IMPACT OF AGROFORESTRY PARKLAND SYSTEM ON MAIZE PRODUCTIVITY BY SMALLHOLDER FARMERS IN EASTERN HIGHLANDS OF KENYA

[IMPACTO DE UN SISTEMA AGROFORESTAL EN LA PRODUCTIVIDAD DE MAÍZ DE PEQUEÑOS AGRICULTORES DE LA REGIÓN ESTE DE LA SIERRA DE KENYA]

Elton Ndlovu[1*], Kamau Ngamau[1], Catherine .W. Muthuri[1,2] and Jonathan K. Muriuki[2]

[1]Departmement of Horticulture, Jomo Kenyatta University of Agriculture and Technology, P.O Box 62000- 00200. Nairobi - Kenya. Emails: elgatsheni@gmail.com, k_ngamau@yahoo.com
[2]World Agroforestry Center (ICRAF), P.O Box 30677- 0100 Nairobi - Kenya. Emails: cmuthuri@cgiar.org; jmuriuki@cgiar.org.
**Corresponding author*

SUMMARY[1]

A field experiment was carried on farms at Kyeni South in Eastern highlands of Kenya. The purpose of this study was to investigate on the effects of identified common tree species on growth and yield of maize on farms. The selected tree species found to be prevalently growing on farms were *Croton macrostachyus* Hochst. Ex Delile, *Cordia africana* Lam. and *Grevillea robusta* A. Cunn. Growth in basal diameter, height, leaf chlorophyll content and final grain yield was assessed on maize plants selected from the plots under the trees and control plots (away from trees). The maize plants in *G. robusta* plots had significantly lower mean basal diameter of 1.67 cm at 6 weeks after crop emergence (WACE) and 1.96 cm at 9 WACE. No significant differences were observed in plant height in plots under different tree species. Significant suppression of chlorophyll development in maize (indicated by SPAD readings) was observed in all the plots under the identified tree species at 6 WACE ($P < 0.01$). *G. robusta* plots had significantly lower grain yield of 1.57 t ha^{-1} compared to the control plots that had the highest mean yield of 2.21 t ha^{-1}. Proper crown management is necessary in agroforestry systems.

Key words: Agroforestry; Land degradation; Maize; Trees on- farms.

RESUMEN

Se llevó a cabo un experimento de campo en granjas de Kyeni Sur en las tierras altas orientales de Kenia. El propósito de este estudio fue investigar los efectos de las especies arbóreas comunes identificadas en el crecimiento y rendimiento del maíz en las granjas. Las especies arbóreas seleccionadas que se encuentran predominantemente en las granjas fueron *Croton macrostachyus* Hochst. Ex Delile, *Cordia africana* Lam. y *Grevillea robusta* A. Cunn. El crecimiento en el diámetro basal, la altura, el contenido de clorofila foliar y el rendimiento final de grano se evaluó en plantas de maíz seleccionadas de las parcelas bajo los árboles y parcelas de control (lejos de los árboles). Las plantas de maíz en las parcelas de *G. robusta* tuvieron un diámetro basal significativamente menor de 1.67 cm a las 6 semanas después de la emergencia del cultivo (WACE) y 1.96 cm a 9 WACE. No se observaron diferencias significativas en la altura de la planta en parcelas bajo diferentes especies arbóreas. Se observó una supresión significativa del desarrollo de clorofila en el maíz (indicada por las lecturas de SPAD) en todas las parcelas bajo las especies arbóreas identificadas a 6 WACE ($P < 0.01$). Las parcelas de *G. robusta* tuvieron un rendimiento de grano significativamente menor de 1.57 t ha^{-1} en comparación con las parcelas control que tuvieron el mayor rendimiento promedio de 2.21 t ha^{-1}. El manejo adecuado de la corona es necesario en los sistemas agroforestales.

Palabras clave: Agroforesteria; degradación del suelo; Maíz; árboles en granjas.

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INTRODUCTION

Population pressure in high agricultural potential areas of Eastern highlands of Kenya has increased demand on food production, forcing smallholder farmers to practice poor methods of farming such as continuous cultivation, limited crop rotation and clear large areas of natural forests (Shisanya, 2003). The bush fallowing which is an agroforestry system that has been practiced by the communities for a long time is no longer sustainable due to reduced sizes of arable land and increased population growth (Sekubyu and Mosango, 2012). This has resulted in severe land degradation and consequently reduced farm productivity (Solomon *et al*., 2007; Lobell *et al*., 2009).

