academicJournals

Vol. 10(24), pp. 2399-2406, 11 June, 2015
DOI: 10.5897/AJAR2014.8825
Article Number: 5FB21C353350
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Influence of selected tree species on soil characteristics, growth and yield of maize in Western Kenya

Noella Ekhuya[1]*, John Wesonga[1], Jonathan Muriuki[2] and Jeremias Mowo[2]

[1]Departmement of Horticulture, Jomo Kenyatta University of Agriculture and Technology, P. O. Box 62000-00200 Nairobi, Kenya.
[2]World Agroforestry Centre, International Centre for Research in Agroforestry, P. O. Box 30677-0100 Nairobi, Kenya.

Received 6 May, 2014; Accepted 15 April, 2015

Low purchasing power of inorganic fertilizers by farmers among other factors has led to a decrease in maize production in Kenya. Growing trees on-farm can improve the situation. A study was carried out at three sites in Western Kenya to investigate the effects of selected tree species on total organic carbon, cation exchange capacity, pH, growth and yield of maize. Top soil (0 to 15cm) and maize plants were sampled for measurements under the canopies of selected tree species at (2, 7 and 12 m) from trees. A complete randomized block design with four tree species, three levels of distance and three stages of growth was used. Soils under *Grevillea robusta* had a significantly higher pH (p=0.02) at Ulafu. Soil CEC under *G. robusta* and *Leuceana leucocephalla* were significantly lower (p< 0.001) compared to *Markhamia lutea* and *Mangifera indica* at Ulafu. Maize under *G. robusta* at Bumula had the highest yield (3.91 t ha^{-1}). A significantly lower (p=0.001) maize yield was revealed under *M indica* in both Ulafu and Ndere. The study suggests some positive influences from all the trees by increasing total organic carbon in soils. Therefore, increasing the number of trees on farms may improve soil fertility and maize production.

Key words: Soil pH, total organic carbon, cation exchange capacity, tree species, maize growth and yield.

INTRODUCTION

Maize is one of the most important crops in Kenya (Howell et al., 1999) with current production standing at 2 tonnes per hectare (t ha^{-1}) against a potential yield of 5 to 8 t ha^{-1} (MOA, 2013). Factors contributing to this yield gap include poor soil fertility, poor crop husbandry and use of low yielding varieties among others (Murithi et al., 1994; Achieng et al.,2001). Western Kenya is among the areas in the country with great potential for crop

*Corresponding author. E-mail: noella.ekhuya@gmail.com.

Abbreviations: CEC, Cation exchange capacity; **MASL**, meters above sea level; **SIMLESA,** sustainable intensification of maize-legume cropping systems for food security in Eastern and Southern Africa; **TOC**, total organic carbon; **WACE**, weeks after crop emergence.

production due to high rainfall (1,740 to 1,940 mm/annum). However, the soils in this region are currently depleted due to soil acidity and continuous cropping without soil replenishment. In fact the use of fertilizers by the small holder farmers is limited by high fertilizer cost and poor distribution (Kiptot, 2008; Sanchez et al., 2009).

Smallholder farmers in western Kenya rely on organic, or a mix of organic and inorganic fertilizer application for maize production. Those who do not have access to manure, and cannot afford inorganic fertilizers constitute the majority of farmers and experience recurrent low yields due to lack of capital to invest in the necessary technologies (Murithi et al., 1994; Kapkiyai et al., 1998). Use of locally available organic materials from trees and shrubs has the potential to improve soil fertility even though this has not been applied to a large extent in western Kenya. Intercropping nitrogen fixing trees such as *Gliricidia sepium* Kunth ex Steud. with crops has been shown to improve the long-term efficiency of nutrient use and a positive nutrient balance in Malawi and Zambia (Mafongoya et al., 2006; Akinnifesi et al., 2007). Intercropping *Glirici*dia with maize increased maize yields by between 100-500% with an average of 315% over a ten-year period (Akinnifesi et al., 2006). Increase in yield was apparent from the third year after tree establishment. According to these authors, unfertilized maize under *Gliricidia* maintained yield at 3 to 4 t ha^{-1}. When the intercrop plots were amended with 46 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} (representing 50% N and 100% P, respectively), there was a 79% increase in grain yield over the recommended practice, indicating complementarity between the applied fertilizer and organic inputs from *Gliricidia* (Akinnifesi et al., 2007).

Additionally, the use of *Faidherbia albida* for improvement of soil fertility and crop yields has been demonstrated in many parts of Africa (Saka et al., 1994; Kang and Akinnifesi, 2000). This species sheds its leaves during the wet season and resumes leaf growth during the dry season. This makes it possible to grow crops under its canopy with minimum shading on the companion crop. Several studies in Africa showed yield benefits when crops were grown under the canopy of *F. albida.* Saka et al. (1994) reported 100 to 400% increase in maize yield in the Lakeshore plain of Malawi. Others by Akinnifesi et al. (2008) showed that planted fallows of *Sesbania sesban* in Zambia, Malawi and Zimbabwe had doubled tripled maize yield compared with control plots. In a similar study in Kenya, soil organic matter fractions were significantly greater under the *gliricidia*-maize intercrop than under sole maize (Pers Com, 2008). These studies show potential of having an integrated approach that incorporates appropriate trees species in cropping systems for sustainable crop production. The influence of large canopy tree species on soil properties and maize yield has however not been extensively studied in Kenya. This study, therefore, sought to establish the influence of common tree species established in croplands on soil properties (soil pH, CEC and TOC) and maize yield in Western Kenya.

