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Introduction from the Wild and Growth Characterization of Three Provenances of *Calotropis procera* (Ait) in a Domesticated State in Dry lands of South Eastern Kenya

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ABSTRACT

Calotropis procera is a wild species that is drought-resistant and important in production of wool, fibre, biomass among other uses. There exist high demand of the wool in Asian countries and collection from the wild has been going on in Kenya and other countries. However, this collection does not meet the quantity required. Domestication of the species may be the key in bridging the quality and quantity demands for the wool. A study is being undertaken to evaluate growth, phenology and wool productivity of selected provenances of *C. procera* in dry lands of S. Eastern Kenya. The research site is situated between 01.31358^{0}S, 037.75546^0 E and 01.31422^{0}S, 037.75576^{0}E and elevation of 1173m a.s.l in South Eastern Kenya University (SEKU), Kitui County, Kenya. The research started in January 2015 with the main focus on monitoring the growth, phenological characteristics and wool productivity of the species in a typical farm setting. This paper focuses on growth characterization of three provenances of *C. procera* under different spacings (1.5mx1.5m, 2mx2m and 3mx3m). Results indicate that the species can be domesticated, it is hardy and capable of achieving an average field survival of over 97%. The species is multi-stemmed with Tharaka provenance showing highest mean branching of 13.25 followed by Baringo (12.22) then Kibwezi (11.98). Kibwezi recorded a slightly higher DBH growth of 3.90cm followed by Baringo (3.83) then Tharaka (3.82). Tharaka had highest mean height of 187.89cm, Baringo (184.25) and Kibwezi (182.63). Test of homogeneity of variances showed significant statistical differences (P<0.5) with Kibwezi being the least significant (0.043), Baringo (0.01) and Tharaka (0.000). All provenances showed a strong positive correlation (Pearson, P<0.01, n = 12) of branching, DBH and Height with Kibwezi recording $r_s = 0.975$, Baringo ($r_s = 0.988$) and Tharaka ($r_s = 0.996$). Differences in spacing levels started affecting growth parameters from the age of ten months with 3x3 showing highest DBH followed by 2x2 then 1.5x1.5. In terms of height, 1.5x1.5 has the highest (182.85cm), 2x2 (172.42) and 3x3 (168.65). 3x3 was not statistically significant (0.806, P<0.05) while 2x2 and 1.5x1.5 had significance of 0.001 and 0.000 respectively. All spacing levels showed strong positive correlations (Spearman, P<0.01, n = 12) of the study parameters where 1.5x1.5 had $r_s = 0.614$, 2x2 ($r_s = 0.972$) and 3x3 ($r_s = 0.986$) all at P<0.01. The study can authoritatively conclude that the species can establish and grow well in a typical farm setting in dry lands. Spacing affects growth parameters from the age of 10 months. Baringo provenance and 2x2 spacing have performed best. The study recommends analysis of wool productivity to justify the best provenance and spacing.

Keywords: Calotropis procera, Domestication, Kibwezi Provenance, Tharaka Provenance, Baringo provenance

1. Introduction

With the ever increasing population pressure and fast depletion of natural resources, it has now become necessary that attention is paid to exploring the possibilities of exploiting new plant resources in order to meet the growing needs of the human society (Dansi et al., 2009; Adéoti, et al., 2009 and Vodouhè et al., 2011). The interest in under-utilized plants is derived from a variety of human concerns, themes and perspectives. Some of these are ethical or humanitarian; others relate to self sufficiency, economic gains, resource management, agricultural diversification, germplasm conservation or augmentation, nutrition and energy independence. *Calotropis procera* is one among the many under-utilized plant species with a wide range of economical and ecological uses. *Calotropis procera* is a wild species that is drought-resistant, salt-tolerant to a relatively high degree, and it disperses seeds through wind and animals. According to Galal et al (2015), the species is hardy xerophytic plant, which is distributed globally in many countries and has important economic and ecological functions. The species is found in most parts of the world with a warm climate in dry, sandy and alkaline soils. It is native to India, Pakistan, Nepal, Afghanistan, Algeria, Iran, Iraq, Israel, Kenya, Kuwait, Niger, Nigeria, Oman, Saudi Arabia, United Arab Emirates, Vietnam, Yemen and Zimbabwe (Kumar, et al., 2013). *Calotropis* is primarily harvested because of its distinctive medicinal properties (Meena, et al. 2011). According to Orwa et al (2009) and Galal et al (2015), it has a wide range of uses such as medicinal, bark and latex are used in brewing and to curdle milk. Young pods used for fodder, stems produce good charcoal, fibre from stem and white silky tufts, latex or rubber for tannin or dyestuff, poison for arrows and spears, soil fertility, pollution control by monitoring sulphur dioxide emissions in the air and suitable indicator of exhausted soil.

