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Full Length Research Paper

Quality of tree seedlings across different nursery ownerships in Central Gondar Zone, Ethiopia

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Qualities of planting stocks are critical factors for the success of forest plantations. Despite the huge number of annual seedling production in tree nurseries, awareness on quality of seedlings is very limited. This study evaluates the seedling quality across nursery ownership types in terms of morphological attributes and examines the effect of seedling quality on early growth and survival. Three nursery ownerships (private, GO and NGO) were selected from three districts of central Gondar zone with the assumption of different nursery management practices. Four tree/shrub species were selected purposively (common in all the nursery ownership types) and seedlings for quality assessment were sampled randomly. The study indicated that seedling qualities differ across the selected nursery ownership types and have significant effect on survival and early growth. Significant differences (α<0.05) were observed in the mean shoot length, root collar diameter, shoot and root dry masses among different tree nursery owners. These differences could be rooted from different management in different nursery ownership types. There were relatively higher seedling proportions having measured parameters out of threshold standards for height, root collar diameter, shoot to root ratio and height-diameter ratio in private owner. Generally, *Grevillea robusta* performed better in NGO, *Rhamnus prinoides* and *Cordia africana* in private nurseries and *Cupressus lusitanica* in GO nurseries. However, species, site, and management specific studies must be studied to clearly quantify seedling quality and the associated effect on early growth and survival.

Key words: Quality, tree seedlings, nursery ownerships, central Gondar zone.

INTRODUCTION

The forest sector in Ethiopia plays vital role in mitigating and adapting climate change (MEFCC, 2017a; Demisachew et al., 2018). Also various actors have been involved in tree-planting activities in the country for many decades. However, recent afforestation and reforestation programs were not as such successful due to low survival and establishment, due to inferior quality planting materials and species-site matching (Jaenicke, 1999; Abayneh et al., 2010; Kassim et al., 2016), limited information on quality of seedlings (Belay, 2007). Successful plantation depends on the use of quality seedlings (Bertin et al., 2012). However, forest development in Ethiopia is constrained by several factors (which include, lack of forest seed and seedling regulations, inappropriate site and

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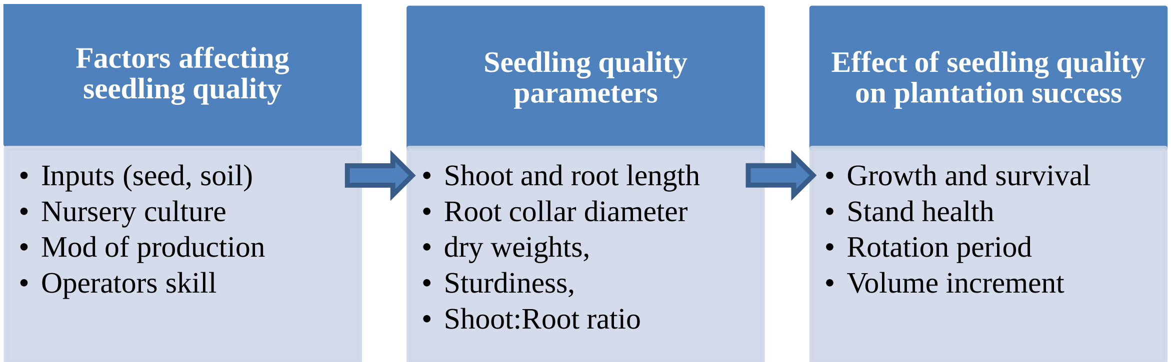

Figure 1. Conceptual framework.

species matching, free gazing, lack of land use planning system etc. (Million, 2011; MEFCC, 2017b). Central to the success of any plantation activity is the quality of the planting stock (Bertin et al., 2013). Seedling quality denotes ability of seedlings to express its full potential after out planted (McCreary and Duryea, 1985). A target seedling is a plant that has been cultured to survive and grow on a specific site (Bertin et al., 2013). It is targeting to meet specific seedling characteristics that can be linked with field performance, termed as "fitness for purpose". It has two main aspects, genetic and physical conditions. A quality tree seedling is one which is healthy, vigorous, and free of diseases, have a robust and woody (lignified) single stem free of deformities and has large root collar diameter that could have high out planting success (Jacobs et al., 2004; Wilson and Jacobs, 2006; Roeland et al., 2006). However, quality of seedling could be affected by species and nursery culture (Anne et al., 2008). Therefore, greater recognition of the role of nursery practices for quality seedlings and the subsequent field performance is needed.

Poor plantation success along with increasing seedling demand has promoted research interests in tree seedlings (Jacobs et al., 2004; Wilson and Jacobs, 2006). Seedling quality and subsequent field performance can be influenced by various management, genetic and environmental factors (Roeland et al., 2006; Pramono et al., 2011; Irawan et al., 2015). Quality standards for nursery crops and the subsequent nursery-planting site interaction are thus urgently needed to ensure reforestation success (Boaz et al., 2015). However, the growth of trees is influenced by a combined factors of genetic and environment (Pramono et al., 2011). Quality assessment can provide technical information to quantify and define minimum seedling attributes for informed decisions (Belay, 2007; Anne et al., 2008; Menzies et al., 2008; Elizabeth et al., 2001; Haase, 2006; Riyong et al., 2016). In order to take advantage of advances made in tree planting, seedling systems should be evaluated and improved. Hence, this study evaluates seedling quality across different nursery ownership types and management practices.

Conceptual framework

The study was guided by the following conceptual framework as depicted in Figure 1.

MATERIALS AND METHODS

Description of study areas

This study was conducted in three districts of central Gondar zone (Gondar zuria, Gondar city and Lay Armachiho) (Figure 2). Districts were selected for this study due to similar agro ecology, species and nursery practices. Major biophysical attributes of the study areas are presented in Table 1.

Description of species and nursery ownership types

Major nursery ownerships considered in this study were government (GO), non-government (NGO) and private nurseries (characterized in Table 2). Among the seedlings produced in the selected nurseries, two indigenous (*Cordia africana* and *Rhaminus prinoides*) and two exotic (*Cupressuss lustanica and Gravelia robusta*) tree species were selected to evaluate seedling quality. The selection of target species was based on their commonly availability in all nursery ownership types in all study areas and the current status of species in commercial plantation.

Experimental settings, data collection and analysis

The study involved an experiment to evaluate seedling quality based on sampled seedlings of selected species from three types of nursery ownerships. In each of the chosen species (*C. africana, R. prinoides*, *C. lustanica and G. robusta*) 100 seedlings per species (100*4 species*3nursery types*3 districts=3,600 seedlings) were selected randomly from all parts of the bed at the time of out planting (Roeland et al., 2006; Haase, 2006). Then, 30 out of 100 seedlings were randomly selected for destructive measurement of morphological traits. Thus, a total of 1,080 seedlings were used for destructive measurement. As indicators of the seedling qualities morphological traits such as shoot and root length, root collar

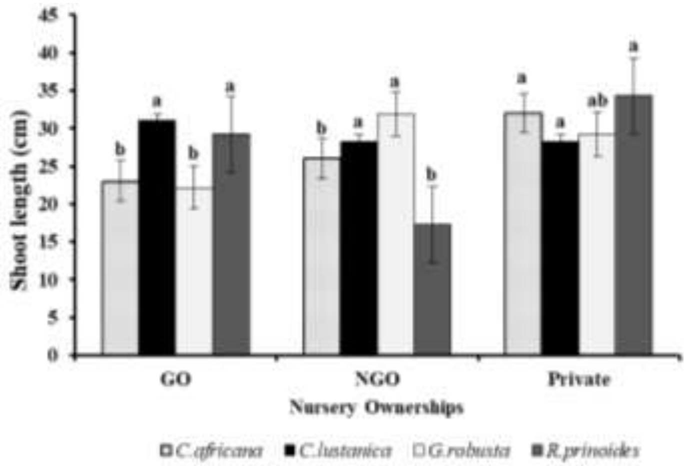

Figure 2. Mean shoot length (cm) across nursery ownership types.

Table 1. Major biophysical attributes of the study areas.

District	Geographical location	Average annual T0 (°C)	Average annual RF (mm)	Agro-ecology	Major soil type	Altitude range
Gondar zuria	12°39'24''N and 37°45'43''E	17.9	1100	Kolla W/Dega Dega	Vertisol, Cambisol	1107-3022 m. a.s.l
Gondar city	1235"60" N and 3728"0.120""E	19.1	1161	W/Dega Dega	Cambisol	2160 m. a.s.l
Lay Armachiho	13° N and 37.167° E	16.9	1100-1300	Dega W/Dega	Cambisol	1500-3200 ma.s.l

diameter, shoot and root dry weights, leaf and branch numbers were measured from the sampled seedlings.

Data was subjected to one Way ANOVA using R-software version 3.5.1, to compare seedling quality parameters across the three nursery categories. Independent analyses were executed for *C. africana, R. prinoides, G. robusta and C. lustanica*. Fisher's LSD test was used for mean separation at α=0.05. The survived seedling was calculated as the proportion of surviving trees to total number of trees of the same species planted. The analysis of variance (ANOVA) was attributed to all data that were generated from the experiment. Also variability among means was described by using coefficient of variation (CV) and Standard deviation (SD). Pearson correlation coefficients (r) were also computed across variables to test the strength of linear relationships.

RESULTS AND DISCUSSION

Seedling quality across nursery ownerships-morphological characteristics

Shoot characteristics

There are some guidelines describing optimal seedling morphological characteristics (Jacobs et al., 2004). Shoot length of seedlings is one of the quality indicators (Haase, 2006). Figure 2 presents the ANOVA result of seedling mean shoot length variation across the three nursery ownerships and for the four types of seedlings investigated. This result concurrently agreed with that of Belay (2007) who reported that nursery management and respective skill of operators can greatly vary and affect nursery stock characteristics. The result indicates that there was a significant variation in the mean seedling shoot length across the nursery categories for *C. africana* (P=0.025) and *R. prinoides* (P=0.003). In both cases the highest mean shoot lengths were recorded in the private nurseries. There was no significant difference in mean shoot length was observed for the species *G.robusta* (P=0.081) and *C. lustanica* (P=0.544). However the highest mean shoot length for *G. robusta* was recorded in NGO nurseries and for *C. lustanica* in GO nurseries. The result could be associated with the specialization of the nursery type for instance indigenous tree species and seedlings with higher market demand have better shoot performance in private nurseries. This result is supported by the reason that private nurseries used better soil mix ratio (Table 2) while seedlings with high demand for industrial plantation is highly specialized and have the highest performance in Government nurseries. As

Table 2. Characterization of nursery ownerships under study.