MATERIALS AND METHODS

The study area

The study was conducted in three sites in western Kenya; Bumula division in Bungoma County, Ndere and Ulafu divisions in Siaya County. Bumula is located within latitude 0° 25.3' and 0° 53.2' N and longitude 34° 21.4' and 35° 04' E. The site is located mainly within the upper and lower midland agro ecological zones (UM1-4 and LM1-3 respectively) (GOK, 2007). The altitude ranges from 1200 – 1800 meters above sea level (masl), with an average temperatures range from 16 to 30°C with an average of 23°C. Most of the soils are well drained (Jaetzold et al., 2007). There are varying soil types in the area with inherently fertile Andisols and Nitisols as the most prevalent. In 2009, the population of Bungoma where the site lies was 914,075 with a density of 515 persons per km^2 and 175,313 households (GOK, 2010). Agriculture is the main economic activity with maize being the main staple food.

Ndere and Ulafu are located within latitude 0° 26' to 0° 18' North and longitude 33° 58' East and 34° 33' east (GOK, 2010). Altitude ranges from 1,140 to 1,400 m above sea level (masl) to 1400 m masl in the (GOK, 2006). The sites receive bi-modal rainfall: long rains fall between March and June, with a peak in April and May while short rains occur between August and November. The County receives between 800 to 1600 mm of rainfall per annum but rainfall amounts are quite variable and the short rains are especially less pronounced and unreliable (Jaetzold et al., 2007). In 2009, the population of Siaya was 550, 224 with a density of 325 persons per km^2 and 175,313 households (GOK, 2010). Ecologically, Ndere and Ulafu sites fall in the lower midland (LM) agro ecological zone. The major agro-ecological zones are Lower midland zone (LM_1), LM_2, LM_3 and LM_4.

Study design

The study was an on-farm trial that followed a complete randomized block design with four tree species, three levels of distance and three stages of growth; a (4 × 3 × 3) factorial arrangement replicated five times. For the maize growth parameters, the three factors investigated were 4 tree species, 3 distance intervals and 3 stages of plant growth; at levels 6, 9 and 12 after WACE in each site. The study units were maize plants selected in the marked plots under the selected tree species in each farm at the different distance intervals.

Management of plots

Land preparation was done manually by farmers and planting was done at the same time in the first two weeks of March. The farmers planted the same maize variety Duma 43 in the selected plots. The plant spacing used was 75 cm × 50 cm to give a plant population of approximately 27 000 per hectare. The farmers used the compound fertilizer (23:23:0) at an application rate of 10 g per planting station with two seeds. Weeding was done by farmers as per their usual practice but at the same time to reduce variability and they were requested not to prune the trees during the cropping season of study.

Sampling procedure and data collection

A baseline survey was carried out at the four study sites (Nzoia, Bumula Ndere and Ulafu) to determine the common tree species growing on farms. Twelve farms were randomly selected from each of the four sites to form a total of 48 farms. Selection of trees was based on stratified random sampling coupled with purposive sampling procedure focusing on farms that had rather common tree species growing along the boundaries of the cropping area. The selection of trees that were used for the study was also based on tree size and only those with diameter at breast height (DBH) between 15 and 25 cm and were separated from other trees by at least 10 m were selected to minimize interference. The DBH was attained by taking the circumference of the trees at 1.3 m above the ground using a tape measure and the diameter calculated. The farms with the trees that showed less variability in size were selected. The tree species that were found common in the three sites and were used for the study were *Grevillea robusta* A.Cunn.ex R.Br, *Leuceana leucocephala (*Lam de-Wit*), Markhamia lutea* (Benth.) K. Schum and *Mangifera indica* L. The study focused on *G. robusta* and *L. leucocephala* in Bumula and Ulafu and on *M. lutea* and *M. indica* in Ndere and Ulafu. Ulafu was the only site with all the four selected tree species. In Ndere and Bumula, 12 trees were sampled while in Ulafu site, 36 trees were used in the study.

