International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211
Volume 9, Issue 5, May -2021, Impact Factor: 7.429, Available online at: www.ijaresm.com

Fundamental Concepts Underlying Strutural Activities of Selected Trees' Roots on the Performance of the Adjacent Native Grass Pastures

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ABSTRACT

Tree root growth structure is a major pathway of enhancing uptake of water and minerals salts to the soil. The main objective of the study was to evaluate the fundamental concept underlying structural activities of selected trees' roots on the performance of the adjacent native grass pastures. The study evaluated the effect of tree stand from a distance of 1, 10, 20,30,40,50 and 60m. A vertical removal of top soil up to 60cm was done. Using vertical soil profile exposed after removal of soil, a small grid cell measures 5x5cm was used to mark the area where roots were exposed. A small knife was used to remove the surrounding soil. The exposed roots were counted inside the area marked by the grid cell. The number of intersection roots of diameters (fine roots between 0.1-1mm,medium roots 1mm-1cm and large diameter roots over 1cm) were manually counted. To the obtain the above ground grass biomass, a radial circle sampling method was used with a radius of 1m all around the marked points in the direction of 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°. A quadrat 0.25m² was laid on each direction and grass samples were collected inside the quadrat. Each marked points (1, 10, 20, 30, 40, 50 and 60m); a serrated knife was used to harvest the grasses that grow the area surrounded by the quadrat. The harvested grass samples were put carefully in labelled bag that included quadrat number and the area collected. The results of the study show that tree root growth morphology influences resource supply to the adjacent native grass pastures. The findings is thought to provide valuable information to National Environmental Management Authority (NEMA), community leaders, extension officers, farmers and NGOs

INTRODUCTION

There is high connection between how plant adjusts rapidly to adverse condition and what extend of adjustment to modify the conditions (Bohra & Singh, 2015). Understanding roots distribution to the adjacent trees and seasonal variations is important in determining competition and complementarily of trees to the adjacent grass pastures (Mattana et al., 2010). Roots depth of adjacent trees species is important in determining the nature of competition for minerals and water. Majority of native grass are shallow rooted with root depth below 30cm from the surface. For their establishments, they highly depend on surface moisture as the main source of water (Pal & Mahajan, 2017). Perennial trees also rely on water for establishment but have adaptations of roots that are able to reach below ground water table for alternative water supply (Mattana et al., 2010). Annual trees and shrubs are less vulnerable to surface water short fall once they become established (Pal & Mahajan, 2017). Surface tree roots remain competitive to the adjacent grass pastures. This does not only depend on density or distribution of roots but activities of the roots in different species within the layers of the soil (Sullivan et al., 2007). Roots less than 2mm in diameter are mostly found in surface layer of 1.0 cm from the ground and have rapid turnover (Sullivan et al., 2007). Variation of root elongation and branching characteristics create morphological differences in length and diameter of roots(Bohra & Singh, 2015). In economic point of view, diameter of root has strong relationship with investment of tree biomass to its roots (Hagen-Thorn et al., 2006). The type of root length and branching pattern play an important role in controlling the manner in which root reinforce and anchor to soil particles. Roots with many branches hold large amount of soil and show a greater resistance to pull out than trees with fewer roots branching density (Bohra & Singh, 2015). Tree roots systems are often complex plant organs. The composed of fine, course roots and stumps. Some ranges of microorganism do associate with them whereby some are damaging (pathogens) and others are beneficial (mycorrhizal fungi) (Hagen-Thorn et al., 2006). The turnover rate of roots builds soil organic matter during forest life since the dead roots act as a source of soil organic matter (Hasanuzzaman, Mahmud & Siddique,2013).Mycorrhizal associations with fine roots are important part of plants nutrient cycle process (Ngoran, et al.,2006).

MATERIALS AND METHODS

(Location of the Study

The study was conducted in Semi-arid South Marmanet forest in an area within 3km square. The area is approximately 300 kilometers from Nairobi. The area lies within the longitudes of $36^0$40" East to $37^0$20" East. The West and East point of the study area, just touches the equator (0^0) and extends to 0^0 15 South and North. The area had gently sloping hills with well drained clay-loam soils. The adjacent native grass areas consist of section of either Eucalyptus plantations (*E. Globules)*, Cypress or Acacia tree stands.

Climatology

The study area had daily temperatures ranges between 14 to 25^0C; Altitude - 2200 to 2400 m above sea level. On average, the warmest month(s) are January and February. Most rainfall (rainy season) is received between the month of April and June. The average rainfall ranges between 500 mm - 700 mm (Kenya Forestry Service, 2009).