Variables to characterize nurseries	Nursery ownership type		
	GO	NGO	Private
Average land area	0.5 ha	0.225 to 0.35 ha	0.1 to 0.125 ha
Production capacity (2018)	300,000 to 500,000 s	130,000 to 370,000	8,000 to 45,000 seedlings
Number of species raised	8-13 species	7 to 11 species	5 to 7 tree/shrub species
Major seed sources	Purchased and local collection	Purchased, local collection	purchased and local collection
Major nursery problems	Seed quality, input delay and salary, water	labor, input delay, skill, water,	labor, technical and financial, market
Sowing date for the selected tree/shrub species for the year 2018/2019	*C. africana* from March.1 to 30 *R. prinoides* from Nov.1 to Dec.15 *G. robusta* from Dec.1 to Jan.30 *C. lustanica* Nov.1 to Dec.30	*C.africana*April1 to 30 *R. prinoides* Jan.1 to 30 *G. robusta* Dec.1 to 30 *C. lustanica* Nov.1 - Jan.-30	*C. africana* from March.1 to 15 *R. prinoides* from Oct.1 to Nov.30 *G. robusta* from Dec.1 to Jan.15 *C. lustanica* Nov.1 to Jan.30
Number of workers	10 to 18 workers	8 to 18 workers	3 to 5, family members
Age of nursery	15 to 30 years.	7 to 16 years	2 to 10 years
Forman's education level	High school and below	High school and below	High school and below
Forman's experience	3-26 years	6-12 years	2-8 years
Average soil mix ratio used at different nurseries	2:2:1 (compost, local and sand)	2:2:1 (compost, local, sand)	3:2:1 (compost, local and sand)
Type of nursery	Generally, permanent	Mostly permanent	Mostly temporary
Document organization	Poorly organized	Well-organized	No document at all
Training and extension	Trainings to operators	Trainings to operators	Rare cases
Common nursery culture activities	Root pruning, watering, weeding, transplanting	Root pruning, watering, weeding, transplanting	Root pruning, watering, weeding, transplanting

reported by Belay (2007) the average shoot length of *G. robusta* seedlings was 18.3 cm which is lower than the result found in this study (27.8 cm).

Seedlings should be out planted as soon as they have reached their optimum size depending on the species and the site, but it will usually be a height of 15-30 cm. According to this assumption, seedlings coming out of the selected nurseries more or less meet the standard. However, initial shoot length alone has provided inconsistent ability to predict seedling field performance for some species (Haase, 2006).

Mean shoot dry weight is another indicator for seedling quality (Wilson and Jacobs, 2006). As illustrated in Figure 3, significant difference was observed in the mean shoot dry weight of *G. robusta* (P=0.007), *R. prinoides* (P =0.03). There was no significant difference observed in mean shoot dry weight for *C. africana* (P=0.063) and *C. lustanica* (P =0.151) among nursery ownership types (Appendix Table 1). The highest shoot dry weights were recorded in private nurseries for *C. africana* and *R. prinoides*. Likewise, for *G. robusta* the highest was recorded at NGO nurseries. Belay (2007) reported that the average shoot dry weight of *G. robusta* was 1.14 g per seedling which is lower than the result found in this study (3.9 g) Similarly, for *C. lustanica* relatively higher result was observed in GO nurseries. These could be directly related with shoot length.

Leaf and branch number could affect seedling quality. As illustrated in Figure 4, significant difference was not observed in mean leaf number of *C. africana* (P=0.34), *R. prinoides* (P =0.954), *G. robusta* (P=0.334) and branch number of *C. lustanica* (P=0.312) (Appendix Table 1). The highest mean leaf number was recorded in private nurseries. For *C. lustanica*, the highest mean branch was observed in GO nurseries. These

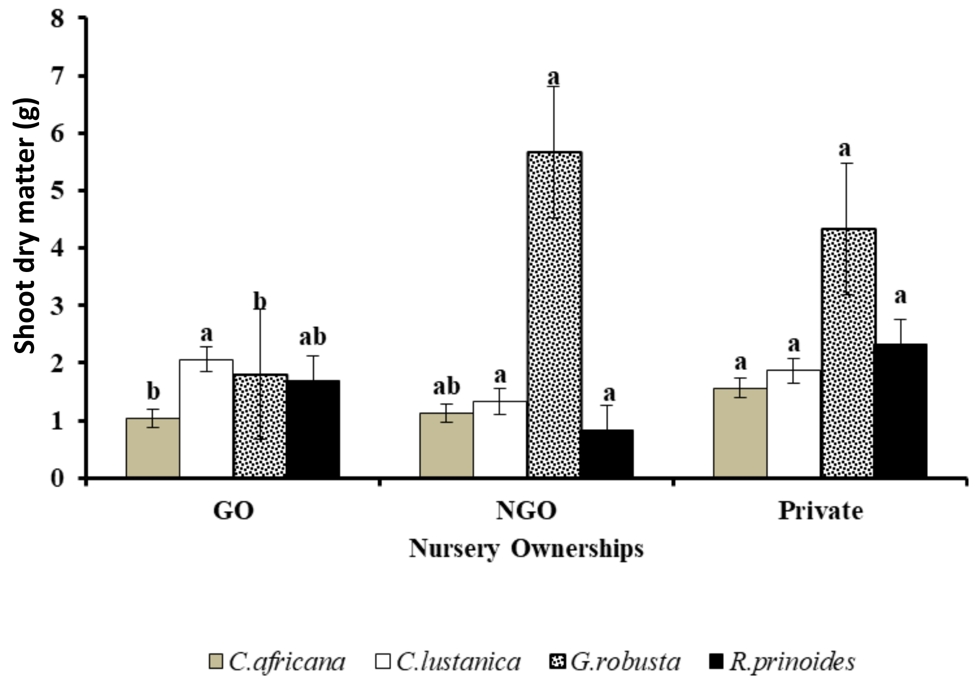

Figure 3. mean shoot dry weight (g) across different nursery ownership types.

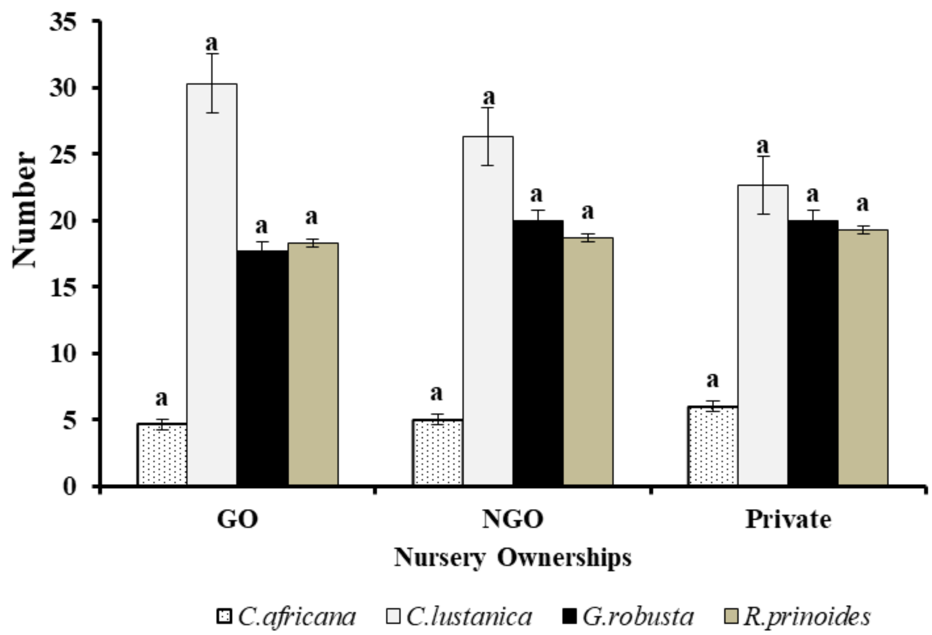

Figure 4. Mean numbers of leaves and branches (*C. lustanica*) of seedlings.

could be associated with shoot length and age of seedlings. Number of leaves ranged from five (*C. africana*) to 20 leaves per seedling in *G. robusta*. For *C. lustanica* number of branches per seedling ranged from 23 in private to 30 in GO nurseries.

Root characteristics

As illustrated in Figure 5, root collar diameter of *C. africana* (P=0.08), *R. prinoides* (P=0.02), and *G. robusta* (P=0.01) shows significant difference across the nursery

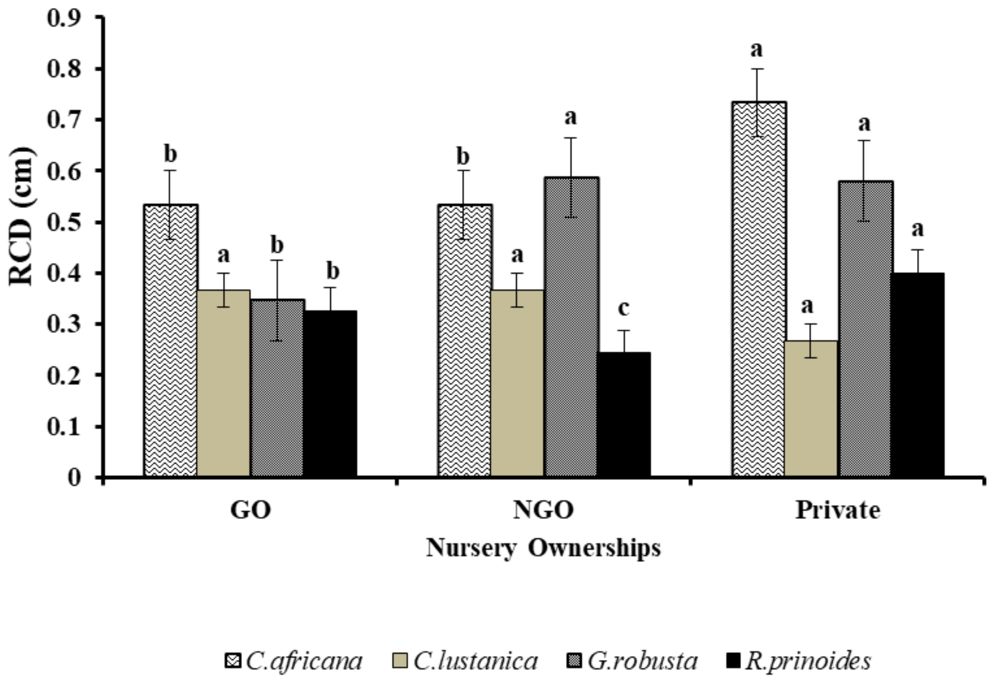

Figure 5. Mean root collar diameter of seedlings from different nursery types.

categories. Significant difference was not observed for *C. lustanica* (P=0.296). In the cases, Cordia (0.73 cm) and Rhaminus (0.4 cm) the highest root collar diameters of seedlings were recorded in private nurseries. For *G. robusta*, the highest root collar diameter was attained in NGO nurseries. This result could be associated with the special experience and species preference of the respective nurseries. On the other hand no significance difference were observed in root collar diameters of *C. lustanica* (P=0.296) seedlings across the nursery ownership types. MEFCC (2017a) and Belay (2007) reported that average root collar diameter of *G. robusta* seedlings was 0.25 cm, which is lower than the finding obtained in this study (0.5). According to the quality standard used for container-grown seedlings, minimum root collar diameter ranges from 3.0-4.0 mm (Menzies et al., 2008). Thus, seedlings from target nursery owners meet the standard except *R. prinoides* from NGO nurseries (0.24 cm). Discussing root characteristics provides a quantitative description of seedling root systems (MEFCC, 2017a; Demisachew et al., 2018). Using the same type of container, nursery owners result different data of root characteristics for tested species. This could be attributed to different management and sowing dates. Root collar diameter take part the entire morphological response of seedlings to the environment and its correlation with other attributes such as the shoot length, shoot length, shoot and root dry weight (Jacobs et al., 2005).