Data collection

Study points were selected and fixed at 2, 7 and 12 m, away from each selected tree for soil sampling and measurement of the growth and yield of maize. Soil sampling was done before the start of the long rains crop season in April 2012. Four soil samples were randomly collected at a 1 m radius using a soil auger around each marked point and mixed to come up with a composite sample for each point. This was replicated for two other trees of the same species in the same farm. Sampling of top soil was done at 0 to 15 cm from the soil surface. The soils were analyzed for soil pH, total organic carbon (TOC) and cation exchange capacity (CEC). The total organic carbon content of the soil was determined by the modified Walkley-Black procedure (Nelson and Sommers, 1996), the pH of the soil was determined in 0.01 M $CaCl_2$ by pH meter method in a ratio of 1:2:5 soils to water while the CEC was determined using the pH 7 ammonium Acetate method Chapman (1965). These three soil properties were selected due to their significance in influencing the quality of soil for agricultural production. Soil pH was determined (1:2 soil/solution ratios).

Maize was planted in the selected farms at the beginning of the long rainy season in March 2012. Six maize plants were selected randomly at each marked study points at 2, 7 and 12 m away from the selected trees for growth assessment. The maize plants were marked with a ribbon for repeated measurements. The measured parameters included: basal diameter and height of the maize plant (from the soil surface to the top of canopy) which were measured. The measurements were done at 6, 9 and 12 weeks after crop emergency (WACE). The maize yield in each farm was assessed at the end of the cropping season. The yield measurements included fresh cob weight and dry grain weight. The cobs were separated from the stover and weighed separately during harvesting. The maize cobs were placed in labeled bags and oven-dried at (105°C) for four days. The dry weight of the maize grain was then determined after shelling the cobs.

Data analysis

The data were analyzed with analysis of variance (ANOVA) using GENSTAT 13 statistical software. Significant difference means were separated using Fishers protected Least of significant test (L.S.D) at P=0.05 (Tulema et al., 2008).

RESULTS

Effect of tree species and distance on pH, CEC and TOC in Western Kenya

Tree species influenced soil pH differently at different study sites with some showing a significant influence (Table 1). At Ulafu site, the results showed a significant difference ($p<0.05$) in the pH of soils sampled under the canopies of *G. robusta* species. Unlike in Ulafu site where the soil sampled under the canopies of *G. robusta* had a significantly higher pH than soils sampled under canopies of *L. leucocephalla,* the pH of soils sampled under the canopies of *G. robusta* was not significantly different from the pH of soils sampled under the canopies of *L. leucocephalla* in Bumula site (Table 1). In both Ndere and Ulafu, plots with *M. indica* did not show any significant differences on soil pH with those under *M. lutea* (Table 1). Findings on soil pH revealed no significant difference (Table 1) at the three distance intervals for the entire selected tree at the three sites.

The CEC of soils sampled under *G. Robusta* at 2, 7 and 12 m in both Ulafu and Bumula was not significantly different from the CEC of soils sampled under the canopies of *L. leucocephalla* (Table 1). The soil sampled under *M. lutea* had the highest mean CEC of 70.07, 70.6 and 66.56 at 2, 7 and 12 m respectively. Soils under G. *robusta* canopies had the least CEC with a mean of 33.51, 34.03 and 35.80 at 2, 7 and 12 m away from the tree. The CEC of soils under *M. lutea* and *M. indica* was significantly different ($p<0.05$) from the CEC of soils under *G. robusta* and *L. leucocephalla* (Table 1). At Ulafu site, the TOC of soil sampled at 2, 7 and 12 m under the canopies of *G. robusta* was significantly higher ($p < 0.05$) compared to the TOC of soils sampled under the canopies of *M indica, M. lutea* as well as *L. leucocephalla* (Table 1).

G. robusta canopies revealed the highest value of 3.3% TOC at 2 m in Ulafu site while *L. leucocephalla* had the least value of 0.84% TOC at 12 m. While the TOC of soils sampled under the canopies of *G. robusta* was significantly different from the TOC of soils under the canopies of *L. leucocephalla* in Ulafu, soils under *G. robusta* canopies in Bumula showed no significant difference in TOC from soils under *L. leucocephalla* canopies (Table 1). Soils under *M. lutea* were not significantly different from soils under *M. indica* in the amount of TOC in both Ulafu and Ndere.

Effect of tree species on the growth of maize in Western Kenya

At both Bumula and Ulafu sites, there was no significant difference in the height of maize under *G. robusta* and *L. leucocephalla* at 6, 9 and 12 weeks after crop emergence (Figure 1). However, the height of maize sampled at 2 m

Table 1. Influence of selected tree species on pH, CEC and TOC in Western Kenya in 2012.