Marking of Plots Distance

Experimental marked points which start from the tree stand were made. A distance of 1, 10, 20,30,40,50 and 60m from each tree stand was marked. Each of the above marked points; a radial circle sampling method was used to get the litter and soil samples. This involves a radius of 1m all around the marked points in the direction of 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°. This sampling method was adopted to ensure a collective litter and soil samples were taken from each marked point in different directions

Obtaining Soil samples

Soil samples of each depth 0-15cm were collected at the start of the experiment. A distance of 1, 10, 20,30,40,50 and 60m from each tree stand was marked. Each of the above marked points; a radial circle sampling method was used to get collective soil samples. This involved a radius of 1m all around the marked points in the direction of 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°. Another soil samples was taken at the end of dry season and finally at the end of wet season. A soil borer (4 cm in diameter) was used to dig out soil samples. Soil samples were homogenously mixed and put in plastic bags for analysis in every season. A total 84 soil samples were collected of which 28 soil samples were collected initially, 28 other were collected during dry season and another 28 were collected during wet season. They were taken to the laboratory for physical and biogeochemical analysis. All the soils collected were put in plastic bags to prevent moisture loss and stored in temperature of 5°C before taken for analysis.

Determining Root Density/Branching

From each marked point distance of 1, 10, 20,30,40,50 and 60m, a vertical removal of top soil up to 60cm was done. Using vertical soil profile exposed after removal of soil, a small grid cell measures 5x5cm was used to mark the area where root was exposed. From each depth (1, 10, 20,30,40,50 and 60m), a horizontal lay down of grid cell (5x5cm) was done three times on the same depth. An average root samples were obtained by dividing the sample got by 3 for each depth. A small knife was used to remove the surrounding soil. The exposed roots were counted inside area marked by the grid cell. The number of intersection roots using three diameter (fine roots between 0.1-1mm,medium roots 1mm-1cm and large diameter roots over 1cm) was manually counted. Roots were removed, stored to a temperature of 5°C before taken to the lab for further analysis.

Determining the Diameter of the Roots

From each marked point distance of 1, 10, 20,30,40,50 and 60m, a vertical removal of top soil up to 60cm was done. A volume of soil of 100cm³ cylinder was collected at a depth of 1-60cm.Soil core in the cylinder was split into several blocks. They were put in Petri dish. They were manually split into small fragment with needles and made to spread all over the Petri dish. Visible roots were observed due to their shinny white surface when light with LED bulb. Roots diameter were measured using Ocular micrometer with magnification of x 100.The diameter of the roots were later recorded.

Determining the Root Length

From each marked point distance of 1, 10, 20,30,40,50 and 60m, a vertical removal of top soil up to 60cm was done. A volume of soil of 100cm³ cylinders was collected at each depth. This was aimed at determining horizontal root distribution. The soil auger was used to dig out soil samples. Roots were washed. Visible roots were observed due to their shinny white surface when light with LED bulb. An average root length samples was obtained at each point.

Quantifying Species Composition

A taxonomist from Kenya Forest Service (KFS) South Marmanet Forest was contacted to determine grass species composition. The names of individual grass species within the quadrat was evaluated by identifying their taxonomical names (both scientific and common names). The frequency of the grass species was also evaluated by counting the number of individual grass species as they occur within the quadrat. Their frequency varied from 0% to 100%.

Determining percentage of Species Cover

After the taxonomist from the Forest Service (KFS) had established the individual grass species, the numbers of individual grass species within the quadrat were evaluated by counting the number of individual grass species and dividing them by area of the quadrat.

$$\frac{\text{Number of species in the quadrat X 100}}{\text{Area of quadrat in m}^2}$$

Determining Percentage of Species Richness

After identification of individual species, the level of disturbance was evaluated by comparing relative abundance of species between along the adjacent pastures and the open grass pasture.

$$\frac{\text{Number of species in the quadrat X 100}}{\text{Number of species in the quadrat in open grass land(Undisturbed vegetation)}}$$

Measurement of the Soil Porosity

To determine soil porosity, soils from different adjacent pastures, sample soil was put in a beaker at the same level. The water was then poured into each of the beaker until it reaches the top .The porosity was determined by dividing the volume of water that was able to be poured into the soil inside the beaker by total volume of the soil in the beaker. The result was the expressed as percentage

Measurement of Soil pH and Soil Moisture

An appropriate amount of soil (10-20 g) was dried at 105°C for 24 hours (Blakemore et al., 1987). Soil moisture was calculated as the weight lost per gram after oven drying for 105°C. A 10 g (dry weight equivalent) sample of moist soil was dispersed in 20 ml of deionized water and the pH was measured after 30 minutes (Blakemore et al., 1987).

Measurement of Ectomycorrhizal (ECM) present

Root samples were put in to 50% ethanol at 5 ºC. They were cleaned in 10% KOH and stained with aniline blue following the procedure of Grace and Stribley (1991).For each tree stands, three specimens were assessed. Root segments of 1-2 centimeters were observed. Structures of mycorrhizal (arbuscules or hyphae) were examined in stained roots. Fine roots from each selected sample were cleaned and put in a Petri dish with a grid of 1 x 1 cm. While observing long each grid line, roots crossing the grid line were noted until the whole grid is examined. Centimetre of root length were represented as you move across each line. The same procedure was repeated but only mycorrhizal root tips that cross a line are noted. This was then expressed as mycorrhizal tips per cm of root.