Mean root length was computed from the sampled seedlings as it is an indicator for seedling quality (Anne et al., 2008). However, this study showed that mean root length had negligible effect on early growth and survival except *C. lustanica*. Seedlings with well-developed and extensive root system can be considered as best quality. However, relationship between diameter and survival could be affected by root mass (Haase, 2006) which may be affected by management, root pruning. As illustrated in Figure 6, significant difference was observed in the mean root length of *C. africana* (P=0.002), *R. prinoides* (P =0.039), *G. robusta* (P =0.036), and *C. lustanica* (P =0.006). Similar trend was observed in the performance of seedlings in terms of root length. For *C. africana* (16.3 cm) and Rhaminus (15.3 cm), the highest root lengths were recorded in private nurseries. While the highest root length for Gravelia (17.3 cm) was observed in NGO nurseries. Cupressuss most dominantly produced in Government nurseries and attained the highest height (16 cm). Belay (2007) reported that average root length of *G. robusta* seedlings was 10.4 cm which is lower than the result found in this study (15.6 cm) (Figure 6).

Plants with higher plant dry matter had significantly greater early growth and survival (Elizabeth et al., 2001; Haase, 2006; Jacobs et al., 2005). As illustrated in Figure 7, significant difference was observed in the mean total dry weight of *C. africana* (P=0.035), *R. prinoides* (P =0.004), *G. robusta* (P=0.01) and *C. lustanica* (P=0.045). The highest total dry weights were recorded in private nurseries for *C. africana* and *R. prinoides*. Likewise, for *G. robusta* the highest was recorded at NGO nurseries. Similarly, for *C. lustanica* the highest result was observed in GO nurseries. These could be directly related with the

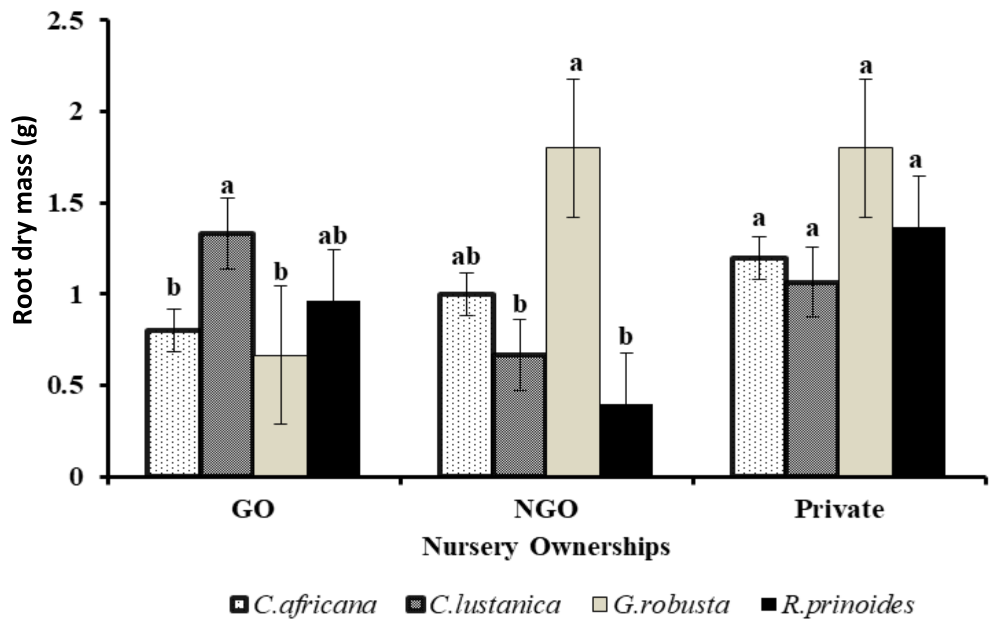

Figure 6. Mean root dry weight (gm) across nursery ownership types.

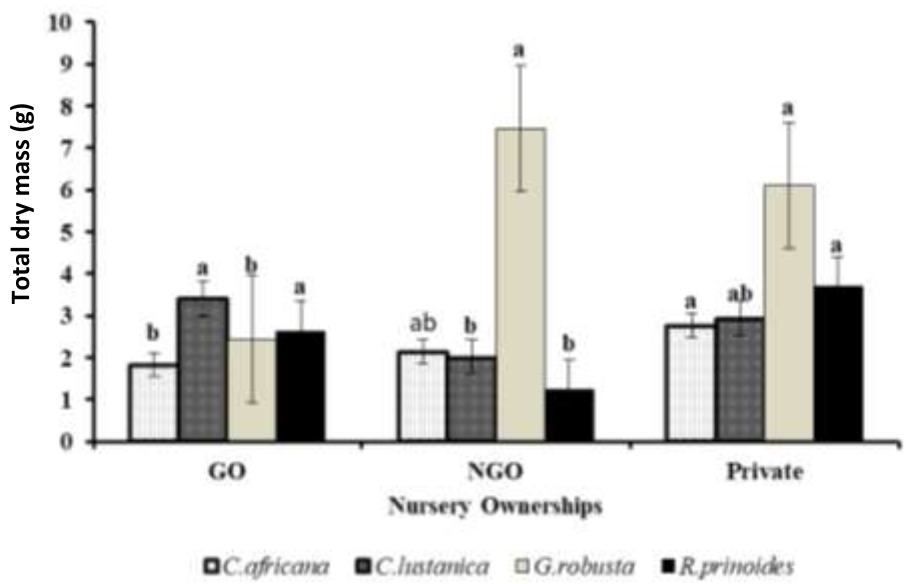

Figure 7. Mean total seedling dry matter (g) across nursery ownership types.

total seedling mass (shoot and root masses) and sturdiness.

Nursery stock quality indicators: Shoot: root length ratio

Seedlings with quality indicators out of the acceptable ranges do not perform well (Bertin et al., 2013; Nestor et al., 2015). Unbalanced plants have too many leaves and too few roots (Roeland et al., 2006). As illustrated in Figure 8, significant difference was not observed in the mean shoot to root length ratio of *C. africana* (P=0.765), *R. prinoides* (P =0.092), *G. robusta* (P=0.136) and *C. lustanica* (P=0.63). The highest mean shoot to root length ratio was recorded in private nurseries. These could be directly related with root pruning activities. NGO and GO nurseries have obviously a successful pruning concept.

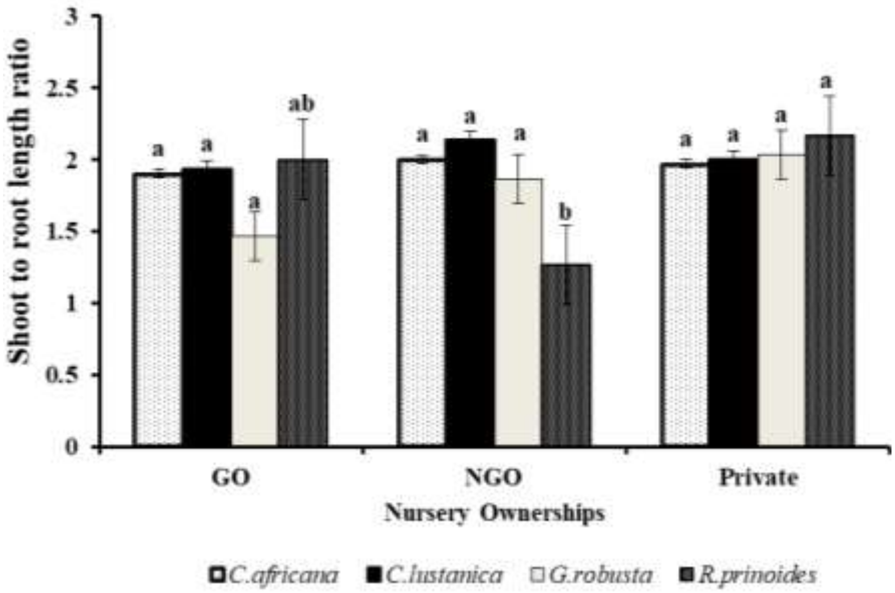

Figure 8. Mean shoot to root length ratio of seedlings across nursery ownerships.

Mostly, private nurseries have better root pruning concept. However, shoot to root length ratio may not be affected by root length only for container seedlings since pot size is similar, rather could be influenced by shoot length. This indicated that shoot and root lengths might not be related for container seedlings due to root pruning. In this study average shoot to root length result of 1.8 was observed for *G. robusta* seedlings from different nursery owners and this result agreed with that of Belay (2007), who found 1.73 for the same species.

Mean sturdiness ratio (sturdiness quotient (SQ) or height-diameter ratio) is an important seedling quality indicator (Jaenicke, 1999). As illustrated in Figure 9, significant difference was observed in the mean sturdiness ratio of *G. robusta* (P=0.035), *R. prinoides* (P =0.029). There was no significant difference observed in sturdiness ratio for *C.africana* (P=0.266) and *C. lustanica* (P =0.342) among nursery ownership types. The highest sturdiness ratios were recorded in NGO for *C. africana* (4.8) and GO for *R. prinoides* (8.9) and *G. robusta* (6.3). Similarly, for *C. lustanica* the highest result was observed in private nurseries (9.7). This could be directly related to shoot length and root collar diameter. According to Jaenicke (1999) small ratios of sturdiness show a sturdy plant with a higher expected chance of survival (<6). Based on this assumption, *C. africana* and *G. robusta* seedlings from all owners meet the general expectations while *R. prinoides* and *C. lustanica* do not in all the three ownerships. However, it differs from species to species and could be affected by the negative correlation between sturdiness ratio and root collar diameter. Average sturdiness ratio of *G. robusta* seedlings was 5.6, which is lower than the out the gate result reported by Belay (2007), which was 9.7.