Site	Species	2	sd	7	sd	12	sd
				pH			
		Distance from trees (m)					
Site	**Species**	**2**	**sd**	**7**	**sd**	**12**	**sd**
Ulafu	*G. robusta*	6.49^{a}	0.43	6.49^{a}	0.48	6.27^{a}	0.52
	L. leucocephalla	5.90^{b}	0.36	5.99^{b}	0.53	5.97^{b}	0.48
	M. lutea	5.83^{b}	0.27	5.80^{b}	0.53	5.88^{b}	0.29
	M. indica	5.91^{b}	0.44	5.81^{b}	0.36	5.79^{b}	0.31
	LSD	0.54		0.43		0.36	
Ndere	*M. lutea*	6.12^{e}	0.45	5.8^{e}	0.57	5.87^{e}	0.66
	M. indica	6.75^{e}	0.06	6.58^{e}	0.73	6.38^{e}	0.64
	LSD	0.69		0.9		0.54	
Bumula	*G. robusta*	6.23^{x}	0.18	5.55^{x}	0.44	6.03^{x}	0.48
	L. leucocephalla	6.07^{x}	0.45	5.92^{x}	0.17	5.95^{x}	0.14
	LSD	0.46		0.48		0.37	
				CEC (Cmolkg^{-1})			
Ulafu	*G. robusta*	33.51^{b}	5.9	34.03^{b}	10.6	35.80^{b}	8.01
	L. leucocephalla	32.09^{b}	15.54	37.51^{b}	11.34	30.86^{b}	10.04
	M. lutea	70.07^{a}	15.3	70.60^{a}	21.43	66.56^{a}	20.16
	M. indica	66.02^{a}	18.58	67.53^{a}	19.02	68.84^{a}	20.05
	LSD	18.71		18.65		16.97	
Ndere	*M. lutea*	38.63^{f}	18.05	33.23^{e}	13.56	34.60^{e}	13.32
	M. indica	47.50^{e}	18.14	40.65^{e}	24.43	39.93^{e}	11.23
	LSD	8.74		7.7		7.11	
Bumula	*G. robusta*	36.47^{x}	11.08	38.9^{x}	22.97	35.57^{x}	15.13
	L. leucocephalla	40.47^{x}	10.15	40.83^{x}	21.14	37.56^{x}	7.44
	LSD	8.21		9.89		7.46	
				TOC (%)			
Ulafu	*G. robusta*	3.3^{a}	2.14	1.24^{a}	0.78	1.89^{a}	1.21
	L. leucocephalla	2.14^{b}	1.31	1.63^{a}	1.14	1.55^{a}	0.76
	M. lutea	1.55^{b}	0.62	1.49^{a}	0.71	1.54^{a}	0.54
	M. indica	1.63^{b}	0.57	1.43^{a}	0.11	1.50^{a}	0.33
	LSD	1.68		1.07		0.61	
Ndere	*M. lutea*	2.13^{e}	0.23	1.65^{e}	0.66	1.50^{e}	0.65
	M. indica	1.69^{e}	0.79	1.91^{e}	0.71	1.47^{e}	0.19
	LSD	0.68		0.41		0.47	
Bumula	*G. robusta*	1.2^{x}	0.36	1.04^{x}	0.45	1.11^{x}	0.49
	L. leucocephalla	1.31^{x}	0.43	1.25^{x}	0.49	0.84^{x}	0.36
	LSD	0.27		0.39		0.34	

*****Means in the same column followed by the same subscript letters are not significantly different at 5% probability based on Fishers protected Least of significant test (L.S.D).

recorded the least growth length at every growth period recorded compared to the height of maze plants sampled at 7 and 12 m away from trees (Figure 1). At Ndere site, the height of maize varied substantially. At 6, 9 and 12