Measurement of Arbuscular Mycorrhizal (AM) present

To identify AM present, air-dried samples of fungal spores approximately 20 g were extracted using wet screening-sucrose gradient centrifugation. Colour of the spore, size and mycelia connected were observed using a light microscope. Spores were put in a glass slide mixed with 40% glycerol. A record of spore colour, size and connective mycelia were observed using a light microscope. Using a manual identification of AM fungi developed by Schenck and Péréz (1988), the number of AM fungal spores in a sample of the soil be isolated, counted and recorded.

Measurement of Root Biomass

Roots production and root biomass were measured by ingrowths method as describe by (Mancuso, 2012).This consists of a bag with 2 mm mesh with root free soil that allows the growth of new fine roots inside the core with a cylindrical container with a diameter of 5cm and a height of 15 cm volume of soil. Nine ingrowths cores per plot were placed randomly in the first three weeks. The mesh permits the ingrowths of fine roots smaller than 2 mm. After one month, the ingrowth cores were taken out of the soil and brought to the lab for analyses. Roots were separated from the soil, washed and cleaned and separated into life versus death roots and fine (<2 mm) versus coarse (>2 mm) roots. A record of fine root biomass (g C·m-2) were recorded.

Treatments

- **Seasons Treatments**. There were two seasonal treatments (i) Dry season (ii) Wet season(ii)
- **Vegetation Treatments**.The experiment consisted of four different vegetation types (i) Eucalyptus tree Cypress tree's roots (ii) Native Acacia tree's root (iv) Open Native grass with no tree nearby (Control)
- **Distance Treatments** There was seven marked point distance from each tree stand measured in metres as follow: 1, 10, 20, 30, 40, 50 and 60m.

Data Analysis

The data was analyzed on the five main variables covered by the research. Average scores for each treatment were plotted. All collected soils samples was analyzed in the lab which includes; interactions between species, biomass parameters, soil phosphorus, Nitrogen and Carbon. The data was organised as per the research objectives and subsequently coded. The coding was to facilitate the development of an appropriate data structure to enable its entry into computer. Data was then summarized using excel package and then analyzed using Statistical package for social sciences (SPSS) for window version 22. Statistical significance was determined at $p < 0.05$ level. Pearson correlation analyses were employed to determine the relationships between litter decomposition indices and soil properties. Linear regression for the relationship between variables were deliberated and drawn. Regression lines differences between two slope coefficients were compared.

RESULTS

Stands Root Influence on Grass Mycorrhizal Associations

The study result table 1 shows that the adjacent tree stand mycorrhizal type had no significant effect on grass mycorrhizal type. Ecto- mycorrhizal showed significant increase in mycorrhizal colonization percentage during dry season than in wet season. AM grass associate was positively associated with moisture condition in wet season. Higher moisture condition increased the percentage of Arbuscular mycorrhizal (AM) than in Ecto-mycorrhizal (ECM). Increase in the number of root counts did not affect the percentage increase in mycorrhizal association. No significant relationship was found with influence of the stand on mycorrhizal association in both AM and ECM. The findings concur with the work of Ayres et al. (2009) that ecto-mycorrhizal fungi have the ability to produce more stable nitrogen pool in the soil than Arbuscular mycorrhizal due to their persistence in substrate utilization. Ngoran, et al.(2006) also observed that ecto-mycorrhizal fungi has high substrate utilization efficiency and produces cellular enzymes that enable them to colonize substrate efficiently.

Table 1 Stands Root Influence on Grass Mycorrhizal Associations

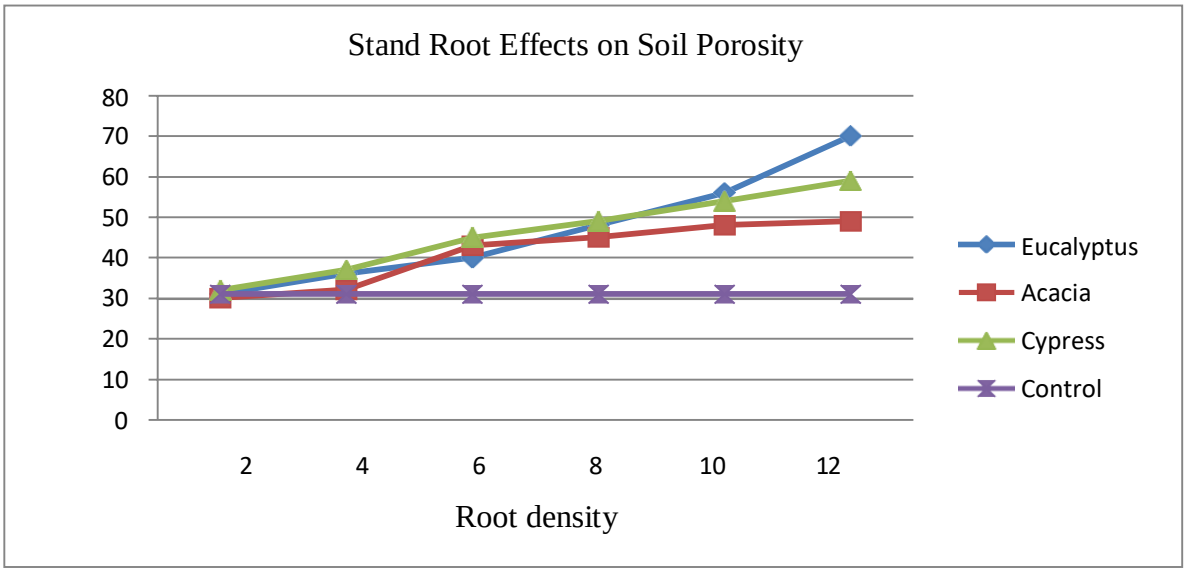
Species	Adjacent Grass Mycorrhizal Association				
Eupt	ECM	Seasons	Counts	Colonization %	Total root counted
		Dry	167	65%	256
		Wet	179	63%	282
	AM	Dry	111	39%	278
		wet	121	48%	249
Acacia	ECM	Dry	126	43%	288
		Wet	122	41%	295
	AM	Dry	172	60%	287
		Wet	176	66%	267
Cypress	ECM	Dry	142	62%	223
		Wet	134	60%	222
	AM	Dry	146	50%	287
		Wet	132	54%	244

