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Research Application Summary

Effect of biochar on water use efficiency of legume fodder *Dolichos lablab* (*Lablab purpureus* L.) Sweet in semi-arid and arid soils of Mwea and Bura, Kenya

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Abstract

Production of legume fodder in arid and semi-arid regions remains a problem due to constraints of low soil moisture and limited farming technologies that can improve water retention in soil. Mwea and Bura soils are vertisols, compacted, with poor hydraulic-conductivity and aeration which reduce root development. The objectives of the study were to i) improve water use efficiency of drought tolerant *Dolichos lablab* Rongai using biochar, ii) to determine the most suitable soil amendment rate of biochar. Percentage soil moisture content in amended plots/control was measured using a soil moisture meter at 10 cm depth. Water use efficiency was calculated based on oven-dry-weight of shoot and seed-grain at 50% flowering and maturity, evapotranspiration rate for the growing season ETo, and established crop-coefficient values (Kc) for Dolichos at respective stages of harvest post-planting. Matric potential was determined using ceramic plate pressure chamber and soil–moisture retention curves developed for 0, 3, 10 and 30 ton ha^{-1}. Hydraulic conductivity was determined by KSAT method. Results demonstrate a significant increase of l02% in water retained between pF 0.3 and pF 10 amended at 10 t ha^{-1}; and 70.2 % increase and 30 t ha^{-1} compared to the control only in Mwea soil ($P< 0.05$). Biochar increased porosity, hydraulic- conductivity reduced bulk density in both soils. A significantly higher water use efficiency of 4.99 kg ha^{-1} mm^{-1} at 50% flowering in Mwea soil amended at 10 t ha^{-1} compared to values in control and 3 t ha^{-1} which measured 2.2 kg ha^{-1} mm^{-1} and 3.2 kg ha^{-1} mm^{-1} $p< 0.05$. Based on these results, Mwea soils should be amendment with 10 t ha^{-1} biochar for maximizing productivity and water retention.

Key words: Bulk density, crop coefficient, evapotranspiration, hydraulic conductivity, matric potential, water potential, water use efficiency

Résumé

La production de légumineuses fourragères dans les régions arides et semi-arides reste un problème en raison des contraintes de faible humidité du sol et des technologies agricoles limitées qui peuvent améliorer la rétention d'eau dans le sol. Les sols Mwea et Bura sont des vertisols, compactés, avec une mauvaise conductivité hydraulique et aération qui réduisent le développement racinaire. Les objectifs de l'étude étaient les suivants: i) améliorer l'efficacité de l'utilisation de l'eau de Dolichos lablab Rongai tolérant à la sécheresse en utilisant du biochar, ii) déterminer le taux d'amendement du sol le plus approprié pour le biochar. Le pourcentage d'humidité du sol dans les parcelles / témoins modifiés a été mesuré à l'aide d'un humidimètre du sol à 10 cm de profondeur. L'efficacité de l'utilisation de l'eau a été calculée sur la base du poids à sec au four des pousses et des graines à 50% de floraison et de maturité, du taux d'évapotranspiration pour la saison de croissance ETo et des valeurs de coefficient de culture (Kc) établies pour les Dolichos aux stades respectifs de la récolte après -plantation. Le potentiel matriciel a été déterminé à l'aide d'une chambre de pression à plaque céramique et de courbes de rétention sol-humidité développées pour 0, 3, 10 et 30 t ha-1. La conductivité hydraulique a été déterminée par la méthode KSAT. Les résultats démontrent une augmentation significative de l02% dans l'eau retenue entre pF 0,3 et pF 10 amendé à 10 t ha-1; et 70,2% d'augmentation et 30 t ha-1 par rapport au témoin uniquement dans le sol de Mwea (P <0,05). Le biochar a augmenté la porosité, la conductivité hydraulique a réduit la densité apparente dans les deux sols. Une efficacité d'utilisation de l'eau significativement plus élevée de 4,99 kg ha-1 mm-1 à 50% de floraison dans le sol de Mwea modifié à 10 t ha-1 par rapport aux valeurs de contrôle et 3 t ha-1 qui mesurait 2,2 t ha-1 mm-1 et 3,2 t ha-1 mm-1 (p <0,05). Sur la base de ces résultats, les sols de Mwea devraient être modifiés avec 10 t ha-1 de biochar pour maximiser la productivité et la rétention d'eau.

Mots clés: densité apparente, coefficient de culture, évapotranspiration, conductivité hydraulique, potentiel matriciel, potentiel hydrique, efficacité d'utilisation de l'eau

Introduction

Worldwide, drylands occupy 43% of the total land area out of which and 62% is under reclamation through irrigation to enhance crop production (Rengasmy, 2006). About 83% of Kenya's land mass lie in arid and semi-arid regions characterized by low variable rainfall, prolonged frequent droughts which threaten production and quality of rangeland pasture. Bura and Mwea are marginal lands that originally practiced range system of livestock pastoralism but have under gone land use change to include crop production. Establishment of drought tolerant endemic legume landraces robust enough to withstand protracted dry spells and contribute directly to nutrition is required. Both regions have potential for fodder production in mixed, mono or rotational farming due to settled agrarian, pastoral communities with titled land holdings and available fresh water from River Tana despite soil salinity. In Bura, soils are sandy clay, saline with low in organic carbon in its top soil (Sombroek *et al.,* 1974) while Mwea soils are low fertility clay types (Muchena, 1981). There is increasing infertility in Mwea soils due to intensive rice cultivation.