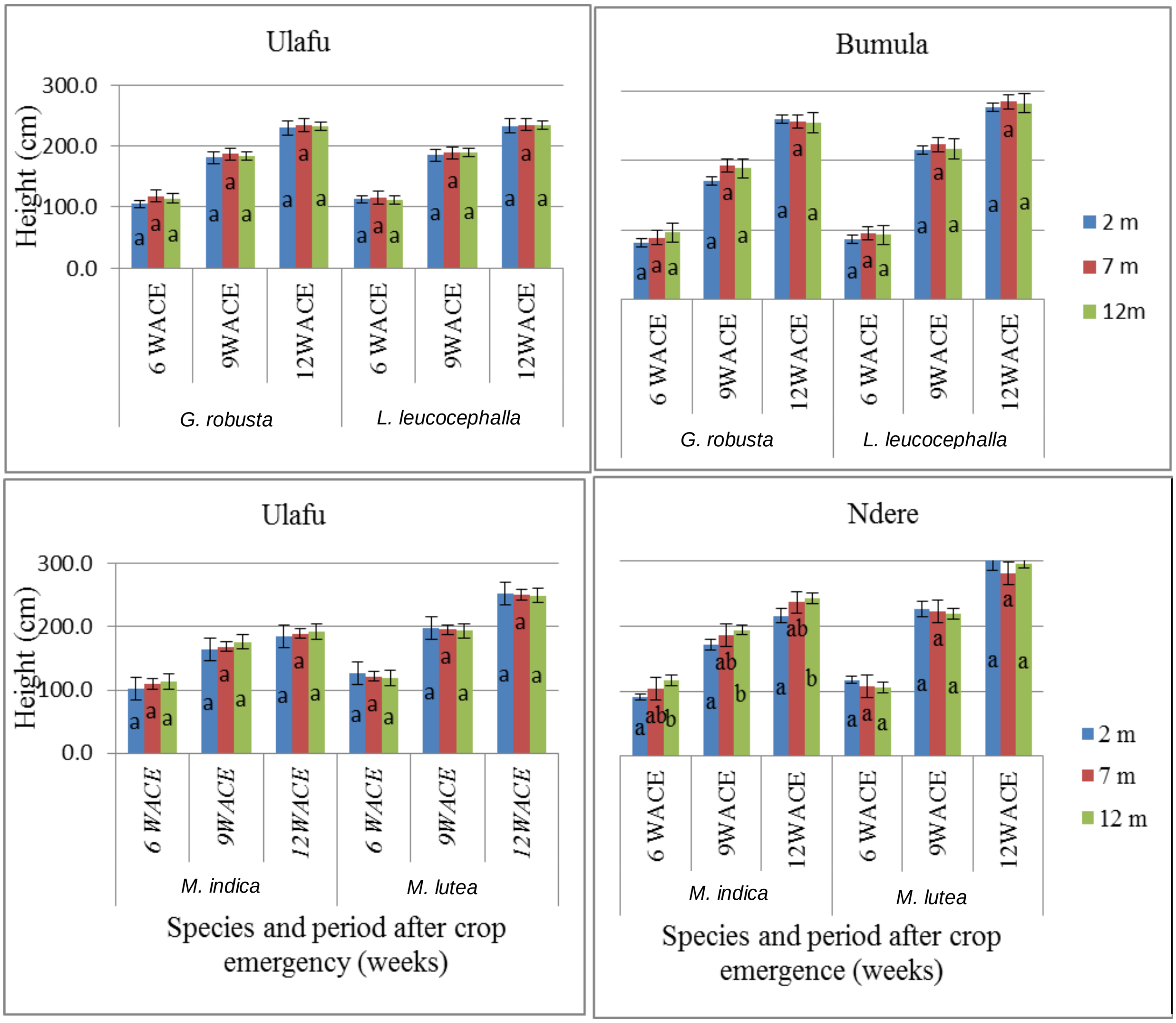

Figure 1. Effect of tree species on the height of maize (cm) in Western Kenya in 2012. The error bars show the standard error of means. Bars with different letters at each site show no significant differences on height of maize as influenced by the trees at $p < 0.05$.

weeks after crop emergence, the height of maize sampled 2 m away under the canopy of M. *indica* was significantly lower ($p<0.01$) than the height of maize sampled at 12 m under the same canopy (Figure 1). The height of maize plants under G. *robusta, M*. *indica* and *L*. *leucocephalla* increased with increase in distance from the tree but this was not the case under *M. lutea*.

Effect of tree species on the basal diameter (cm) of maize in Western Kenya

At Ulafu and Bumula sites, the basal diameter of maize plants sampled under the canopies of both *G. robusta* and *L. leucocephalla* did not show a significant difference ($p>0.05$) at 6, 9 and 12 weeks after crop emergence. Similarly in Ndere and Ulafu sites, maize plants under the canopies of *M. lutea* and *M. indica* did not show any significant difference in the basal diameter of maize and all the stages of growth (Figure 2).

Influence of tree species on the yield (t/ha) of maize in Western Kenya

The selected tree species influenced growth and yield of maize differently. Maize plants sampled under the canopies of *G. robusta* at Bumula had the highest average yield (3.91 t ha^{-1}) at 12 m. *M. indica* at Ndere had the lowest average yield of 1.6 t ha^{-1} at 2 m. At Ulafu and Bumula sites, the yield of maize under canopies of *G. robusta* and *L. leucocephalla* was not significantly