Effect of Tree Stand Roots Density on Soil Porosity

From the study results below figure 1, soil porosity in eucalyptus adjacent pastures increases with the number of root present within the area of influence. Higher root density of 13 $\pm$2.68 recorded the highest (69%) soil porosity in

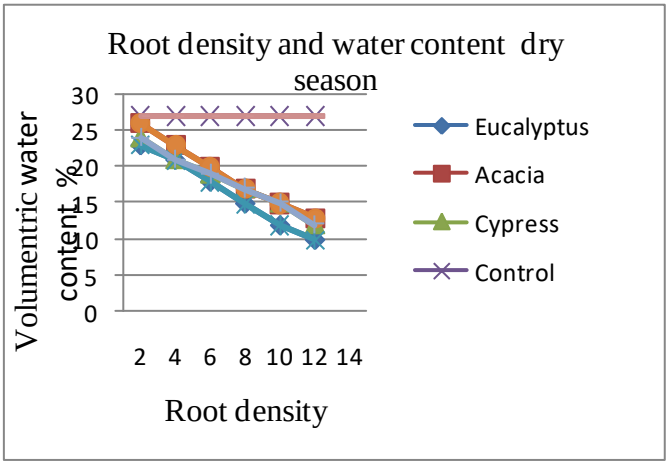
eucalyptus adjacent pastures. Soil porosity in eucalyptus decreases with decrease in root density. Cypress adjacent pastures had also higher soil porosity when the root density is low. The highest was when the root density was 12 ±2.28 (58%).The soil porosity characteristics decrease as the root density decreases just like the eucalyptus adjacent pastures. There was no significance difference in the soil porosity after 2 ±1.37 against control. Acacia had a closer soil porosity relationship with the control though there was increase of root distribution. This mean that Acacia stand had other characteristics outside root density that reduces high soil porosity at high root density

Figure 1 Effect of Stand Roots on Soil porosity



Effects of Stand Roots on Soil Moisture

Soil water content was measured six times during dry and wet seasons. Average volumetric water content was recorded. The results is as shown in figure 1 and figure 2



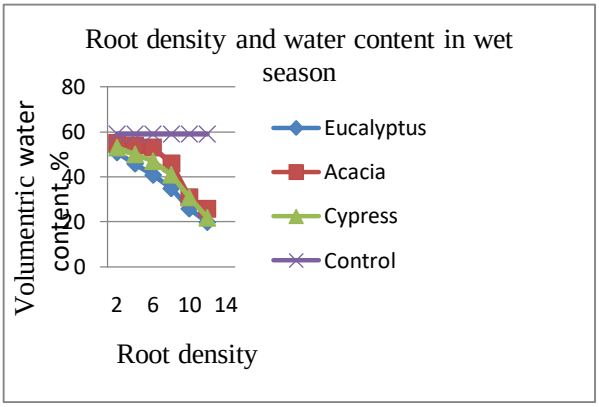


Figure 1 and 2 Effect of Root density on Soil Moisture

From the study results, there was a sharp increase in both wet and dry seasonal water content in low root density across all stands. Acacia adjacent pasture recorded higher water content with increase of root density than the other adjacent pastures. Other plant characteristics could have led to the retention of water in Acacia in it adjacent pastures with high root density. Eucalyptus adjacent stand was the most affected by water content even in lower root density across all stands and the control. Soil porosity and changes in soil structure could have contributed to this. Cypress had relatively lower water content than Acacia and the control. The decrease in water content decline linearly as the density of the roots increases. The observation agreed with the work of Aweto et al.(2005) that Eucalyptus tree species lower soil tables, reduce water availability, increased hydro-phobicity, high rate of transpiration and biodiversity disruption in

associated soils

Table 2 Correlation coefficient of Water Content in Different Seasons

Seasons	Eucalyptus DS	Acacia DS	Cypress DS	Control DS
Eucalyptus WS	.992**	-.933*	.934**	.241
Acacia DS		.945**	-.980**	-.087
Cypress DS			.966**	.332
Control DS				-.349

Key-Wet Season (WS) Dry Season (DS)
**. Correlation is significant at the 0.05 level (2-tailed)

From the Pearson correlation coefficient table 2, there were positive correlations coefficient r^2=0.992 ($p<005$) between Eucalyptus mode of response in root density as the moisture increases. Another positive correlation was between eucalyptus and Cypress r^2=0.934 ($p<005$).