C. procera is assumed to be an environmental invasive (Dietmar, 2005). It escaped from cultivation in Hawaii (Wagner, Herbst and Sohmer 1999). It quickly becomes established as a weed along degraded roadsides, lagoon edges and in overgrazed native pastures. It has a preference for and is often dominant in areas of abandoned cultivation especially sandy soils in areas of low rainfall; assumed to be an indicator of over-cultivation. However, Kumar et al (2013) suggests that the species does not require cultivation. Information on its cultivation is scanty while that on its domestication process is lacking. According to Dansi et al (2009) and Vodouhè et al (2011), the collection of plants from the wild for cultivation on farm (fields or home gardens) is a common practice continually being carried out under diverse agro ecosystems. Many varieties, landraces and cultivars of plants have been developed through this process to meet human (and /or animal) demand for food, fibre, medicine, and building materials (Sweeney and McCouch, 2007). Different steps exist in the plant domestication process (Dansi, et al., 2009; Adéoti, et al., 2009; Vodouhè et al., 2011). Step 0: Species entirely wild and collected only when needed, Step 1: Wild species maintained in the fields when found during land preparation (clearance, burning and weeding) due to its proved utility and regular need, its scarcity around habitations and the difficulties for getting it on time, in quality and in quantity. These preserved plants are subject to regular observations for the understanding of their reproductive biology. Step 2: Farmers start paying more attention to the preserved plants (weeding, protection against herbivorous) for their survival and their normal growth. A sort of ownership on the plants start. Step 3: The reproductive biology of the species is known and multiplication and cultivation of the species in the home gardens or in selected parts of cultivated fields are undertaken by farmers or healers. At this stage, farmers tend to conduct diverse experiments (date of planting, sowing or planting density, pest and diseases management) in order to master mass production of the species in the future. The ownership on the plant is more rigorous. Step 4: The species is cultivated and harvested using traditional practices. Step 5: To improve the quality of the product, farmers adopt specific criteria to select plants that better satisfies people needs. The best cultivars/plants (good grain/fruit quality, resistant/tolerance to diseases and pests) are known and technical package are adopted for their development and multiplication. At this stage access to market is considered and some species benefit from traditional post harvest technologies (method for processing, cooking or conservation.) to meet consumers' needs. Step 6: Selection initiatives continue with cooking qualities, protection against pests and diseases in cultivation and storage. Income generation is more clearly taken care of: market demands (quantity and quality) are also taken into account and species; varieties that meet consumers' preferences are selected and produced.

In Kenya, *C. procera* wildly grows in Kitui, Machakos, Makueni, Tharaka, Baringo, Kibwezi, Turkana among other arid and semi arid areas (ASALs). The species has been used for a number of traditional uses. However, in the recent past (International Centre for Research in Agroforestry (ICRAF) in partnership with local farmers has been collecting the silky wool from the wild mainly for export to China. However, the quantity from the wild has failed to meet the demand for the wool. According to Dansi, et al (2009) and Vodouhè et al (2011), one of the key drivers in domesticating wild landraces/cultivars is the scarcity of the cultivar around habitations and the difficulties for getting it on time, in quality and in quantity. To bridge the gap between demand and supply of the

C. Procera wool, a study has been proposed with the aim of subjecting the species to specific but critical steps of the domestication process. The study focuses on collecting the species' seeds from the wild, growing them in a laboratory and nursery conditions to understand its germination and early growth and finally growing the seedlings in a typical farm setting with a view of understanding its growth, phenology and wool production. These diverse experiments are critical stages in the domestication process since they aid in the mastery of mass production of the species in the future.