Low farm productivity by smallholder farmers has remained a major contributing factor to the deepening poverty cycle. Maize yields in Eastern highlands of Kenya still average less than 2 t ha^{-1} (Gitari *et al*., 1996; Hassan *et al*., 1998). Declining soil fertility and poor crop husbandry have been identified as the leading factors in declining yields in the region (Murithi *et al*., 1994; Micheni *et al*., 2002). The situation has been exacerbated by recent erratic rainfalls that are highly variably spatially and temporally (Njoroge *et al*., 2010). Due to the effects of climate change the situation warrants the need for manipulation of the micro-climate that can buffer extreme conditions at farm level. Besides employing soil conservation measures to enhance and maintain soil fertility other systems that are complementary are inevitable (Shisanya, 2003).

Low-cost and sustainable technologies to address problems associated with drought and land degradation are very crucial in Kenya and the Sub-Saharan region at large and are needed on a scale wide enough to improve the livelihood of farmers (Pretty, 1995).Conservation agriculture with trees is now emerging as the most promising land use option to sustain agricultural productivity and livelihoods of farmers (Syampunani *et al*., 2010). However, agroforestry research has typically focused on fast-growing shrub species also known as fertilizer trees to restore soil fertility. Woody multi-purpose and probably adapted tree species have been neglected (Ong and Leakey, 1999).

Modern agroforestry techniques like biomass transfer, fodder banks and alley cropping are being promoted while traditional methods like agroforestry parkland systems are neglected. Agroforestry parkland systems are mainly cropland areas with dispersed trees characterized by the diversity of woody or often indigenous species (Boffa, 1999). The system provides environmental services and off-farm products that are either traded or used to confer multiple livelihood and environmental benefits; this can alleviate malnutrition, hunger and poverty in resource poor smallholder farmers (Mosango, 1999; Palm *et al*., 2001; Leakey, 2005; Sileshi, 2009; ICRAF, 2009; Sekubyu and Mosango, 2012). Trees control the water table, break the strong winds, sequester carbon and mitigate floods (Sileshi *et al*., 2007; Verchot *et al*., 2007; Nair *et al*., 2009).

Potential benefits of trees on farms have been proven in Zambia, Malawi and Tanzania where the intervention has been widely adopted (Kwesiga *et al*., 2003; Nyadzi *et al*., 2006; Akinnifesi *et al*., 2009; Sileshi *et al*., 2009). However, much focus has been on the nitrogen fixing abilities and reverse leaf phenology of the *Faidherbia albida* tree which has potential benefits in terms of enhancing soil fertility and improving crop yields (Saka *et al*., 1994; ICRAF, 2009). In Eastern and Western Kenya, the use of *Tithonia diversifolia*, *Senna spectabilis*, *Sesbania sesban* and *Calliandra calothyrus* tree species planted as farm boundaries, woodlots and fodder banks has proven to be beneficial as a source of soil nutrients in improving maize production (Palm *et al*., 2001). A study by Gachengo (1996) found that the use of *Tithonia spp* green biomass grown outside fields and transferred into the fields was effective in supplying N, P and K to maize equivalent to the amounts of recommended commercial inorganic NPK fertilizer. However, biomass transfer technologies require large amounts of labor for managing and incorporating a leafy biomass, if used for the production of a low value crop like maize. Thus, it is more profitable in high value crops like vegetables (ICRAF, 1997), unlike the generally positive influence of trees scattered in cropping area (Ong and Leakey, 1999). Thus the importance of maintaining trees scattered within the cropping area for improvement of soil and growth of crops like maize. The need for this agroforestry system is particularly great in densely populated sloping areas where soils are often degraded by soil erosion; typically the forest cover has been cleared extensively for timber, charcoal, and agriculture (Young, 1997).