However it was negatively correlated with Acacia in the mode of responses in root density r^2=0.933 ($p<005$).Another negative correlation was found in Acacia- cypress r^2=0.980 ($p<005$).The results indicate that other plant characteristics that enhances water content could have promoted to this trend.

Effect of Branching Density on Species Composition

Figure 3 shows effect of branching density on species composition. Eucalyptus exhibited the highest root density per unit quadrat. All grass species were affected by large density exhibited this type of tree stand. At a root density of 40 root/unit quadrat, *cymbopogon* grass species has the highest percentage of 8%. *Digitaria* grass species has 7% while *Cynodon* and *Chloris* grass species had 3% and 4% respectively. In lower root density rise in species composition per unit quadrat increased. *Cymbogon* had 42@, *digitaria* had 32%, *Cynodon* and *Chloris* had 8% and 7% respectively. The result from the study of Eucalyptus shows that some species were unable to tolerate high density branching density. Perennial grasses like *Cynodon* which become unpalatable during maturity stage remain while other grass species are consumed by herbivores.

This increases their percentage over the others. Cypress has the second grass species diversity percentages in the composition of grass species. Only grass species such as *Cymbogon* could survive in high branching root density. The relative percentages reveals disparities in term of species composition whereby *Cymbogon* had 49%, *digitaria* 36% while *Cynodon* and *Chloris* had 8% and 7% respectively in low root density.

In high root density, *Cymbogon* had 20%, *Digitaria* had 19% while *Cynodon* and *Chloris* had 9% and 8% respectively. There were decreases in species composition in high branching percentage. Acacia provided a balanced species composition even in high density rooting system. Lower root density, *Cymbopogon* had 42%, digitaria 32% while *Cynodon* and *Chloris* has 27 and 26% respectively. In high density rooting system, differences in percentage of species composition were higher than other adjacent grass species. *Cymbopogon* had 32%, *digitaria* 32% while *cynodon* and *chloris* has 27% and 26% respectively. Acacia root move vertically unlike Eucalyptu stand

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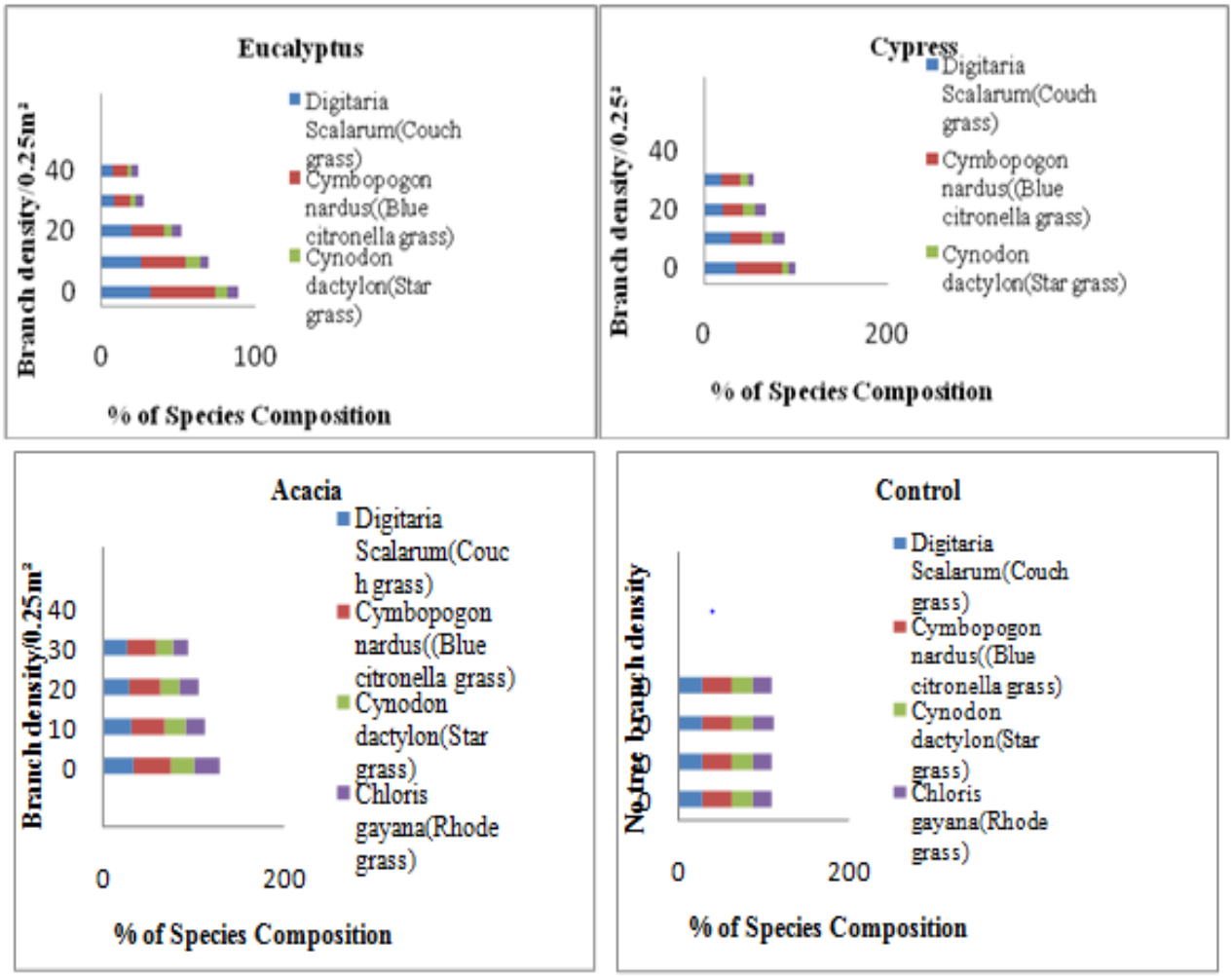
Volume 9, Issue 5, May -2021, Impact Factor: 7.429, Available online at: www.ijaresm.com