2. MATERIALS AND METHODS

2.1 Study Site

2.1.1 Geography

The study was carried out at South Eastern Kenya University (SEKU) situated in Kitui County. The research site is located 15 Kilometers off Kwa Vonza Market, along the Kitui-Machakos main road, Kwa Vonza/Yatta ward, Lower Yatta, Kitui County. Geographically, the research plot lies at 01.31358^0S, 037.75546^0 E and 01.31422^0S, 037.75576^0E at a general elevation of 1173m a.s.l (Figure 1).

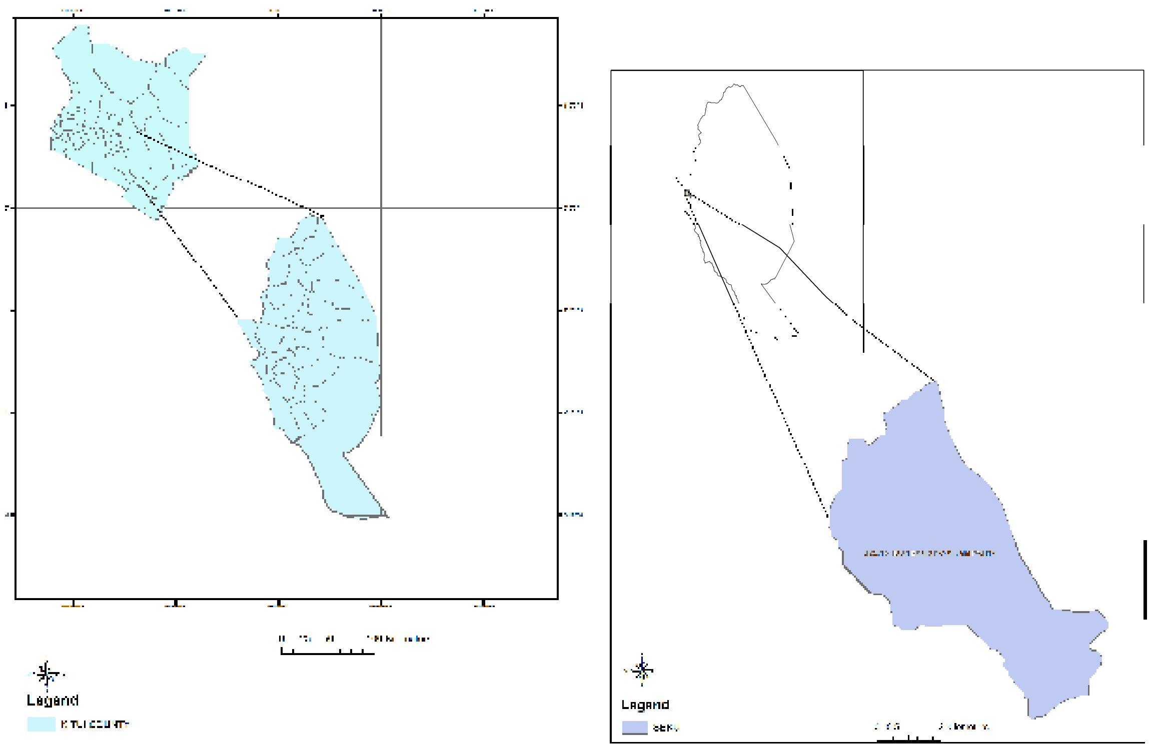

Figure 1: Location of research site in SEKU, Kitui County, Kenya

2.1.2 Climate of the study site

The climate of the study areas is semi-arid (Agroecological zone IV) with very erratic and unreliable rainfall. The rainfall pattern is bimodal with the short rainy season occurring between November and December and the long one between April and May. The short rains are more reliable than the long rains (Pauw et al., 2008). The mean annual rainfall ranges between 500-1050 mm with 40 per cent reliability. The site experiences high average temperatures throughout the year, which range from 16^0C to 34^0C (Pauw et al., 2008). The hot months are between January and February and June and September characterized by mean minimum and maximum temperatures of 28^0C and 32^0C respectively.