Adoption has been hampered by many factors amongst them farm management practices and perceived negative effects of these trees on growth and yield of crops (Gitari and Friesen, 2001). It is undisputable that negative effects of trees like above and below ground competition and allelopathic effects are existent but more benefits have been reported (Gill, 1992; Van Noordwisk and Purnomoshidi, 1995; Mughal, 2000). Kater *et al*., (1992) stated that differences in yields under crowns of varying sizes and shapes indicate an effect of light competition between crops and trees.
Grevillia robusta is considered by farmers in the highlands of Kenya to be an outstanding agroforestry tree (Muthuri *et al*., 2005). It is thought to be deep rooted and to possess few lateral roots, which suggests good potential for below-ground complementarity

hence used for mulching in tea and coffee on steep mountain slopes (Lott *et al*., 1996; Howard *et al*., 1997; Ong *et al*., 2000). Farmers are concerned about the adverse effects of the trees that are scattered within the cropping area and grow with the crops on farms (Bhatt *et al*., 1993). As such, most farmers are not willing to grow trees together with crops within their cropping area which is limited for growing only food crops like maize and legumes. There is inadequate awareness about the potential benefits of trees that grow on farms to the millions that still live in poverty (Garrity, 2006). Lack of knowledge and evidence on the potential agroforestry tree species and benefits of tree-crop interactions motivates the removal of the trees scattered on the fields as traditional parklands systems. This study seeks to give an insight on the potential agroforestry tree species to farmers and interested stakeholders to promote the system. There is need to select trees with desirable crown architecture that will be compatible with food crops under different agroforestry systems (Bationo *et al*., 2008). The objective of the study was to investigate on the effects of the selected tree species growing on farms in Eastern highlands of Kenya on growth and yield of maize.

MATERIALS AND METHODS

Study site

The research study was carried out on farms at Kyeni South a sub-location in Embu County. Embu is located in the Central highlands of Kenya between 0º.00' N and 38º.00' E. Situated about 120 km North-east of Nairobi, towards Mt. Kenya. It lies between 760 in Lower highlands (LH5), Agro-ecological Zone (AEZ) and 2070 meters above sea level (masl) in LH1. The average annual temperatures range between 9 ºC and 31 ºC. The area receives bimodal rainfall with the long rainy season from March to June and the short rain season from October to December. This study was carried out during the long rainy season that stretched from March to June in 2012. The average annual rainfall is estimated at 1206 mm. The county has a diverse agro-ecology with very fertile soils influenced by Mt Kenya. The dominant soils are Rhodic Nitisols and humic Nitilsols that are characterized by red to reddish brown deep clay soils of more than 35% clay content. The soil pH is generally low (< 5.5) due to leaching of soluble bases.

Study design and Sampling procedure

The study was set up following a complete randomized design (CRD) with one factor (type of tree species) at three levels. The experimental units were the 8m x 8m plots marked under the selected trees and control plots (no trees), replicated three times.

In this study a two stage purposive sampling was used. First a list of farmers in the group that worked previously with the Sustainable intensification of maize-legume cropping systems (SIMLESA) project at the site was acquired and 15 farmers were selected randomly. This constituted more than half of the group members. The selected farms were visited and an inventory of all the tree species growing on farms was conducted. This was done to identify the most common tree species growing especially within the cropping area and thereafter purposive sampling of farms with high numbers of the identified common tree species was done. Four farms were selected and the study was carried out on three common tree species that were selected. The most prevalent tree species that were selected were; *Grevillea robusta* A. Cunn. ex R. Br., *Cordia africana* Lam., *Croton macrostachyus* Hochst. ex Delile.

The selection of the four farms was based on the availability of the selected tree species and their positioning on farms. Farms with at least three individual trees of the identified species growing within the cropping area and isolated at least 10 meters away from any other tree were selected from each site. The selection of the trees was also based on the size in diameter at breast height (DBH), farms with the trees to be compared that showed less variability in size were selected . The experimental units were plots measuring 8m x 8m to accommodate 10 rows of maize plants marked under the trees in each farm leaving the tree centrally located in each plot. In addition three plots measuring 8m x 8m were also selected at least 10 meters away from any tree to act as a control. Precaution was taken in selecting the trees so that they were at least 10 meters away from the canopy edge of the nearest tree to avoid effects of the neighboring trees.