Effect of Branching Density on Species Composition

Figure 3 Effect of Stand Br



Anching Density on Species Composition

Effect of Stand Branching Density on Species Richness

Figure 4, below shows mean number of species expressed per unit branching density of the roots. General observable phenomenon shows that there was an effect on species richness and the density of the root. Eucalyptus adjacent pasture mean number of species per unit quadrat of $0.25m^2$ was the lowest in high root density. Mean number of species per unit quadrat was 23. In lower root density the average number of species rose to 27 species / $0/25m^2$. The result of this study is a clear indication that the numbers of species are significantly affected by the density of the roots. Cypress adjacent pastures had similar characteristics like those that were observed in Eucalyptus. At a higher root density, the mean number of species per $0.25m^2$quadrat has an average of 31 grass species. Just like in the Eucalyptus, effect of root density was found to affect the number of species per $0.25m^2$quadrat.

Acacia had the highest number of species per $0.25m^2$ unit quadrat. Higher density recorded an average of 32 grass species per $0.25m^2$ quadrat. This average species number was highest across the entire stands in such a root density. Lower root density also recorded higher number of species across all the stands but slightly lower than that of control. Majority of root branches in Acacia were found to grow vertically, creating less competition pastures hence higher species number per unit quadrat.

Effect of Stand Branching Density on Species Richness

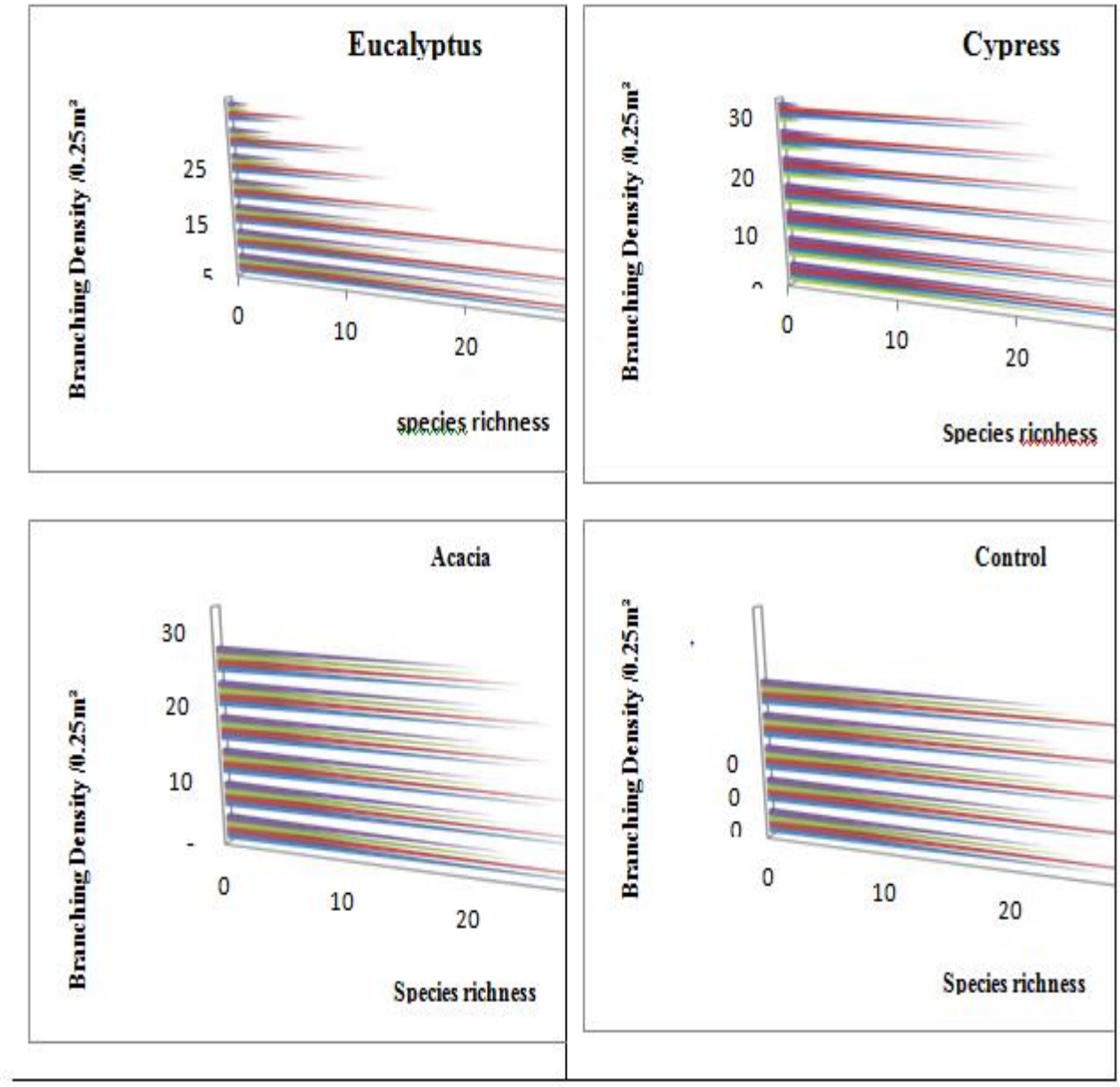


Figure 4 Effect of Stand Branching Density on Species Richness

Effect of Stand Branching Density on Species Cover

Figure 5 shows effect of root density of species cover per unit quadrat (0.25m^2). In Eucalyptus adjacent pastures, higher root density significantly reduced the species cover and encourages bare ground cover. A root density of 20 branches of root per 5cm^2 grid had 40% species cover and 60% bare ground cover. A lower root branches density of less than 5 root branches / 5cm^2 grids had 78% species cover and 22 bare ground cover. Cypress adjacent pasture also had similar characteristic but had a higher species cover. A root density of 20 branches /5cm^2 grid were found to have 62% species cover in a square quadrat and 38% bare ground cover. Adjacent pastures to acacia were found to have the highest species cover per unit quadrat but slightly lower than that of the control. The highest root density had 77% species cover and 23% bare ground cover. At a lower root density, 89% were species cover and only 11% was under bare ground cover. The general observation of exotic stands is that root density has considerable significant effect on species cover that the native tree stands. The numbers of root branches were also found to affect the adjacent pasture across all stands against control.