Biochar, a thermo-chemically degraded organic biomass and a major by-product of pyrolysis, plays multiple agronomic roles in soil by improving soil physical and chemical properties. Compared to fertilizers, biochar has long-term environmental benefits such as reducing underground water pollution and greenhouse gas emission and improved water holding capacity which makes it more suitable for sustainable agriculture. However the benefits of biochar can vary depending on soil type and texture (Lehmann, 2006; Kimethu *et al.,* 2011).

As such contrasting reports on its effect on soil water holding capacity and water movement rate in soil (Laird *et al.,* 2010; Githinji 2014a; Changanti, *et al.,* 2015; Liu *et al.,* 2016). Information is also limited on the effect of biochar on water use efficiency of a resilient forage legume Dolichos lablab (*Lablab purpureus* L.) Sweet. During this study, *D. lablab* Rongai variety endemic to Bura was collected in the arid and semi-arid ecosystems of Bura Usage of lablab as fodder in these areas is low due to constrains of low soil moisture and rainfall (Karachi, 1997). Thus, introduction of fodder production to build resilience in Kenyan drylands and contribute to high quality fodder for animal production was evaluated with respect to water use efficiency and productivity. Legume are however sensitive to low soil moisture and stressful environmental conditions. The aim of this study was therefore to improve water use efficiency of drought tolerant *D. lablab* in Mwea and Bura.

The specific objectives of the study were to (i) determine the effect of biochar amendment on soil water retention, bulk density and porosity, hydraulic conductivity in Mwea and Bura soils, and ii) determine water use efficiency of *D. lablab* Rongai in biochar amended soils at 3, 10 and 30 t ha^{-1}.

Weather and geographical position of the study areas. Mwea Irrigation Scheme (MIS) lies within coordinates 37 ' 13 E to 37 º 30 E; and 0 º 32 S to 0 º 46' S, 1120 msl in Kirinyaga County. It experiences mean minimum-maximum temperature of 19-29 C and 27.4 C/year, 950 mm/year of bimodal rainfall between March-May, and October-December [Mwea climate traverses three agro-climatic zones, with maximum moisture availability ratio of 0.65 for zone III on slopes of Mt Kenya, 0.5 -zone IV and in the semi-arid towards Tebere. Bura Irrigation scheme (BIS) is located 1.5 S, 01 30 S, 40 01'E, 78-112 msl, is in Tana River County and experiences mean annual temperature range of 27-33 C and average rainfall of less than 350 mm/year. Mwea and Bura soils are vertisols and vary in textural properties but Bura soils are saline. The study was conducted at the National Irrigation Board in Mwea experimental sites for two seasons in 2014 and 2015. Three biochar soil amendment rates were studied. These included 3, 10 and 30 t ha^{-1}. The experimental design was a CBD with three replicates planted at rate of 20 t ha^{-1} in 3m x 3m plots, an inter-row spacing of 60 cm, 1 m spacing within the row. Parshall flume was used to quantify irrigated volume. Percentage content of soil moisture at 10 cm of the rooting system was read from a hand held soil moisture-meter. Destructive sampling was carried out at 50% flowering and maturity to obtain herbage and seed grain drymass. Plant water use efficiency was calculated using ET_o for the growing season and Kc for Dolichos at flowering (1.91) and mature stages (0.94) of growth. Soil water retention was determined using ceramic plate pressure chamber at the soil laboratories, University of Nairobi from saturated cored rings collected at a depth of 15 cm and 15-30 cm transferred at, 0, 3, 5, 10 and 15 bar and over a period of 16 hours from the 3 amendment rates and un-amended control. Bulk density was determined from oven dried soils at 105 ^oC for 2-4 days. In another set of rings, Hydraulic conductivity was determined by measuring reflux of water passed through a saturated soil column of uniform cross sectional area. One way ANOVA was used for analysis of drymass weight. Treatment means were separated by Tukey ($P<0.05$). Conversion for water use efficiency was done using the formular:

(WUE) =Y/ETo*KC was calculated from the generated means

Table 1. Effect of biochar from modernized carbonizer on physical properties (Hydraulic head conductivity, bulk density porosity of Mwea and Bura soils

	Treatment	depth cm	KSAT (cm/h)	Bulk density (g cm^{-3})	Porosity	%clay	%sand	%silt
	Biochar		0.1873					
Mwea	Control	0-15	0.36 ± 0.5	1.19	55.1	57.4	42.4	0.2
	3 t ha^{-1}	0-15	1.08	1.08	59.06			
	10 t ha^{-1}	0-15	0.84± 1.41	1.06	59.86			
	30 t ha^{-1}		1.01	61.85				
Bura	Control	0-15	0.944± 0.8	1.03	61.02	37.6	60.4	2.0
	3 t ha^{-1}	0-15	1.84 ± 0.9	1.05	60.35			
	10 t ha^{-1}	0-15	3.14 ± 2.4	0.96	63.00			
	30 t ha^{-1}	0- 15		0.67	74.00			