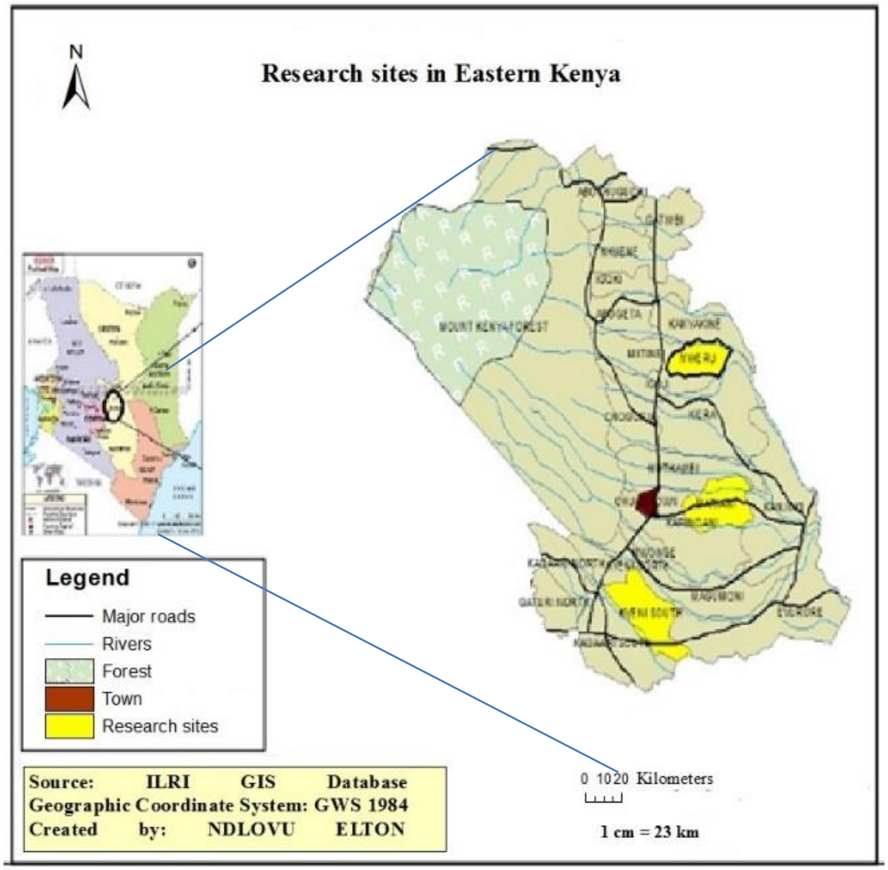

Figure 1. Location of Kyeni South research site in Eastern highlands of Kenya (bottom yellow shaded area). The other two yellow shaded areas at the top were research sites in Meru where the project operated.

Field Measurements

Vegetative growth data on non-destructive measurements

Non-destructive measurements were taken at 2, 6 and 9 weeks after crop emergence (WACE). Two maize plants were randomly selected in each direction of the tree (N, E, W and S) and labeled with tape to facilitate repeated measurements, thereby providing a total of 8 plants around each tree for non-destructive analysis. Eight maize plants were also selected randomly in control plots. Parameters measured included basal stem diameters, and plant height (measured from the soil surface to the tip of the top youngest leaf flag using a tape measure).

Chlorophyll content determination in maize

Soil and Plant Analysis Device (SPAD-502 meter, Minolta, Japan) was used to take readings on leaves of eight selected plants only at 6 weeks after crop emergence (WACE). The instrument uses measurements of transmitted radiation in the red and near infra-red wavelengths to provide numerical values related to chlorophyll content (Lawson *et al*., 2001). SPAD readings were taken at four positions along the third youngest leaf of each marked plant and an average was recorded. This was to give an indication on the effect of shading by trees on chlorophyll content in maize. A possible source of inter-specific variation in photosynthetic activity may be differences in the constitution of the photosynthetic apparatus, particularly chlorophyll content.

Grain yield at maturity

The yield of maize harvested from net plot (7m x 5m) of each experimental unit (plot) was assessed at the end of the cropping season. After attainment of physiological maturity the cobs were harvested from the plots manually. . Husk covers that cover and protect the corn grain were removed, placed in separate labeled bags and the ears were oven dried at (70 ºC) for one week to 12.5% moisture content. Then mean grain yield in (t ha $^{-1}$) was determined.

Agronomic practices

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 DK 8031 in the selected plots for the survey. The plant spacing used was 75cm x 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. Farmers also used some cattle manure. 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. The plots were managed by the farmers.

Data analysis

Data on plant height (in cm) , basal diameter (in cm) and SPAD readings obtained from measuring eight plants that were selected from the net plots of each experimental unit (marked plots) and yield measurements (in t/ha) obtained from all the net plots were statistically analyzed using Genstat 13th edition. One-way Analysis of Variance (ANOVA) for repeated measurements was used to detect significant differences in mean height, basal diameter, SPAD values and yield of plants under the canopies of different tree species at 95% level of significance. Where there were significant differences at alpha level of 0.05 the means were separated using the least square differences. All the data was first tested for normality and homogeneity to ensure the assumptions of the ANOVA were not violated and all the data was normal and no transformations were done.