Effect of Stand Branching Density on Species Cover

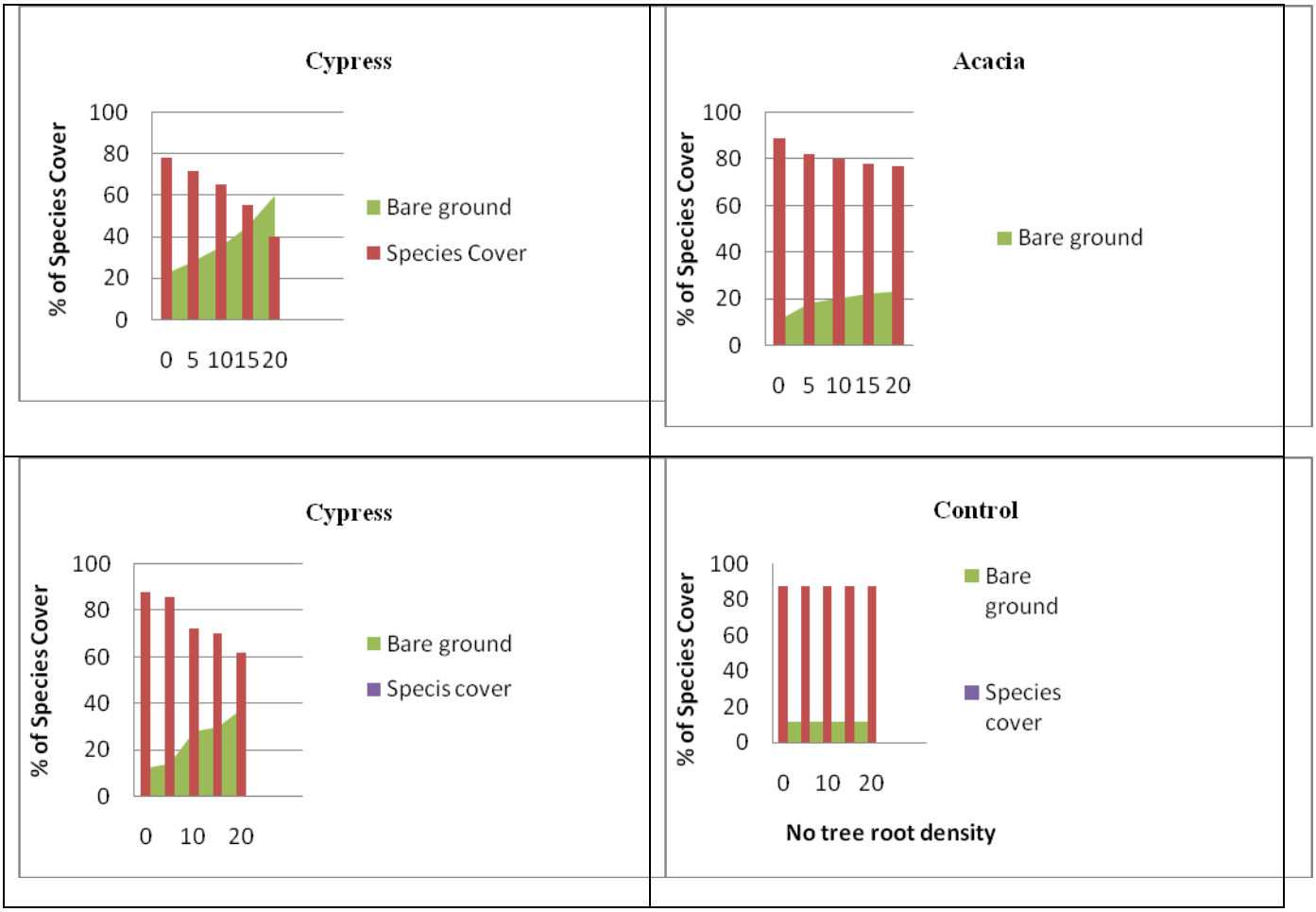


Figure 5 Effect of Root Density on Species Cover

Linear Regression Model Analysis of the roots and the below ground Resource influence

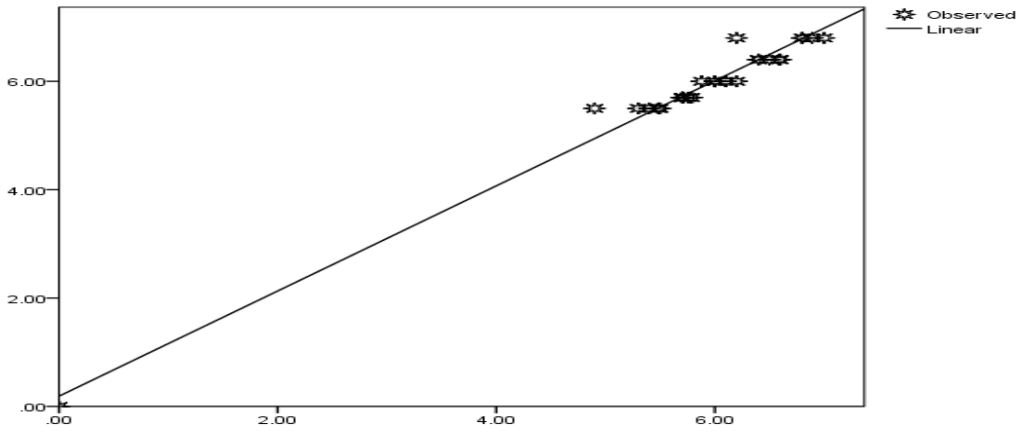


Figure 4.5.10 Shows Regression analysis Model of Roots Structure and their Effects on Soil Porosity, Soil structure, Soil moisture and Mycorrhizal association

Soil porosity	Soil Structure	Soil Moisture	Micorrhizal
r^2=0.61	r^2=0.65	r^2=0.62	r^2=0.68

From the regression analysis (figure 4.5.10), root structure slope (y=34.2x +4) significantly affects the below ground processes. Soil porosity had a significant correlation of r^2=0.61 ($p<0.05$).This suggests that root structure strongly influence below ground resources such as water percolation and aeration which are major components of soil porosity. The root structure in relation to changes in soil structure also had significant relationship of r^2=0.65 ($p<0.05$) while soil moisture had r^2=0.62 ($p<0.05$) and mycorrhizal association with r^2=0.68 ($p<0.05$).This shows that root structure strongly influences below ground resources which affect the above ground native grass characteristics.

CONCLUSION

- From the study results, roots distributions depend on the activities of a given tree. Significance differences were observed between seasons in the number of roots' length for the three stands. Eucalyptus and Cyprus roots explored the soil more in both seasons than in Acacia. This affects the performance of the adjacent native pastures
- The mineral deficits created by elaborate roots structure affect the association of mycorrhizal of the adjacent native grass' roots. Grass species associated with Ecto-mycorrhizal were higher in the two exotic stands than native Acacia. More Aburscular mycorrhizal associated roots of adjacent pastures were found on pastures close to Acacia.
- High roots density spread in areas of influence could explain reasons for high nutrient uptake in soil solution. This affected the performance of adjacent native pastures and also mycorrhizal association
- The annual fine root turnover is an important input for replenishment of organic matter and return of nutrients to the soil. More annual roots turn over were observed in Acacia. This enhances nutrient cycling and therefore the performance of adjacent native grass pastures
- There is strong relationship between root density and various performance of adjacent grass. Significant differences on the performance of adjacent native grass pastures in terms of species composition, cover and richness were observed
- High growth rate of fine roots in the two exotic stands mean that large amount of soil is penetrated. Competition for available water and nutrients begins. High hydro-phobicity was found to encourage surface run off. This affected the performance of adjacent native grass pastures in terms of species composition, cover and richness.
- Soil porosity is a significant factor in the performance of the adjacent pastures. This was found to depend on distance from the tree stands and the type of the tree species. This affects drainage and encourage surface run off.