2.1.3 Hydrology and Water Resources

Few water sources exist in the research site. The major sources of water are Mikuyuni and Mwita Syano seasonal streams. Virtually all of the seasonal rivers in the research area drain into the Tana River drainage basin, Kenya's largest river that drains the Eastern flank of the Aberdares and the Southern slopes of Mount Kenya. The river flows in the research area are characterized by very low flows (base flows) in dry season and high flows during rainy seasons, April-May and November-December respectively. Most of the ephemeral streams generally become dry within one month after the rainy season (Borst and De Haas, 2006). The flows are usually fast and turbid due to high sediment concentration associated with soil erosion in the catchment area.

2.1.4 Soils and Geology

Soils are predominantly sandy to loamy sand texture, hence they are susceptible to erosion and are limited in their capacity to retain water and nutrients. The major soil type of the area is lixisols (red soils). Alluvial deposits (fluvisols) occur in isolated patches along rivers and on hill slopes. The soils are generally poorly drained and easily eroded by runoff (Borst and De Haas, 2006). Some patches of the research area are overlain by red well drained sandy loam soils which have quartz and feldspar grains and felsic gravel rock fragments. Soil depths (thickness) vary from between 1.2m (upslope) to nearly 2.0m at the downslope side of Mwitasyano stream. The soils reduce in thickness upslope where rock outcrops are found jutting above the surface of the soils. The study site has a similar geology composed of high grade regional metamorphic granitoid granulites which are composed of quartz and feldspars (over 90%) and mafic hornblende and pyroxenes (about 10% or less).

2.2 Selection of the Study Site

The experiment on domestication of the *C. procera* targets dry lands. The SEKU study site was selected subjectively based on the following criteria. First, the site represents typical semi-arid conditions that characterize the larger Kitui County and other dry lands in the country. Secondly, the study required that nursery and field experiments be undertaken. The SEKU site has existing tree nursery with enough space and other requirements for setting up nursery and field experiments.

2.3 Selection of C. Procera Provenances

To capture the dry land conditions in the country, seeds were collected from three areas in Kenya: Baringo, Kibwezi and Tharaka Nithi.

2.4 Field Experimental Design

The experiment focused on monitoring the growth, phenological characteristics and wool productivity of *C. procera* in a typical farm setting. A 60m by 80m plot was cleared and leveled. 27 subplots were demarcated within the main plot. The subplots were laid out in a randomized complete block design within the main plot. In each of the subplot, 12 planting pits (1ft by 1ft) were dug but at different spacing. For each provenance, three spacing types were used: 1.5m by 1.5m, 2m by 2m and 3m by 3m. These were replicated three times to give a total of 9 treatments. The spacing between subplots was 4m. The seedlings were transplanted into the pits. The main plot was weeded 2 weeks after transplanting. Subsequent weeding was done depending on the intensity of the weeds until the plants were fully established to withstand competition from weeds. In the field, the following data was collected.

2.4.1 Survival count

Survival count was done after 21 days after transplanting. This was done to capture incidences of seedling establishment failure in the field. However, no replacement was done for dead seedlings to avoid data distortion in the research plot.