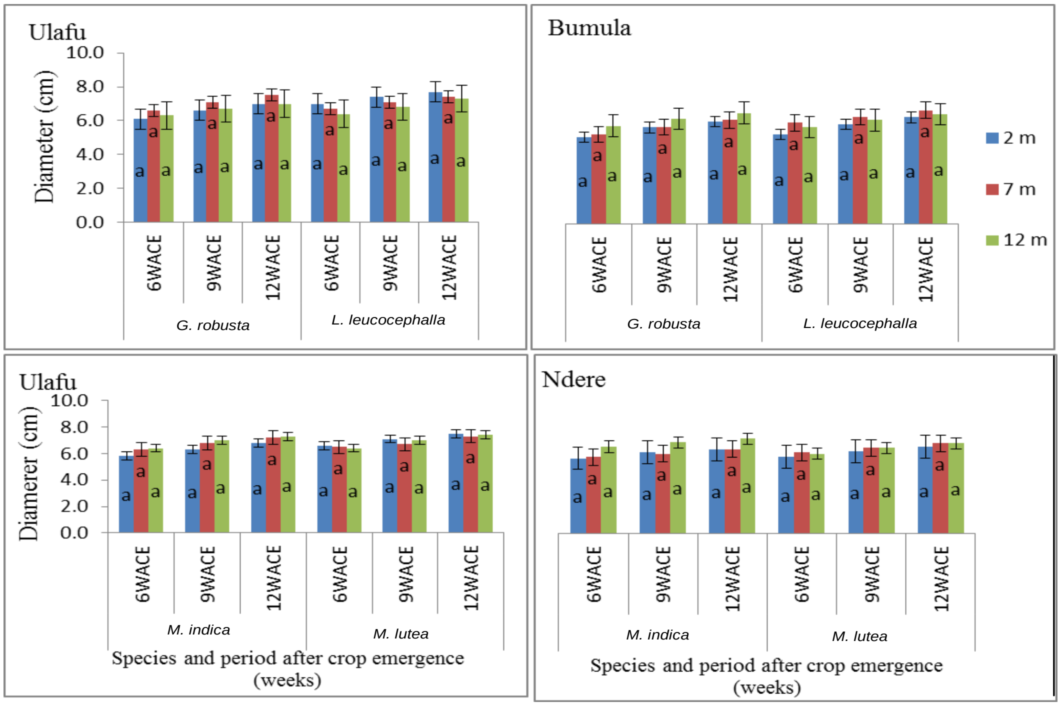

Figure 2. Effect of tree species on the basal diameter (cm) of maize in Western Kenya in 2012. The error bars show the standard error of means. Bars with different letters at each site show no significant differences on the basal diameter of maize as influenced by the trees at $p < 0.05$.

different $p<0.05$ (Figure 3). Findings revealed a significant difference $p=0.001$ in yield of maize under *M. indica* in both Ulafu and Ndere. The yield of maize sampled at 2 m under *M. indica* in Ulafu was significantly different from the yield of maize sampled at 12 m in the same site. At Ndere site the yield of maize at 2 m under canopies of *M. indica* was significantly lower compared to the yields at 7 and 12 m under the same canopies (Figure 3). Yields of maize under *M. lutea* did not show any significant difference in both Ndere and Ulafu sites.

DISCUSSION

The tree species had less influence on the mean soil pH of soils as shown by the soil pH at the various point away from the tree species. Only soils under *G. robusta* at Ulafu site had a significantly higher pH than soils under the canopies of the other trees. *G. robusta* increased soil pH hence lowering the acidity of the soil. These findings are in agreement with those of Nsimabamana (2008). However, the findings in this study contradict Ndlovu et al. (2013), whose study showed a significantly low soil pH value beneath the canopies of the *G. robusta* tree species when compared to other tree species.

High CEC recorded in soils under *M. indica* and *M. lutea* was significantly different from the soils under *G. robusta* and *L. leucocephalla*. The highest soil CEC was recorded under *M. indica* while the least CEC was recorded under *G. robusta.* The differences in the soil CEC could be attributed to the amount of organic matter in the various soils (Ndlovu et al., 2013). The significantly high levels of soil organic carbon revealed in soils sampled under the canopies of *G. robusta* at Ulafu site may be explained by fast decomposition of its litter. These findings differed from the reports of Ndlovu et al. (2013) lower soil organic carbon was found under *G. robusta* tree species and attributed it to slow decomposition of its leaf litter despite the heavy leaf fall as observed under its canopies. However, Salazar et al. (2011) observed that agroforestry has positive effects on carbon stocks in the upper soil layer than the other crop management systems. The inclusion of trees in the farming system especially nitrogen fixing trees have great potential to increase TOC, aggregate stability and soil infiltration rates. This is because as the leaves of the trees and stem biomass decompose, they contribute to improving the organic matter content of the soil and also release nutrients which can then be used up by the adjacent crops (Dahiya et al., 2007). The influence of these trees on soils is mainly ascribed to the recycling of organic materials from the trees to the soil, which can eventually improve the physicochemical, nutritional, and biological properties of soils (Diaz et al., 2004).

The significantly lower height of maize at 6 and 9 weeks after crop emergence, under the canopies of *M.*