Though it requires destructive methods, mean shoot to root ratio is an important predictor for survival and growth (Hasse, 2006a). As illustrated in Figure 10, significant difference was not observed in mean shoot to root ratio of *C. africana* (P=0.56), *R. prinoides* (P =0.539), *G. robusta* (P=0.277) and *C. lustanica* (P=0.244). The highest shoot to root ratios was recorded in NGO nurseries. These could be directly related with shoot and root characteristics. Also dry mass of seedlings might be affected by other factors such as age, branch and leaf numbers. Physical quality that should not be overlooked is seedling balance. Seedlings with a larger shoot mass have a greater photosynthetic capacity and potential for growth. However, a greater transpirational area may lead to moisture stress (Haase, 2006; Jacobs et al., 2005). Generally, quality container seedlings have shoot: root of 2:1 or less (Haase, 2006). Based on the computed results, *C. africana,* and *C. lustanica* from the three nursery categories fit to the general expectations of balanced shoot to root system. But, *G. robusta* from all owners and *R. prinoides* from NGO do not meet this assumption.

Mean shoot: root ratio for *G. robusta* was 2.8, agreed with the finding of Belay (2007) who found mean value of 2.91. *G. robusta* from GO and *C. africana* and *R. prinoides* from NGO nursery in general are produced as smaller plants lacking a suitable size of the shoots and roots, which resulted in a diminished survival after out planting. This agreed with the findings of Jacobs et al. (2005). Cao and Ohkubo (1998) also reported that shoot: root ratio can increase linearly with increase in plant height for the saplings <1.5 m. NGO nurseries were found

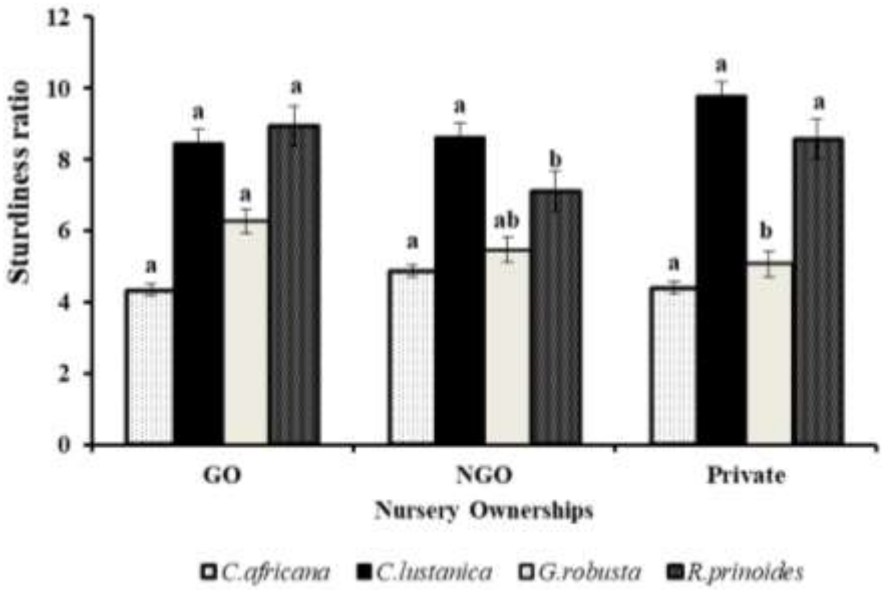

Figure 9. Mean sturdiness ratio.

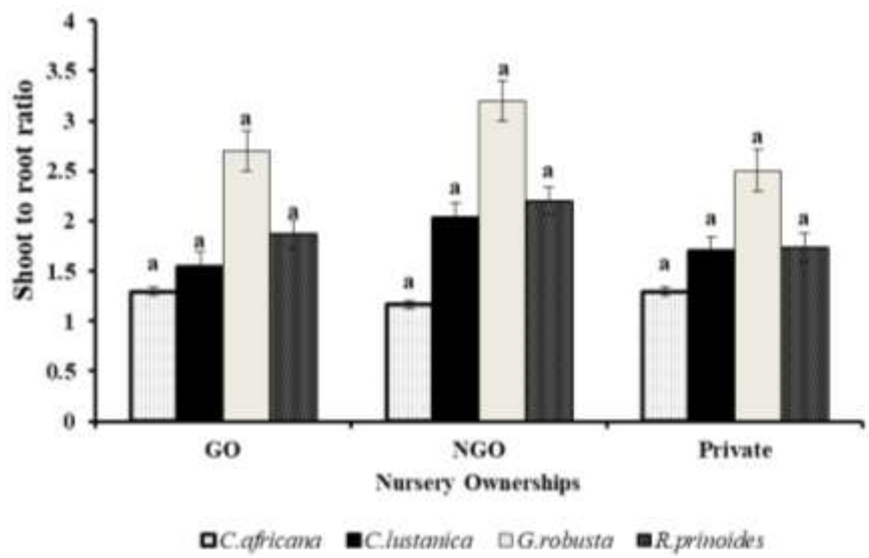

Figure 10. Mean shoot to root ratio.

to have more seedlings with values out of the acceptable range (SRDM) (Demisachew et al., 2018) meaning that shoot biomass is too high compared to root biomass. This can be explained by either a more intensive pruning practiced by nursery owners or the similarity of ratio per its respective seedling size.

CONCLUSION AND RECOMMENDATIONS

Tree nurseries produced millions of seedlings of different trees/shrub species in central Gondar. However, there are no established quality standards. This study evaluates quality of tree seedlings across different nursery ownership types indicating different nursery management practices. Various morphological variables were evaluated in order to examine seedling quality. Results showed that initial seedling attributes such as height, root collar diameter and shoot and root dry weights have significant effect on early growth and survival of tree seedlings. Thus, it is possible to conclude and prove that seedling quality greatly affects field performance. Significant variations were found among nursery owners for most of the morphological characteristics analyzed. Significant variations were not observed in growth and survival among nursery categories at three month after planting except, *R. prinoides*. It is possible to conclude from this study that potential field performance could be influenced and accurately predicted by morphological attributes of seedlings. In general, seedlings coming out of private nursery are with better qualities which could be due to the profit motives of private nurseries. Also small scale nature and absence of any beaurocracy and material delay like GO and NGO nurseries. Generally, the nursery stock characteristics of the observed tree species are not similar across tree nursery ownership types. This could be attributed to different operational exercise, different local expert knowledge of operators. Also there is no general guidelines for optimal nursery operation and are not clearly known. Thus, operational effectiveness of the sub sector is vital to improving quality of seedlings and the subsequent plantation development. Finally, this morphological seedling quality evaluation method is very important since it is practical and enables easy detection of the relationship between parameters.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Morphometrics of *Pinus patula* crown and its effect on cone characteristics and seed yield in Kenya

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***Pinus* species and other conifers have cones as an essential unit for seed production. Cone production in pines is not uniform and often varies among compartments and sectors within the crown. Many countries experience challenges in seed production from orchards due to poor practices. The present study aimed to evaluate within-crown cone production patterns, cone characteristics, and seed yield in a *Pinus patula* clonal seed orchard in Londiani, Kenya. Crown height was divided into three equal portions and a further subdivision done for each of the parts into two sections. There were differences in cone characteristics within the crown, between the sections and compartments. The majority (67.1%) of the cones in the present study were curved. The study also showed that cone shape had no significant influence on seed yield. The present study observed cones collected from the top portion of the crown yielded the highest amount of seed (33.3±4.91 seeds) (p<0.05) while the bottom part had the lowest (14.4±2.76) (p<0.05). The study recommends the collection of *P. patula* seeds from the upper part of the crown in unmanaged stands. Further, it suggests that management through pollarding needs to be done regularly to minimize within-crown differences.**

Key words: *Pinus patula*, crown, cone characteristics, seed yield, clonal seed orchard.

INTRODUCTION

Management practices on seed orchards and seed stands have been postulated to increase the seed yield (Moreno-Fernández et al., 2013; Nguyen et al., 2019). Also observed is the dwindling acreage of seed sources, regionally, especially in sub-Saharan Africa (Marunda et al., 2019). These challenges have led to higher pressure on the production of seeds from the existing seed sources (Owens, 1995). Cones are an essential unit of seed production for *Pinus* species and other conifers (Calama and Montero, 2007; Loewe-Muñoz et al., 2020). *Pinus patula* is an essential commercial plantation species in sub-Saharan Africa (Chamshama and Nwonwu, 2004; Cheboiwo, 2018; Valera and Kageyama, 1991). Some studies have observed that cone production by *Pinus* spp. *(Pinus halepensis* and *Pinus sylvestris)* is not uniform and often varies among compartments within

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the crown (Ayari et al., 2012; Abdelaziz Ayari and Khouja, 2014; Iwaizumi et al., 2008). These variations are considered to be associated with resource-related factors such as collection practices, crown size, stand density, and light intensity (Iwaizumi et al., 2008). It has been studied in other select pine species that the number of cones produced was more significant in the upper layer (Debain et al., 2003; Iwaizumi et al., 2008; Karlsson, 2000). The focus on such studies of pines crown production patterns are generally few and have not included *P. patula.* These studies have also not focused on cone characterization, production, and subsequent seed yield from different parts of the crown or even subsections of the crown of *P. patula* (Dyson, 1964; Nel, 2002).

Seed orchards are established from known materials with the assumption of high performance for industrial, commercial forestry (Hall et al., 2020; Kaviriri et al., 2020). Seed orchards, unlike other commercial plantations, are managed differently in term of wider spacing, pollarding and roguing for robust branching to maximize on seed production (Loewe-Muñoz et al., 2019; Weng et al., 2020; 농업생명과학연구, 2019). Management of seed orchards in most developing countries faces many challenges: (i) lack of assessment on the effectiveness of management practices in established and maintenance of seed orchards, and (ii) poor seed collection practices in terms of where to collect from the crown and yield from the different parts of the crown. There is scanty literature focusing on the crown compartment and sections of *P. patula* for seed collection as such literature, when available, will lead to improved seed orchard management and seed collection practices (Marunda et al., 2019; Tong et al., 2020).

Previous studies have focused on other pines in terms of crown variations by height. There is no literature focusing on the horizontal variability in seed production, especially in *P. patula* seed orchards. Similarly, few studies are focusing on the impacts of cone shape and effects on seed production, with no research focusing on *P. patula* cone shape and effect on seed production (Aniszewska, 2006; Guo et al., 2020; Udval and Batkhuu, 2013).