RESULTS AND DISCUSSION

The analysis of variance on studied traits in maize growth and yield revealed that the three tree species significantly suppressed plant growth in height and chlorophyll development the same way. *Grevillea robusta* tree species significantly suppressed plant basal diameter more than the other two species at 9 WACE. Furthermore the final grain yield obtained in *G. robusta* plots was significantly lower than that in control plots.

The influence of trees species on maize height at different stages of growth

All the three tree species showed suppression of maize growth in height at 6 and 9 WACE (Figure 1). The plants in control plots (away from trees) revealed significantly higher height than those measured under the trees at 6 and 9 WACE. This may be attributed to the shading effect by trees on the crops; reduced growth due to intercepted photo synthetically active radiation (IPAR) has been reported by Sinclair and Muchow (1999); and Liu *et al*., (2012). During the early stages of maize growth (2 WACE) the effect of inhibited photosynthesis by the trees is evidently insignificant but very influential during the critical stages of yield determination in maize.

The *G. robusta* plots were significantly suppressed in plant basal diameter when compared to control plots at 2 WACE. *G. robusta* continued to show significantly lower basal diameter at 6 and 9 WACE (Figure 2). Evidence of increased sensitivity to light competition was revealed in maize stem diameter expansion than in stem elongation in this study. This explains the reduction of plant biomass by light interception during the vegetative growth stages of maize due to reduced storage of assimilates.

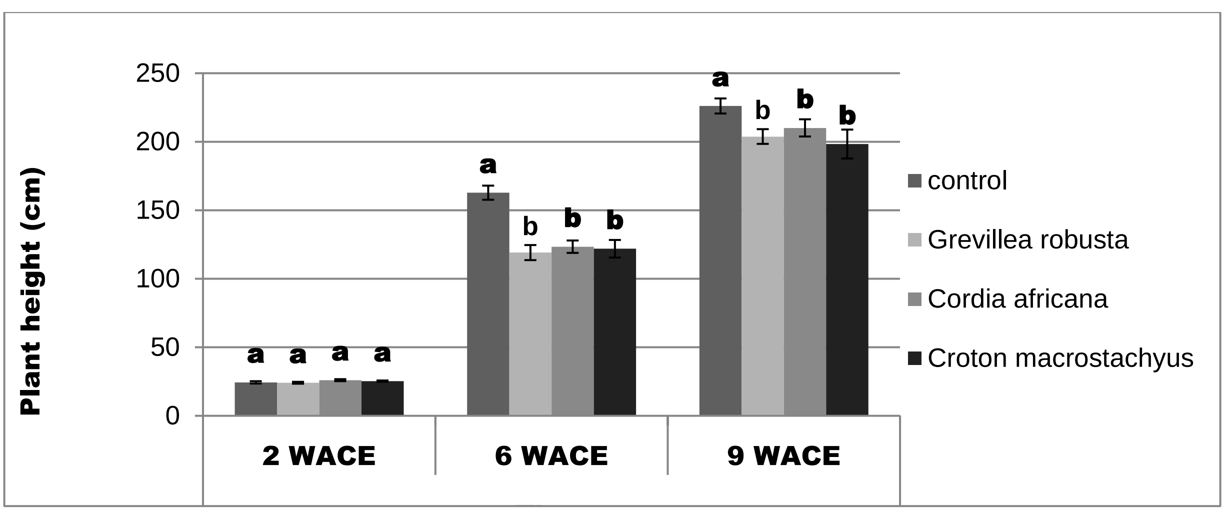

Figure 1. Height for maize planted under the canopies of different tree species
The vertical bars on each bar show the standard error of the mean and the bars with the same letter at each time point in each site show no significant differences in plants height in relation to the influence of tree species.