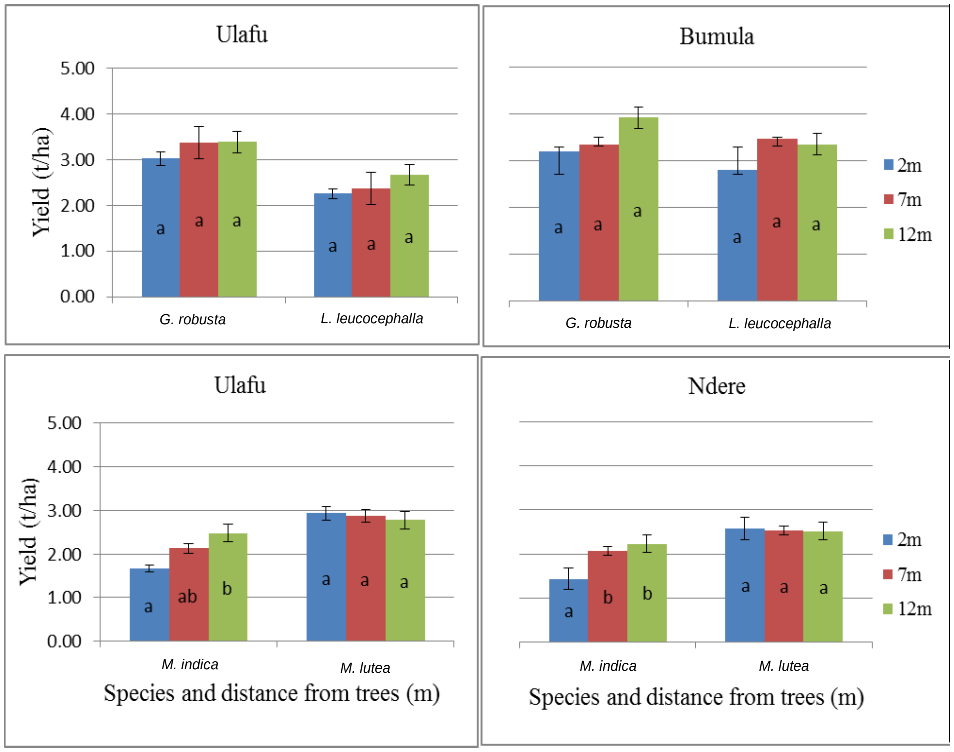

Figure 3. Influence of tree species on the yield (t/ha) of maize in Western Kenya in 2012. The error bars show the standard error of means. Bars with different letters per tree species show no significant differences on yield of maize as influenced by the trees at $p < 0.05$.

indica is due to light competition between the crop and trees. Maize was more suppressed at 2 m under the canopies of *M. indica* at Ndere compared to the other tree species. The suppression of maize may be attributed to the shading effect of tree (which has a dense crown) on the crops and thus reduced growth due to intercepted photo synthetically active radiation (IPAR) as has been reported by Sinclair and Muchow (1999) and Liu et al. (2012).

The low maize grain yield at 2 m under the canopies of *M. indica* canopies at both Ndere and Ulafu could have been due to the interaction of shading effect and low soil fertility under the *M. indica* trees that suppressed growth of maize. This is reflected in the growth parameters (height) of maize under the *M. indica* species which was consistently lower under the canopies of other species. The higher maize grain yield under G. *robusta* could be attributed to the higher levels of TOC recorded on soils beneath its canopies when compared to the other tree species. TOC is known to play important roles in the maintenance as well as improvement of many soil properties that affect both the fertility of the soil, the soil water content and infiltration rate. The higher grain yield recorded under the canopies of *G*. *robusta* compared to the yields under the canopies of other trees at the same distance intervals could be as a result that the ability of the tree to improve the nutrient balance of the soil by increasing nutrient inputs through nitrogen fixation and increase biological activities by providing biomass and suitable microclimate (Schroth and Sinclair, 2003).

The findings indicated that the selected trees did not have adverse effects on the crops that were planted under their canopies apart from *M. indica*. The species studied also have other benefits that they give to farmers in terms of products and services implying that raising the number of trees in the fields could improve farm productivity with little effect on the crops up to the point where intense shading reduces crop productivity. Dominant tree species such as *G. robusta* and *M. lutea* are mainly planted due to the ability of the trees to provide timber and fuel wood, although utility of individual species may vary with family needs. Trees such as *Leuceana leucocephalla* is a source of fodder in addition to providing wood fuel while *M. indica* is a source of fruits for farmers and therefore farmers can also derive cash income from such tree species. The shading of crops by *M. indica* can be managed by use of grafted (dwarf) improved varieties which are massively pruned to reduce shade and control mango weevil. This can improve both crops productivity under the species as well as to generate income from sale of fruits from improved varieties. Minor uses of these trees include shadding, medicinal and aesthetic value. The prevalence of indigenous tree species such as *M. lutea* is due to its ecological adaptability and economic importance (Nair et al., 1984; Sebukyu and Mosango, 2012) and they could be useful in farmers' climate change adaptation strategies.

Conclusion

The findings obtained show that majority of the trees investigated had some positive influence on soil properties as well as the growth and yield of maize hence has the potential of improving maize productivity in western Kenya. For example *G. robusta and M. lutea* which showed some potential as soil improving trees in agroforestry based on their influence on soil carbon, hence can be recommended for use by farmers in this region. Only *M. indica* showed negative influence on growth and yield of maize hence farmers should be advised to try other alternative trees and their agroforestry systems.

Further studies should be conducted with grafted varieties of *M. indica* to determine their influence on maize yield.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support from RUFORUM (Regional Universities Forum) and ICRAF (International Centre for Research in Agroforestry). This work was undertaken as an MSc research for the lead author at Jomo Kenyatta University of Agriculture and Technology and all supervisory role, administrative and laboratory assistance by the university staff especially in the Department of Horticulture.

REFERENCES

Achieng J, Frienson D, Odongo O, Odendo M (2001). Sustainability of fertilizer use on maize production in western Kenya through provision of credit. Seventh Eastern and Southern Africa Regional maize conference, 11th to 15th February 2001, pp. 428-431.