Conifers such as *P. patula* have huge importance to developing countries such as Kenya (Limpens et al., 2014; Montagnini et al., 2003) for industrial and commercial purposes. The practice of pine seed collection in Kenya relies heavily on seed stands and seed orchard (Dyson, 1964; Kariuki, 1998). However, there is scanty literature on effective collection practice for *P. patula* cones for seed extraction (Albrecht, 1993). The demand for *P. patula* seed in the country is very high and calls for strategies to increase the supply (Ngugi et al., 2000; Onyango et al., 2020). These collection practices have been lacking data in yielding from the crown compartments focusing on where to collect and (Valera and Kageyama, 1991) to improve the overall seed supply for the species.

This paper aimed to compare the crown morphometrics of *P. patula* and its effects on the cone characteristics and seed yield, with specific objectives being (i) to determine cone characteristics in different crown compartments, (ii) to estimate percent opening and seed yield from cones of separate crown compartments, (iii) to correlate the crown compartments to cone characteristics and seed yield in order to derive the best compartment for seed collection.

MATERIALS AND METHODS

A study was conducted in Londiani, Kenya, using *P. patula* cones collected from a 14-year-old clonal seed orchard in the Kamara area. Kamara is located between 00° 34' 00" S latitude and 35° 48' 00" E longitude at an elevation of 2,639 m above sea level. The collection of cones was done in March, which is usually the peak cone production period for *P. patula* in the region (Albrecht, 1993).

The orchard was divided into three equal plots where ten trees from each plot were sampled and measured for diameter at breast height (dbh) and height. An assessment was done on each sample plot to ascertain whether all the crowns and sections were attainable. Only one tree that had seeded well from each of the three plots and had the most recurrent dbh (~1.3 m above ground) was selected and marked for cone collection. From these trees, measurements were taken for dbh (cm), H-height (m), h-crown height (m), and crown radius (m)=D(m)/2 (Figure 1). The tree measurements lead to a division h(m)/3 of the crown in 3 equal portions; top (A), middle (B), and bottom (C). A further subdivision was done for each of the portions into two sections based on distance from the stem (0-2 m=1, >2 m=2). Section 1 comprised the part that is 2 m from the stem (A1, B1, and C1), section 2 comprised part greater than 2 m from the stem (A2, B2, and C2) (Figure 1 (Bilir et al., 2008).

From each of the crown sections, 15 mature cones were collected, making a total of 90 cones per tree as a sample size. The collected cones were put in separate bags for each sector of the crown and transported to the Kenya Forestry Research Institute-Rift Valley Eco-region Research Programme laboratories in Londiani for the study. Each cone was assessed for maturity and insect damage. Those cones without blemish were given an identity depending on the tree and crown sector from which it was collected to a maximum of ten cones per each crown sector.

Before seed extraction, the following characteristics were established for each cone; shape of the cone (straight or curved (Aniszewska, 2006) length (L1) (cm), diameter at widest part (cm) and weight (g). The cones were placed on uncovered glass Petri dishes and put in a preheated (Yamato DS411) oven at temperature 65°C for 24 h.

This extraction method is derived from observations made by Onyango et al. (In print) that cones dried at 65°C open robustly from 4 to 24 h in their study on *P. patula* cone opening and seed yields. After this treatment (drying in the oven), cones were removed and seeds extracted by tapping gently 15 times on a flat wooden bench. Further measurements of length (L2) of the part of the cone that had opened (cm), the weight of the cone without seed (g), and total seed count from each cone were done. Percent of the cone that opens after subjecting to temperature treatment for seed extraction (p) was calculated by Equation 1; this p is used to compare cone opening length in relation to the shape.

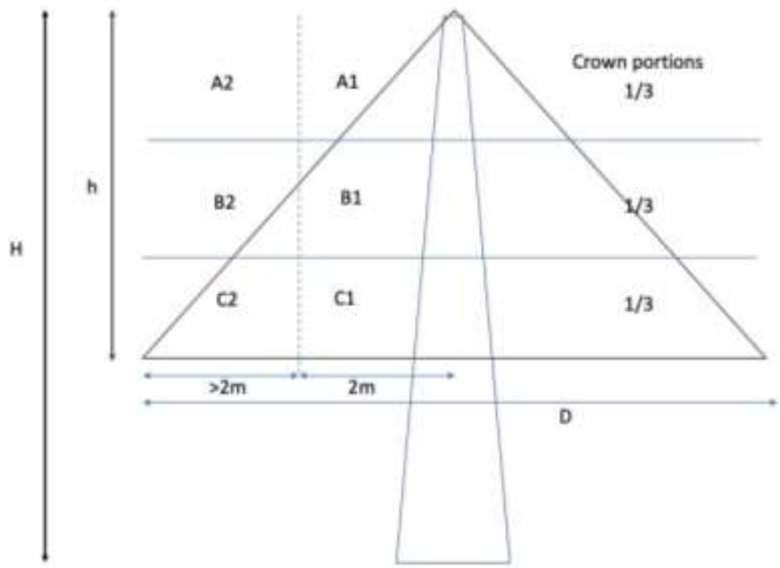

Figure 1. Schematic diagram on crown compartmentalization for sampling area of *Pinus patula* cones. A, B and C show compartments; 1 and 2 show sections.

$$p = \frac{L2\,(cm)}{L1\,(cm)} \times 100 \quad (1)$$

The data was tabulated in the datasheet in MS excel and analysis done for characterization of seed yield (S_y) which was a factor of Y-intercept by crown compartment (β_0); crown sector (β_1); percent opening (β_2) cone shape (β_3) and cone characteristics (β_4) (length, diameter, weight, and percent opened) (Equation 2) (Figure 1).

$$S_y = \beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \varepsilon \quad (2)$$

RStudio Version 1.2.1335 was used for post hoc (Tukey HSD) analysis done to interpret the 2-way ANOVA with crown compartment and cone shape as factors and length, diameter, weight, and seed yield as variables.

RESULTS AND DISCUSSION

The present study observed that the clonal seed orchard after analysis of the crown, compartment A2 was missing in all the trees and this is due to the conical shape of *P. patula* crown when closely spaced in a plantation. The study observed after analysis of the cones from the clonal seed orchard that the majority (67.1%) were curved while a minority (32.9%) were straight (Plate 1). We observed that curved cones were the majority across all compartments in the further description of the shape based on the crown compartment (Figure 2). This observation on cone shape leads to a gap in assessing the seed characteristics at the pine cone's curving location to determine its effects. The present study also observed that the bottom outer part (C1 and C2) of the crown had curved (56%) and straight (44%). We also noted that there was high variability between curved and straight cones in the upper part of the crown (Compartments A and B), ranging from a difference of 43 to 53% between curved and straight cones. While the bottom part (C1 and C2) had a low variability difference of 12% (Figure 2). There is a need to study further the effect of spacing and management practices such as pruning and pollarding on cone shape.

When we measured and analyzed the cone characteristics by compartment, the straight cones from compartment A1 at an average length of 7.9±0.10 cm and diameter of 2.90±0.03 cm and compartment B1 at an average length of 7.6±0.08 cm and diameter of 2.7±0.03 cm were the longest and widest. They showed a significant difference ($p<0.05$) when compared with the others (B2, C1, and C2) (Figure 3a and c). These findings concur with a similar study by Ayari et al. (2012) on *P. halepensis,* showing that the upper crown produces the longest and heaviest cones. Thus, for *P. patula* the observed trend could be attributed to light exposure and space for cone development (Ayari and Khouja, 2014; Iwaizumi et al., 2008).

Analysis of cones by weight revealed that straight cones from compartment B1 and A1 did not show a significant difference in weight ($p>0.05$) (Figure 3e). Overall, compartment A1 had the heaviest (31.6±0.62 g) cones and C2 the lightest (23.1±0.46 g) ($p>0.05$) (Figure 3f). Thereby revealing that superior *P. patula* cone by weight is found at the top part of the crown. Further studies on the effect of management practices need to be

Plate 1. Photograph showing cones of *Pinus patula* ranking based on shape (Straight-top and curved-bottom) with a 30 cm ruler on the side showing scale.

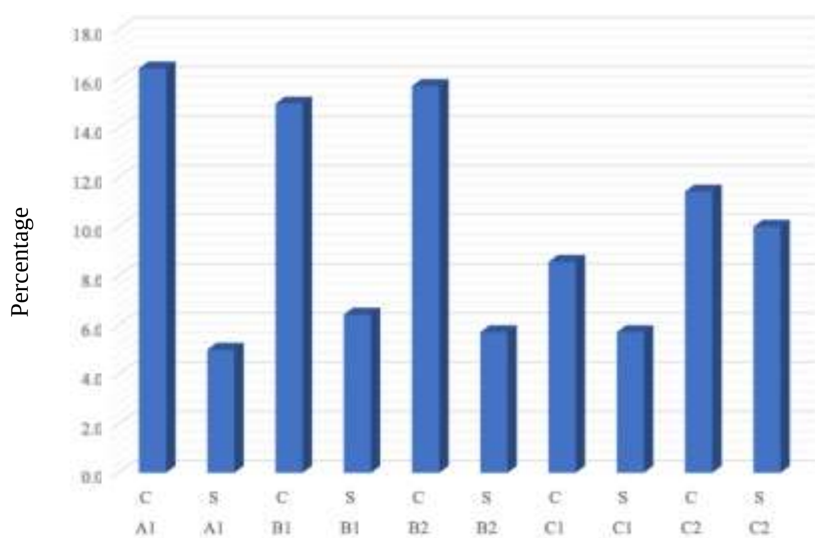

Figure 2. Cone shape by crown compartment and tree.

done. Straight cones of B1 and A1 were not significantly different in weight ($p>0.05$) but were significantly different from all the others ($p<0.05$) (Figure 3e). Curved cones of compartment A1 and straight cones from B1 were also