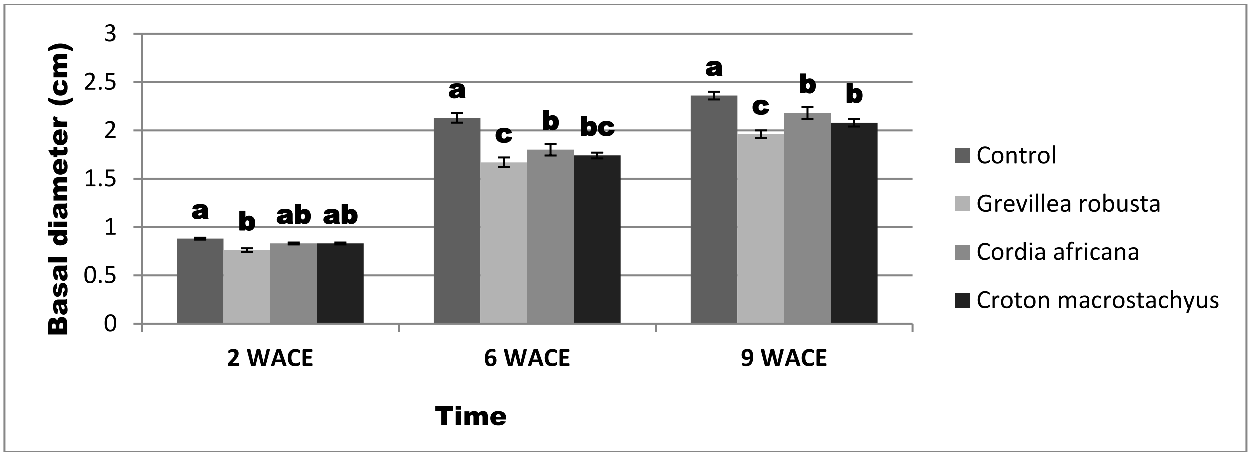

Figure 2. The influence of different tree species on maize plant basal diameter at 2, 6 and 9 WACE.
The vertical bars on each bar show the standard error of the mean and the bars with the same letter at each time point in each site show no significant differences in plants basal diameter in relation to the influence of tree species.

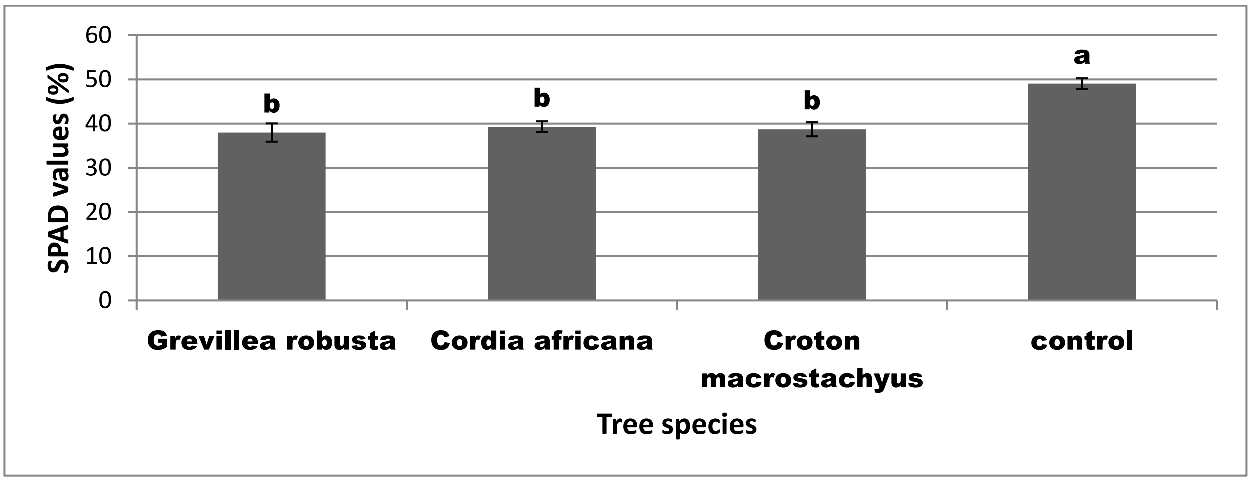

Figure 3. The influence of different tree species on SPAD readings on maize plant leaves at 6 WACE.
The vertical bars on each bar show the standard error of the mean and the bars with the different letters show significant differences in plant SPAD values in relation to the influence of the tree species studied in that site.