2.4.2 Growth parameters

One month after transplanting, four plants for each treatment were selected randomly at the centre core of each subplot and tagged. Boundary plants were avoided. Growth data of interest were the number of branches, DBH and height. A veneer caliper and a ruler were used to measure diameter and height respectively. As the plants grew big, the veneer caliper and the ruler were replaced with a diameter tape and height rod respectively. Subsequent growth measurements were done on the tagged plants every month for one year

3 Data analysis

Ms excel was used to organize the field data and generate means and growth curves. The data was further subjected to two and one-way Analyses of Variance after arcsin transformation (Zar, 1984) to detect and isolate existence of significant statistical differences in the study parameters (branches, DBH and height) for different provenances under different spacing levels. Simple correlation analysis (Pearson and Spearman) were used to examine covariance in occurrences among the study parameters for different provenances under different spacing levels.

4 RESULTS

4.1 Field survival of *C. Procera*

Survival count showed excellent field establishment with Kibwezi provenance attaining 98% while Baringo and Tharaka had 97.5%. Initial field establishment was affected by attack by cutworms before the seedlings became hardy to withstand attack. Later growth was frequently characterized by occasional attack by a stem canker and aphids (*Aphis nerii)*. Lady bird beetle played a key role in controlling the aphids. Attacks by aphids led to rapid yellowing of leaves, defoliation and heavy flower abortion. Rupturing of the canker led to total destruction of the affected part of the stem and subsequent loss of apical dominance and the leader stem (Plate 1a). However, attack by the cutworms, aphids and canker did not lead to death of the affected

Plate 1a: A stem canker leading to loss of apical dominance 1b: Re-sprout of new shoots

Growth performance of the three *C. procera* provenances

C. procera is multi-stemmed with Tharaka provenance showing highest mean branching of 12.7 followed by Baringo (12.2) then Kibwezi (9.9) as shown in figure 2. DBH growth followed a different trend (Figure 3) with Kibwezi recording the highest (3.9cm), Baringo (3.83) and Tharaka (3.82). However, the three provenances showed minor variations in diameter growth in the first six months of field growth. Tharaka had highest mean height of 187.89cm, Baringo (184.25) and Kibwezi (182.63) as shown by figure 4. Test of homogeneity of variances showed significant statistical differences ($P<0.5$) with Baringo being the least significant (0.043), Kibwezi (0.01) and Tharaka (0.000). All provenances showed a strong positive correlation (Pearson, $P<0.01$, $n = 12$) of branching, DBH and Height with Kibwezi recording $r_s = 0.975$, Baringo ($r_s = 0.988$) and Tharaka ($r_s = 0.996$).

