.1	150.4	174.5
	Maize + bean	77.1	141.8	168.1
LSD (5 %)	Tillage (T)	6.51*	9.84*	7.89*
	Cropping sys (C)	5.31	8.65	8.17
	T × C	10.16	16.13	14.57
CV %		4.0	2.5	1.4

* = significant at $p < 0.05$.

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