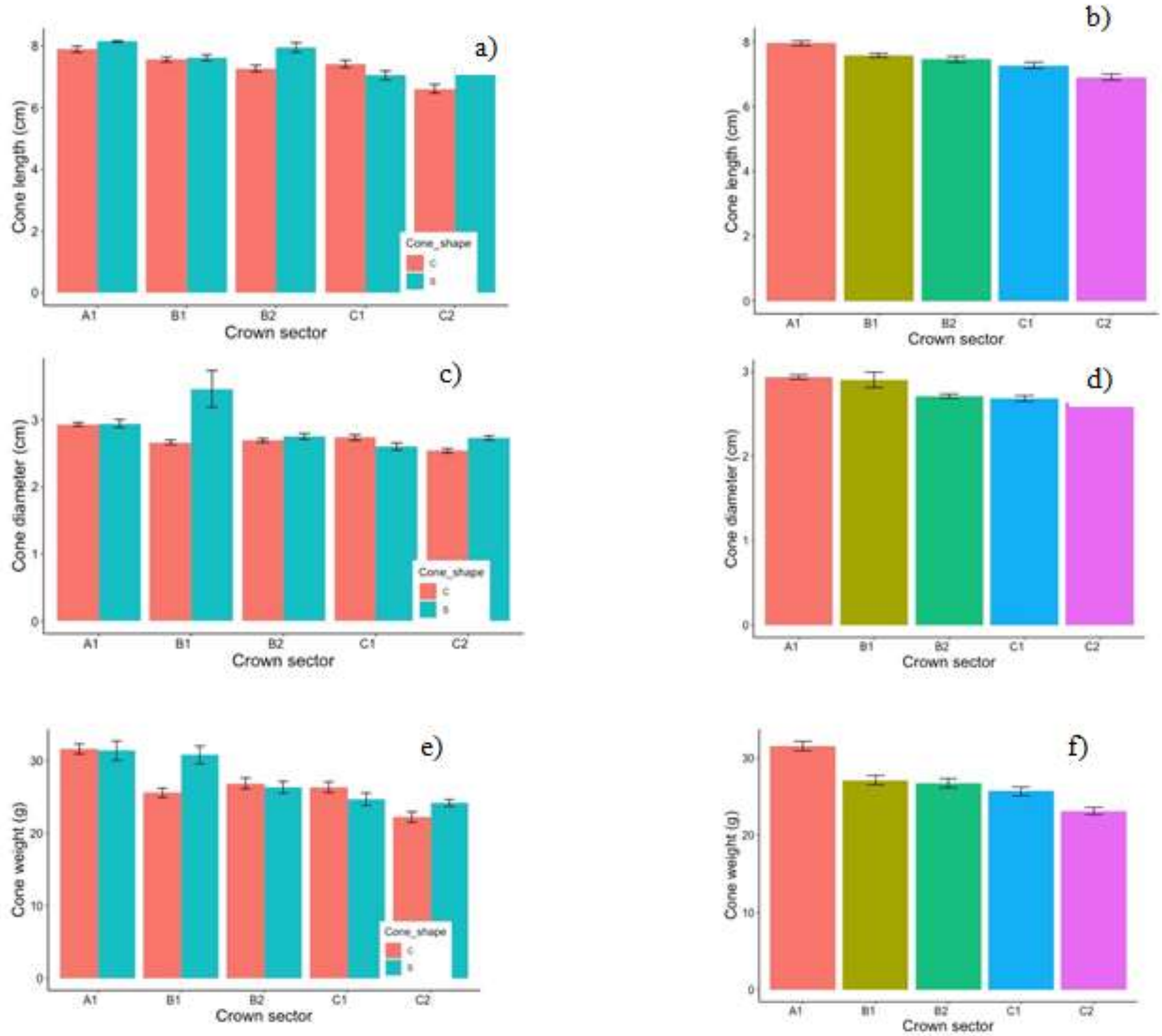

Figure 3. Histograms showing cone length (cm) (a,b), cone diameter (cm) (c,d) and cone weight (g) (e,f) by crown compartment (A1,B1,B2,C1,C2) and shape (C=Curved, S=Straight).

not significantly different in terms of weight ($p>0.05$) but were significantly different from all the others ($p<0.05$) (Figure 3e). These findings are in accordance with observations of Ayari et al. (2012) and Bilir et al. (2008) for other *Pinus* spp. within the same family.

It has been reported from previous studies that from the widest part of the cone to the bottom end, it does not produce viable seed (Bladé and Vallejo, 2008; Valera and Kageyama, 1991). For extraction, it would not be prudent to try to extract from that area of the cone but to try to improve the efficiency of extracting from the other parts. Our study also did not try to extract from that part of the cone but pushed for maximum possible percent opening for rapid seed extraction. With Onyango et al. (In print) obtaining 73% as the highest percentage of opening using temperature and soaking treatment. We observed that cones from compartment C2 had the highest percentage of opening at 46.6±1.98%, which was significantly different ($p<0.05$) when compared with compartment A1, B2, and C1, but there was no significant different ($p>0.05$) when compared with B1 (Figure 4b).

Analysis of seed yield showed no significant difference ($p>0.05$) between straight and curved cones from compartment A1 (Figure 4a and c). Straight cones from compartment A1 and curved cones from B2 showed a

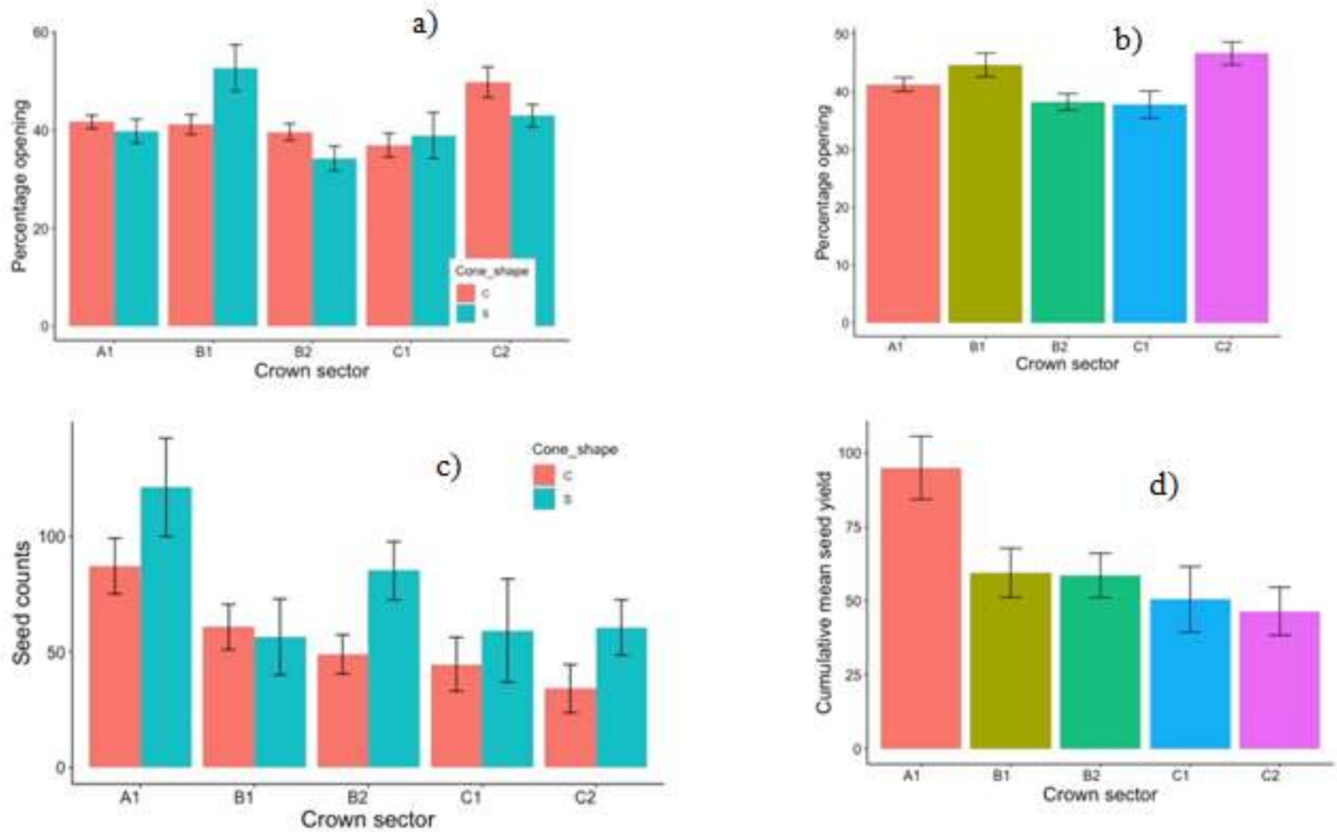

Figure 4. Percent opening of cone and seed yield by crown compartment and cone shape.

significant difference ($p<0.05$) in seed yield (Figure 4c). The study further revealed that the overall cumulative mean number of seeds was the highest from cones collected from compartment A1 at 33.3±4.91 seeds, while C2 had the lowest at 14.4±2.76 seeds (Figure 4d). These results agree with a similar observation by Iwaizumi et al. (2008) in their study on another pine family, *Pinus densiflora*. The research has also revealed that although compartment C2 had the highest percentage of opening at 46.6±1.98%, which did not translate to high seed yield. Further study of the embryonic development and variation in seed production within an individual cone would be prudent, especially in cones at lower crown compartments.

The upper crown compartments (A and B) was observed to outperform the bottom compartment (C), thereby calling for stands to be managed through pollarding early and regularly to minimize variations in crown compartments, especially for clonal seed orchards. In areas where seed collection is not from clonal seed orchard seed collection for *P. patula* should focus on top (A) and middle (B) parts of the crown compartments to guarantee the quantity and quality seed production. Future studies should focus on comparison within families and genetic variability of *P. patula* clonal seed orchards.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Plant species and their importance to housing in the Turkana community, Kenya

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There are many native species that are important to local communities globally. There have been studies on the importance of these plant species for many uses by local communities. Though, there is scanty information on these species' recognition by researchers. Despite the harsh climatic conditions in Turkana (semi-arid to arid), the community has over the years developed strategies for conservation of some sections of important woodland and riparian zones that provide multiple goods and services for the people and livestock. This study seeks to appraise the plant species preferred for construction and related cultural uses by pastoral communities in Northern Kenya where Turkana county in situated. The key results are list of plant species and their uses in regard to housing as well as the relative importance of the plant species to the Turkana pastoral community for housing. This will inform on priority species for conservation and also emphasize on key areas that this knowledge can be used.

Key words: Turkana pastoralists community, housing, indigenous knowledge, plant species.

INTRODUCTION

Drylands occupied 41% of the total earth's land mass, this is about 6 billion ha and is home to over 2.0 billion dwellers majority of whom live in developing countries (FAO, 2016). Over 30% of the drylands are in Africa. People in these areas depend on products from forests and other woodlands, grasslands and trees for livelihood (Stringer et al., 2017). Wild plants play a critical role in the lives of local communities living the drylands all over the world and more so in developing countries. These plants have a significant role in farming systems as a source of food, fodder for animals, fuelwood, and play an important socio-economic role through their application in medicines, dyes, poisons, construction, fibers and religious and cultural ceremonies (Shelef et al., 2016). However, despite these uses, their importance has largely been ignored and received little recognition from the development community. Some of the reasons for neglecting such species include inadequate information regarding the extent of their applications and their importance in rural communities (Govindan, 2019). In addition, there is loss of traditional and ethnobotanical knowledge majorly influenced by urbanization, technology and globalization leading to continuous loss and desertification (Shisanya, 2017; Situma et al., 2019).