Table 2. Effect of Biochar amendment (3, 10 and 30 tons ha^{-1}) on water use efficiency of Dolichos lablab, herbage and seed grain biomass in Mwea

	Herbage drymass (kg/ha)		seed	WUE (kg ha^{-1}/ mm)	
	50% flowering	mature	drymass (g)	50%flowering	mature
Mwea					
Control	907 ± 61.3 a	3154 ± 373 a		877± 218 a	2.242
6.403					
3 tons	1253 ± 186 ab	2606 ± 434 a		867 ± 157 a	3.127
5.089					
10 tons	2016 ± 352 ab	4826 ± 445 b		1680 ± 237 b	4.99
9.840					
30 tons	3399 ± 152 b	6303 ±237 b		1840 ± 296 b	3.31
12.84					

Results and Discussions

Results of the study demonstrated an increase in soil water retention between pF 0.3 and pF 10 by l02% and 70.2 % in 10 t ha^{-1} and 30 t ha^{-1} , respectively is shown in Table 1. It also increased porosity, hydraulic conductivity and reduced bulk density in Mwea and Bura soils. Optimal water use efficiency of Dolichos at 50% flowering in Mwea was 4.99 kg ha^{-1} mm^{-1} at 10 t ha^{-1} compared to control at 2.2 kg ha^{-1} mm^{-1}or 3 tons 3.2 kg ha^{-1} mm^{-1} as shown in Table 2. Based on these results addition of biochar to Mwea soil amended at 10 t ha^{-1} and 30 t ha^{-1} improved soil water retention at 10 t ha^{-1} and 30 t ha^{-1}, increased porosity, hydraulic conductivity and reduced bulk density in Mwea and Bura soils. In Mwea, this resulted in significant increase in shoot drymass and water use efficiency of *D. lablab* Rongai.

Conclusion

Biochar increased water retention capacity, distribution in plant roots, porosity, hydraulic conductivity and evapotranspiration. Based on these results biochar is recommended for adoption in arid and semi-arid ecosystems. During low rainfall seasons, *D. lablab* Rongai should be planted as a monocrop or as an inter-crop with companion cereals (maize, sorghum and millet) or grasses (*E. superba)* in Bura. In Mwea, it can be rotated with rice from December-February and/or Jun-August when rice is off season.

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References

Chaganti, V.N. and Crohn, D.M. 2015. Evaluating the relative contribution of physiochemical and biological factors in ameliorating saline–sodic soil amended with composts and biochar and leached with reclaimed water. Geoderm

Githinji, L.J.N. 2014. Effect of biochar on Physical and hydraulic properties of sandy loam. *Archives of Agronomy and Soil Science* 60 (4): 457-470. DOI: 10.1080/03650340.2013.821698

Karachi, M. 1997. Growth and nutritive value of Lablab purpureus accessions in semi-arid Kenya. *Tropical Grasslands* 31: 214-218.

Kimetu, J.M., Lehmann, J., Ngoze, S.O., Mugendi, D.N., Kinyangi, J.M., Riha, S., Verchot, L., Recha, J.W. and Pell, A.N. 2008. Reversibility of soil productivity decline with organic matter of differing quality along a degradation gradient. *Ecosystems* 11 (5): 726-739.

Laird, D.A., Fleming, P., Davis, D. D., Horton, R., Wang, B.Q. and Karlen. D.L. 2010. Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. *Geoderma* 158: 443–449.

Lehmann, J. and Rondon, M. 2006. Bio-Char Soil Management on Highly Weathered Soils in the Humid Tropics. pp. 517-530. In: Uphoff, N. (Ed.), Biological approaches to sustainable soil systems, CRC Press, Boca Raton. http://dx.doi.org/10.1201/9781420017113.ch36.

Liu, Z.L., Dugan, B., Masiello, C.A., Barnes, R.T., Gallagher, M.E. and Gonnermann, H. 2016. Effect of biochar amendment on water infiltration in a coastal saline soil Impacts of biochar concentration and particle size on hy-draulic conductivity and DOC leaching of biochar-sand mixtures. *J Hydrol* 533:461-472.

Muchena, F.N. 1981. Soils and irrigation of three areas in the lower Tana region. A comprehensive study of soil conditions and Irrigation suitability. KE 1987.01.

Rengasamy, P. 2006. World salinization with emphasis on Australia. *J Exp Bot* 57:1017–1023.

Sombroek, W.G., Mbvi, J.P., Kibe, J.M. and Okwaro, H.W. 1974. A preliminary evaluation of stability of soil conditions on the banks of Lower Tana (Bura East area) for large scale irrigation and development. Site evaluation. Report No. 21, Kenya soil Survey, Nairobi.