Akinnifesi FK, Chirwa P, Ajayi OC, Sileshi G, Matakala P, Kwesiga FR, Harawa H, Makumba W (2008). Contributions of agroforestry research to livelihood of smallholder farmers in Southern Africa: 1. Taking stock of the adaptation, adoption and impact of fertilizer tree options. Agric. J. 3:58–75.

Akinnifesi FK, Makumba G, Sileshi WG, Ajayi OC, Mwete D (2007). Synergistic effect of inorganic n and p fertilizers and organic inputs from gliricidia sepium on productivity of intercropped maize in southern Malawi. Plant Soil 2(94):203– 217.

Akinnifesi FK, Makumba W, Kwesiga F (2006). Sustainable Maize Production using Gliricidia/maize intercropping in Southern Malawi. Exp. Agron. 42:441–457.

Dahiya R, Ingwersen J, Streck T (2007). The effect of mulching and tillage on water and temperature regimes of a loess soil: Experimental findings and modeling. Soil and Till. Res, 96:52–63.

Government of Kenya (2010). Agricultural Sector Development Strategy, 2010-2020

Jaetzold R, Schmidt H, Hornet B, Shisanya C (2007). Farm management handbook: Natural conditions and farm management information. Vol II, 2nd edition.

Kang BT, Akinnifesi FK (2000). Agroforestry as alternative land-use production systems for the tropics, Nat. Res. Forum 24:137–151.

Kapkiyai JJ, Karanja NK, Woomer PL, Qureshi JN (1998). Soil organic carbon fractions in a long-term experiment and the potential for their use as a diagnostic assay in highland farming systems of central Kenya. Afr. Crop Sci. J. 6:19–28.

Kiptot E (2008). Adoption dynamics of Tithonia Diversifolia for soil fertility management in pilot villages of western Kenya. Exp. Agric. 44:473–484.

Liu T, Liu S, Song F, Zhu X (2012). Light interception and radiation use efficiency response to narrow-wide row planting patterns in maize. Austr. J. Crop Sci. (AJCS) 6(3):506-513.

Mafongoya PL, Bationo A, Kihara J, Waswa BS (2006). Appropriate technologies to replenish soil fertility in southern Africa, Nutr. Cycl. Agroecosyst. 76:137–151.

Murithi FM, Macharia G, Hassan RM, Macharia N (1994). Maize farming in the mid altitude areas of Kenya, farmers practices Research and Extension challenges and the potential for increased productivity, Nairobi, Kenya: KARI/CIMMYT maize database project report.

Nair PKR, Fernandes EC, Wambugu PN (1984). Multipurpose leguminous trees and shrubs for agroforestry. Agrofor. Syst. 2:145-163.

Ndlovu E, Ngamau K, Muthuri CW, Muriuki JK (2013). Alteration of soil carbon and pH by selected common tree species on farms in Eastern Highlands of Kenya, *IOSR* J. Agric. Vet. Sci. (May.-Jun. 2013), 3(2):64-71

Nelson, Sommers (1996). Total carbon, organic carbon, and organic matter. In: Methods of Soil Anal. Part 2, 2nd ed., A.L. Page et al., Ed. Inc. Madison, WI. Agron. Am. Soc. Agron. 9:961-1010.

Saka AR, Bunderson WT, Itimu OA, Phombeya HSK, Mbekeani Y (1994). The effects of *Acacia albida* on soils and maize grain yields under smallholder farm conditions in Malawi. For. Ecol. Manage. 64:217-230.

Salazar O, Casanova M, Katterer T (2011). The impact of agroforestry combined with water harvesting on soil carbon and nitrogen stocks in central Chile evaluated using the icbm/n model. Agric. Ecosyst. Environ. 140:123–146.

Sanchez PA, Denning GL, Nziguheba G (2009). The African green revolution moves forward. Food Sec. 1:37–44.

Schroth G, Sinclair FL (2003).Trees, crops and Soil fertility concepts and research methods. CABI Publishing, Wallingfold.

Sebukyu VB, Mosango DM (2012). Adoption of Agroforestry Systems by Farmers in Masaka District of Uganda, Nutr. Cycl. Agroecosyst. 10:59-68.

Sileshi G, Kuntashula E, Mafongoya PL (2006) Effect of improved fallows on weed infestation in maize in eastern Zambia. Zambia J. Agric. Sci. 8:6–12.

Sileshi G, Mafongoya PL (2006b) Variation in macro fauna communities under contrasting land use systems in eastern Zambia. Appl. Soil Ecol. 33:49–60.

Sinclair TR, Muchow RC (1999). Radiation use efficiency. Adv. Agron. 65:215–265.

Tulema B, Aune JB, Johnsen FH, Vanlauwe B (2008). The prospects of reduced tillagein Tef (Eragrotis tef Zucci) in Gare Arera, West Showa zone of Oromiya. Ethiopia. Soil Till. Res. 99:58-65.