Turkana county is a semi-arid region of Northern Kenya with a population of 926,976 people (KNBS, 2019) and

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variable rainfall pattern, which is bimodal in nature but drought is frequent with generally below average annual rainfall ranging from 200 mm in the drier central region to 400 mm in the west and south (CIDP, 2018). Altitude ranges from 370 m at the shores of Lake Turkana to 900 m at the foot of escarpment to west bordering Uganda. Mean annual temperatures for the county is 30° and ranges between 23 and 38°. The vegetation in the county is varied ranging from herbaceous plants, patchy annual grassland interspersed with shrubs and riverine woody tree species (Turkana County Government, 2015). Most regions in the county are covered with bushy species and dwarf shrubs. The county has many ephemeral streams with two major rivers: Turkwel and Kerio. The vegetation along the two rivers play a critical role in the lives of the communities as their livestock depend on the forage during the dry seasons (Opiyo et al., 2015). Arguably, the status and condition of Turkana county can be summarized by the words of Gulliver who stated that in Turkana "there is such a harsh and difficult climate that its effect on social life is all pervasive, inescapable both for the people themselves and for the observer of lives and activities" (Gulliver, 1955).

Turkana people are largely pastoralists about 55% depend solely on their livestock for livelihood. During the rainy seasons the animals are grazed in the lowlands and move gradually to the hills during the dry seasons (Opiyo et al., 2014). Land in Turkana is communally owned, this fits well with their lifestyle of nomadism of mobility to take advantage of seasonal availability of water and pasture (Kameri-Mbote, 2013). Turkana own a wide range of animal's species selected on the basis of tolerance and survivability to harsh climatic conditions. Livestock species kept are camels, cows, goats, sheep and donkeys, while crops farmed along the major rivers are watermelons, sorghum, beans, maize, green grams and cow peas. Over the recent past, the vegetation in Turkana county has come under intense pressure owing to climate change, increase in population, urbanization and sedentarization. These have threatened the backbone of these communities as animals browse on trees while people rely on wild fruits as food during the drought period (Notenbaert et al., 2008).

Despite the harsh climatic conditions in Turkana, the community has over the years developed strategies for conservation of some sections of important woodland and riparian zones that provide multiple goods and services for the people and livestock. They employ traditional ecological knowledge on natural resource management by constructing enclosures known as "Ekwar" reserve grazing areas to be used during extreme dry periods (Barrow and Mlenge, 2003). Traditional ecological knowledge (TEK) globally has played a key role in conservation of natural resources and has been studied and utilized for decades by the pastoral communities.

TEK is a cumulative knowledge, practice and belief which has been passed on from generation to generation by cultural transmission and has proven to be effective mainly because the local communities have interacted with the environment over a long period of time (Gadgil et al., 2003). TEK has shown to provide valuable information particularly in relation to restoration ecology, species selection for planning of restoration programs as well as traditional land management interventions in a short time frame. One of the key product of TEK is the use of enclosures for dry season grazing which has been adopted by the scientific community to allow recovery of degraded lands (Angassa et al., 2010).

Here, we appraise the plant species preferred for construction and related cultural uses by pastoral communities in Northern Kenya where Turkana county in situated, houses are made with materials that make the houses cool because of the hot climate. The materials range from cow dung, grass, stones, shrubs and trees. The houses are arranged in a clustered manner to signify and identify different clans and also for protection against enemies (Medianorth, 2016). Globally, the history of evolution of buildings demonstrates that constructors have always been adapting and upgrading housing structure by modifying locally available materials to meet their building's needs, while taking into consideration the prevailing economic, social and climatic conditions. Buildings have always adhered to local cultures resulting in contextual architecture, corresponding to unique construction methods and specific ways of life (Salman, 2019). Evolution of building structures has been influenced by intermingling among cultures bringing in novel technologies, materials and knowledge, in addition, the quest to sustainably balance between man and nature has resulted in the concept of sustainable development in construction of houses (Joffroy, 2016).

Houses in Turkana are constructed in places adjacent to trees to provide shade during the day and water source for both domestic and for animals. Acacia species which are thorny are used in fencing as they confer security. Their houses also reflect the cultural beliefs for instance we have the night hut, day hut, men's huts, kitchen hut and granary. Species such as *Cadaba rotundiflora,* and *Hyphaene compressa* are preferred as they provide optimum ventilation where these plant materials are available owing to the hot climate in Turkana (Barrow and Mlenge, 2003)

This paper explores the different tree species that are used in the construction of homesteads in Loima sub-county, Turkana county. This will inform future land restoration programs because one of the key drivers of land degradation in the drylands is deforestation mainly due to population pressure and also as the pastoralist's communities' transition from purely nomadic lifestyle to transhumance sedentary lifestyles. Land degradation arising from human activities poses a huge threat to the sustainable development of drylands because of the resulting soil erosion and loss of biodiversity (UNCCD, 1994).

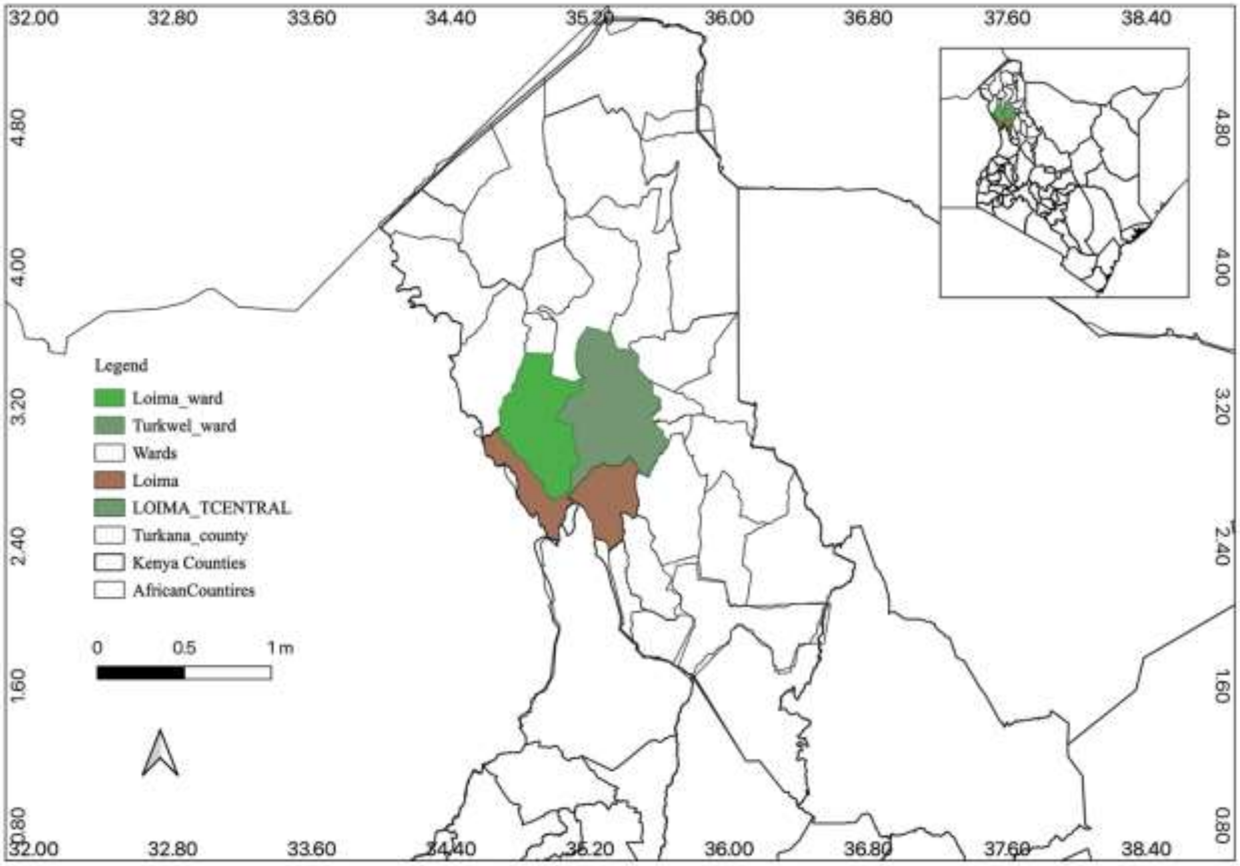

Figure 1. The two wards of Loima sub-county (Turkwel and Loima) from which villages and community was sampled.

Land degradation is estimated to affect the livelihoods of a whopping 1.5 billion people out of which 250 million reside in the drylands. Globally, 20% of all the drylands are degraded and 12 million ha get degraded each year driven mainly by unsustainable land use practices, unfavorable climate and increase in population resulting in decline in food security and vulnerability of the ecosystem to climate variability (Yirdaw et al., 2017). Restoration of damaged land is very costly and when severely damaged then the surrounding communities suffer terribly and economic and environmental benefit are lost as the productivity of land declines and in the pastoral community like the Turkana, animals die and hunger strikes. It is therefore important to assess and evaluate plant species used in construction, since this is one of the major drivers of deforestation which in turn causes land degradation and desertification (Zika and Erb, 2009).

The overall objective of this study was to identify the plant species used for building cultural houses in Turkana community. The specific objectives are (i) to assess the plant species used for fencing and filling in materials in Turkana community, (ii) to identify plant species used for fumigation of houses and thatching houses in Turkana community and (iii) to identify different housing materials from plants used by the Turkana community during different seasons.

MATERIALS AND METHODS

Study area

The study was conducted in Turkwel and Loima wards, Loima sub-county, Turkana county (3.1155°N, 35.6041°E) (Figure 1). Turkana county is an arid and semi-arid county in north-western part of Kenya, characterized by dry and hot climate conditions most of the time. The night time minimum temperature ranges between 24.2 and 26.0°C and the day time maximum temperature oscillates between 35 and 36.0°C. The rainfall pattern and distribution are erratic and unreliable both in temporal and spatial. Turkana county has three main rainfall seasons (long rains occur on March-April-May, June-July-August which occurs in Turkana west, Turkana south, Loima and some parts of Turkana east sub-counties. This is influenced by inter-tropical convergence zone (ITCZ) rainfall bearing systems as well as Cong Airmass (CAM). The short rains occur in October-November-December. The soils in Turkana county are mainly sand with alluvial deposits in areas close to the rivers (CIDP, 2018).

The vegetation comprises densely populated *Prosopis juliflora* and scattered *Acacia tortilis* along the riverine. Other tree species in the area include *Salvadora persica, Acacia melifera, Acacia senegal, Acacia reficiens, Acacia nubica, Terminalia brownii* and *Zyziphus Mauritania*. Annual grass species include *Aristida mustabilis* while perennial grasses are mainly *Cenchrus ciliaris*. The forbs in area include *Indigofera spinosa*. The population of Turkana county is 926,976 and the main economic activity of communities living in Turkana county is pastoralism (KNBS, 2019). Agro-pastoralism is also practiced in areas that receive moderately high rainfall and irrigated farming along the river Turkwel.