The control plots had significantly higher SPAD values when compared to all the plots under the canopies of the tree species (P< 0.001) (Figure 3). This is an indication of significant influence of trees in suppressing the chlorophyll development on maize plants. This may still be attributed to light interception by the trees, decreased chlorophyll concentrations due to shading reported by Hashermi and Herbert (1992). The reduction depends on the leaf area and layers of canopy at different times (Ong *et al*., 1996). The shading effect can be also related to the type and amount of nutrients absorbed by plants from the soil which has been found to have an influence on the chlorophyll concentrations in plants (Kacar and Katkat, 2007; Hawkins *et al*., 2009; Celik *et al*., 2010). Nutrient uptake is increased by transpiration pull; hence shading by the trees which consequently reduce the rate of transpiration may have contributed to reduced nutrient uptake by the plants. This could have consequently hindered some physiological processes like protein formation resulting in low chlorophyll concentrations in maize plants planted under the trees. The rate of leaf senescence is increased under soil mineral deficiencies which can be affected by trees' uptake at a local level (Valadabidi and Farahani, 2010).

The significant reduction in grain yield in plots under the canopies of *Grevillea robusta* tree species when compared to control plots is correlated with suppression of plant growth in stem diameter observed at 6 and 9 WACE (Figure 4). The effects of shading on reduced maize yield under *G. robusta* tree species was reported in a similar study by Ong *et al.,* (2000) in Machakos. The results extend the explanation of suppressed grain yield by the *Grevillea robusta* tree species beyond above ground completion but other factors which are beyond the scope of this study. However the plots under the other two tree species did not significantly differ from that of the control plots in final grain yield.

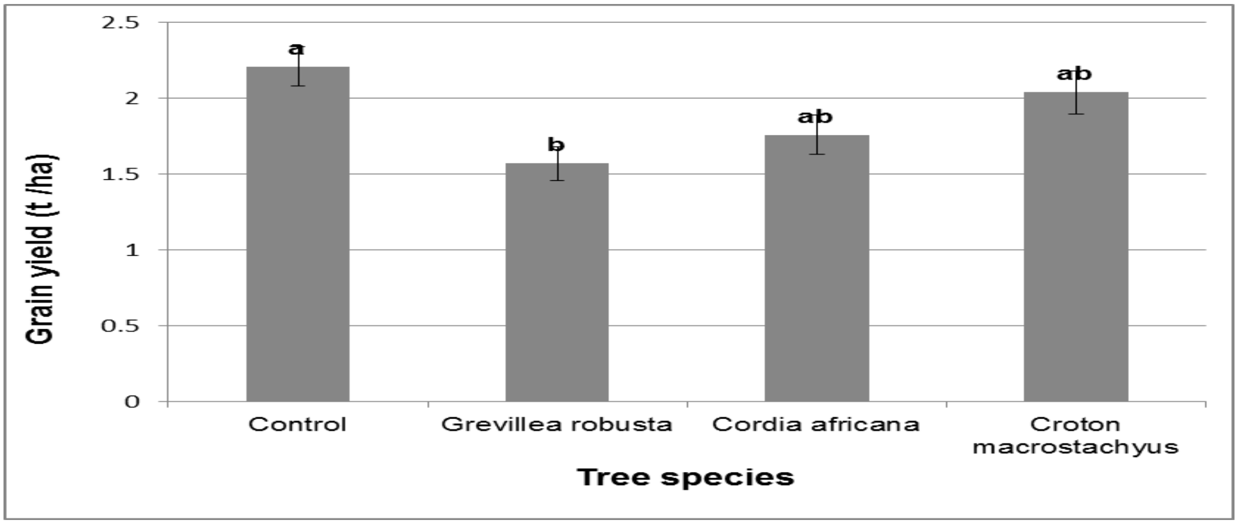

Figure 4. Grain yield on maize harvested under canopies of different tree species.
The vertical bars on each bar show the standard error for the estimation of means and the bars with the different letters show significant differences in grain yield related to the influence of the tree species.

This study was carried out without pruning the tree canopies to 15% as recommended in order to understand the influence of the trees in their normal state. This means the parkland agroforestry system can be practiced on farms without yield losses if good canopy management to reduce the above ground competition is practiced. Despite the negative influences shown by *G. robusta* tree species on farms it is still a potential agroforestry tree given its popularity and multi- purpose use or else it can be planted more on the boundaries if its effects on crops are fully proven. Other sources of competition like the below ground still need to be investigated for these tree species

CONCLUSION

*Grevillea robust*a suppressed growth in plant diameter than other tree species. No significant influence by the trees on grain yield was observed except for *Grevillea robusta* which suppressed the grain yield than the control plots. This means the suppression of vegetative growth by *C. africana* and *C. macrostachyus* did not significantly influence yield reduction in maize.

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