Sampling

Three villages namely Naurenpuu and Lomil in Turkwel ward and Namoruputh in Loima ward were purposively selected as sample sites for this study. The selection of these villages was informed by the semi-sedentary lifestyle adopted by resident pastoralists in a bid to improve their livelihoods. A total of 30 households out of the total 303 households representing 10% of the total household within the three villages sampled. The three villages were sampled randomly and proportionately allocated according to the local information on total households per village. The Naurenpuu village (89 households) was proportionately allocated 9 respondents, Lomil (103 households) 10 respondents and Namoruputh (113 households) 11 households (Kothari, 2004). The desired numbers of household heads per villages were systematically randomly selected from a list of households per village to avoid biasness and for administration of structured questionnaire. A semi-structured questionnaire was administered at household level targeting household heads to provide critical information on the tree species used for cultural housing, fencing, thatching and fumigation by the residents of Turkana community.

Data collection

Data were collected between November and December 2019 using semi-structured questionnaires on plant species' preferred by the community and their important values within the community. Thirty households were interviewed in each of the communities by a team of enumerators, in the local language dialects of Turkana community. The survey covered the following topics: the number of trees planted, their traditional purposes, the uses during dry and wet seasons of the plant species.

Data analysis

The data collected was analyzed using SPSS version 20 after data was entered into Microsoft Excel. Both qualitative and quantitative data were presented through tables. The data were processed through SPSS program to compute the frequencies tables and ANOVA to gain insights into the different tree species and their importance to the community.

RESULTS

The general gender distribution of household showed that 43.33% were males while 56.67% were females. Majority of the respondents did not have any formal education with illiterate household heads accounting for 75% and those with secondary and higher education accounting for an average of only 3.7% of the respondents. Majority of the household heads were in formal marriage (77%) with only 10.00% either divorced or separated (Table 1).

Relative importance values (RIV) of all species from the habitat types are given with the highest (RIV) in different habitats summarized in order of importance (Table 2). A total of 22 wild species were identified as shown in Table 2. All the species are indigenous except *P. juliflora* which is exotic and also known to be invasive (Ngigi, 2017). Thirteen of the species are trees, 4 shrubs, 1 grass species and 4 herbs species.

A total of seven uses had been identified, namely: thatching of houses, production of poles, fumigation, coloring, joining of house structures, filling of the house structure and fencing. Each household was interviewed based on the seven uses and percentage use of each species for different used tabulated (Table 3). Each of the species is used for different purposes with most of the species having more than one use at different degrees per household. The majority of the respondents preferred *H. compressa* (34.8%) in joining house structure, *Boswelia neglecta* for furmigation (33.3%), *Cordia sinensis* for coloring (26.1%) and *S. persica* (20.3%) for filling of house structure (Table 3).

Tests of relationships between the mean number of tree species planted per household and their various uses reveal a number of significant relationships as reported in Table 4. Those households number of trees for thatching ($p<0.05$), fumigation of houses ($p<0.05$), coloring of house materials ($p<0.05$) and filling of house structures ($p<0.05$) are significant at 95% CI.

DISCUSSION

H. compressa is the overall best ranked based on relative importance value analysis with 21.43 average points. This species is also the most preferred for thatching houses ($p<0.05$) and joining of the house structures ($p<0.05$) with 22.95 and 34.78% of households, respectively. *H. compressa* commonly known as doum palm has many other uses in Turkana county and only grows along the riverine areas. Some of the other recorded uses are making of baskets, tablemats, brooms, carpets, ropes, floor mats, lampshades, hammocks and hats. Additionally, livestock such as cattle feed on fresh young palms and dry leaves of doum palm during the dry seasons (Amwatta, 2004). The nuts of the tree are also consumed by Turkana people as alternative source of energy and also provide essential nutrients, overtime however, the species is now threatened due to over utilization and land degradation (Lokuruka, 2007).

Secondly, *C. sinensis* is following in relative importance value with aggregate average of 15.9. It is the most preferred for production of poles together with *P. juliflora* and *A. tortilis* all having 16.39% each, this means that 49.2% of all the construction poles in Loima sub-county come from the three species. *C. sinensis* is also one of the most versatile. It has been used in all the category uses except fumigation and in five of the uses it has over

Table 1. Socio economic of the respondents.

Variable	Area/Villages			Mean of variables
	Lomil	Namoruputh	Naurienpuu	
Gender (Household Heads %)				
Female	60	54.55	55.56	56.70
Male	40	45.45	44.44	43.30
Average age of household heads (Years)	**47.9**	**43.09**	**39.11**	**43.37**
Female	35.67	44	37.8	39.16
Male	66.25	42	40.75	49.67
Education (%)				
Illiterate (none)	90	45.45	88.89	74.78
Basic/pre-primary	0	9.09	0	3.03
Primary school	10	36.36	0	15.45
Secondary	0	9.09	0	3.03
Higher Education	0	0	11.11	3.70
Marital status (%)				
Divorced/separated	0	9.09	22.22	10.44
Married	80	72.73	77.78	76.84
Widow/widower	20	18.18	0	12.73
Main occupation (%)				
Agroforestry	10	0	33.33	14.44
Casual labourer	0	9.09	11.11	6.73
Charcoal burner	0	9.09	0	3.03
Livestock	30	18.18	0	16.06
Self-employed/business	60	63.64	55.56	59.73

15% overall preference, a clear indication that it is highly valued and utilized in this community. Moreover, the leaves of *C. sinensis* are highly palatable and nutritious with 11% crude protein (Khaskheli et al., 2019) and livestock especially goats and camels depend on its leaves in times of scarcity. The tree also produces fruits that the communities depend on during dry seasons providing them with essential phytonutrients.

Thirdly, *S. persica* closes the best three species based on RIV with 14.95 points. This species is the most used in filling of the house structure with 20.34%. Besides, it used in five of the sampled uses except coloring and joining the house structure and has over 10% share in all of the five uses, a significant share, indicative of its importance in the target community. *S. persica* locally known as Esekon is also widely used for oral hygiene as toothbrush. Research done on the efficacy of the species on oral hygiene have shown the presence of significant quantities of antibacterial substances (Araya and Yoseph, 2007). It is also often lopped to provide fodder for goats and camels for the pastoral community (Kumar et al., 2012).

B. neglecta is the most preferred for fumigation with a third of the total percentage share. This is not surprising given that research has shown that *Boswellia* species have wide application in fumigation powders ($p<0.05$) with very high amount of biocidal chemicals such as alcohol (Fanta et al., 2013). On the other hand, *P. juliflora* was one of the most used for production of poles together with *C. sinensis* and *A. tortilis*. Since proposis is a very invasive species. The community need to be encouraged to continue using the species and minimize the cutting of the other two which provide fodder for animals especially during the dry seasons (Achankunju, 2015). *Acacia tortilis* together with *A. reficiens* were the most preferred for fencing both of them taking 43% of the total share among all the species identified showing the degree of utilization of these species given that the pastoral communities have to fence their homesteads to protect their animals.

Conclusion

The effects of climate change and globalization is

Table 2: Traditional plant species and importance in the Turkana community housing

Traditional Plant Species	Proportion in percentage (%) of respondent using the species for various reasons within Turkana county, Kenya							Relative Importance Value	Rank
	Thatching houses	Poles	For fumigation of houses	Coloring of house materials	Joining the house structures	Filling in the house structure	Fencing		
Hyphaena compressa	22.95	6.56			34.78			21.43	1
Cordia sinensis	3.28	16.39		26.09	17.39	15.25	17.02	15.9	2
Salvadora persica	13.11	11.48	12.82			20.34	17.02	14.95	3
Boswelia neglecta		1.64	33.33	8.7				14.56	4
Prosopis juliflora	4.92	16.39		13.04		18.64	12.77	13.15	5
Acacia mellifera			12.82					12.82	6
Sanseveria ehrerbergii	16.39				19.57		2.13	12.7	7
Acacia tortilis	3.28	16.39	2.56		21.74	10.17	21.28	12.57	8
Acacia reficiens		13.11	5.13		6.52	15.25	21.28	12.26	9
Cadaba rotundifolia	14.75		10.26			11.86	4.26	10.28	10
Cissus quadrangle			10.26					10.26	11
Faidherbia albida		1.64		17.39				9.52	12
Diospyros scabra	6.56	3.28		17.39				9.08	13
Cenchrus ciliaris	6.56							6.56	14
Zyziphus Mauritania		4.92	2.56	17.39		3.39	2.13	6.08	15
Boscia coriacea	3.28		7.69					5.49	16
Acacia eliator	1.64	6.56				1.69	2.13	3.01	17
Aloe turkanensis			2.56					2.56	18
Acacia nubica						1.69		1.69	19
Combretum hereroense		1.64				1.69		1.67	20
Balanites aegyptiaca	1.64							1.64	21
Indigofera spinosa	1.64							1.64	22

Table 3. Summary of the most preferred species per category and respective percentage household share.

Species	Use category	Percentage share
Hyphaena compressa	Joining of house structure	34.78
Boswelia neglecta	Fumigation	33.33
Cordia sinensis	Coloring	26.09
Hyphaena compressa	Thatching	22.95
Acacia reficiens, Acacia tortilis	Fencing	21.28
Salvadora persica	Filling of house structure	20.34
Acacia tortilis, Cordia sinensis, Prosopis juliflora	Poles	16.39

Table 4. The *F*-statistic in ANOVAs of mean number per tree species uses.

Use of tree species	Mean number of trees/household	S.E.	F value	P-value
Thatching houses	8.09	0.526	2.059	0.037
Poles for construction	5.60	0.485	1.139	0.361
For Fumigation of houses	3.95	0.390	2.507	0.023
Coloring of house materials	2.71	0.436	1.740	0.031
Joining the house structures	5.00	0.521	1.587	0.137
Filling in the house structure	3.78	0.332	1.927	0.050
Fencing	4.05	0.403	0.452	0.934

threatening the livelihood of the community who are now transitioning from purely nomadic lifestyle to transhumance sedentary living owing to the changing climatic conditions and urbanization. The Turkana community in the sample area has somewhat permanent shelters which they construct using locally available plant species. This change in lifestyle is exerting pressure on the arid environment as this same species provide fodder for their animals and fruits for the community due to limited sources of income. This study puts emphasis on all the stakeholders and especially the development community to recognize the crucial role that wild plants species play in the drylands and develop robust
restoration programs especially for the identified multi-purpose tree species like *H. compressa, C. sinensis, B. neglecta, A. tortilis, S. persica* and many others that are key to both environmental health and pastoral development in the arid and semi-arid regions of Kenya. This paper recommends for future studies a further review of fodder species and also medicinal species use in the pastoral communities during the climate change adaptation process.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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