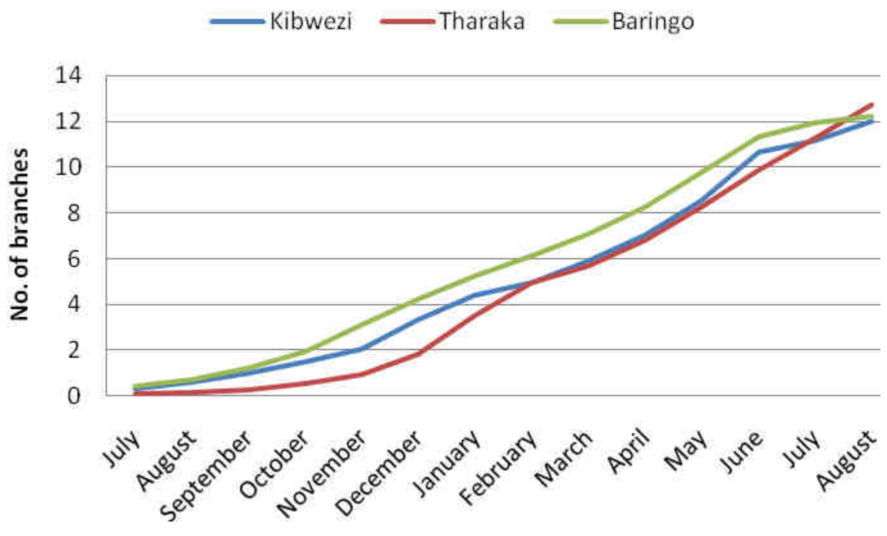

Figure 2: Average branching levels of the three C. procera provenances

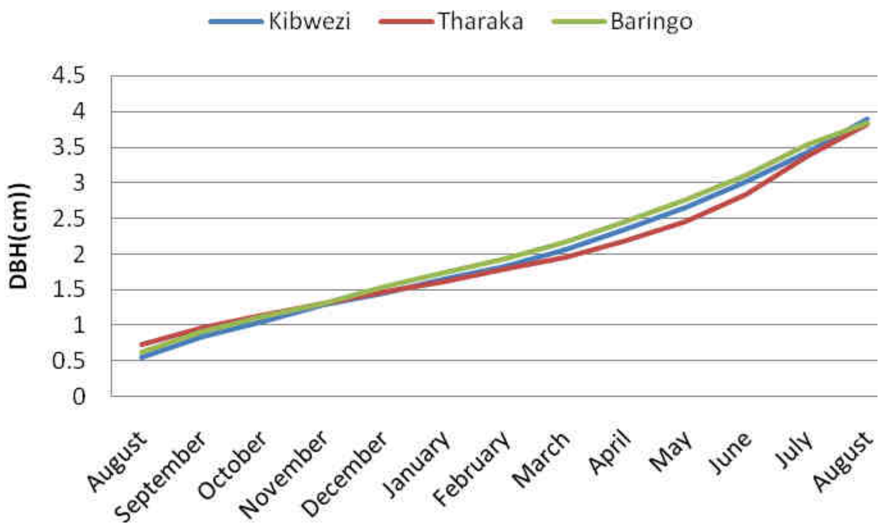

Figure 3: Mean DBH of the three *C. procera* provenances

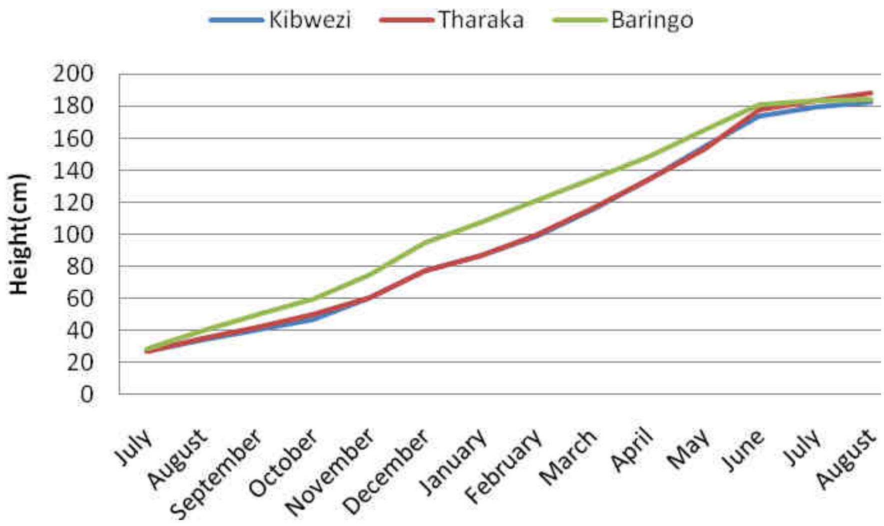

Figure 4: Average Height of the three *C. procera* provenances

Effects of spacing on growth performance of the three *C. procera* provenances

Differences in spacing levels started affecting growth parameters from the age of ten months (Figures 5, 6 & 7) with 3x3 showing highest DBH followed by 2x2 then 1.5x1.5. In terms of height, 1.5x1.5 had the highest (214.36cm), 2x2 (199.62) and 3x3 (189.44). 3x3 was not statistically significant (0.806, $P<0.05$) while 2x2 and 1.5x1.5 had significance of 0.001 and 0.000 respectively. Generally, wider spacing promoted heavy branching and a bigger diameter as the stems approached one year old. All spacing levels showed strong positive correlations (Spearman, $P<0.01$, $n = 12$) of the study parameters where 1.5x1.5 had $r_s = 0.614$, 2x2 ($r_s = 0.972$) and 3x3 ($r_s = 0.986$) all at $P<0.01$.

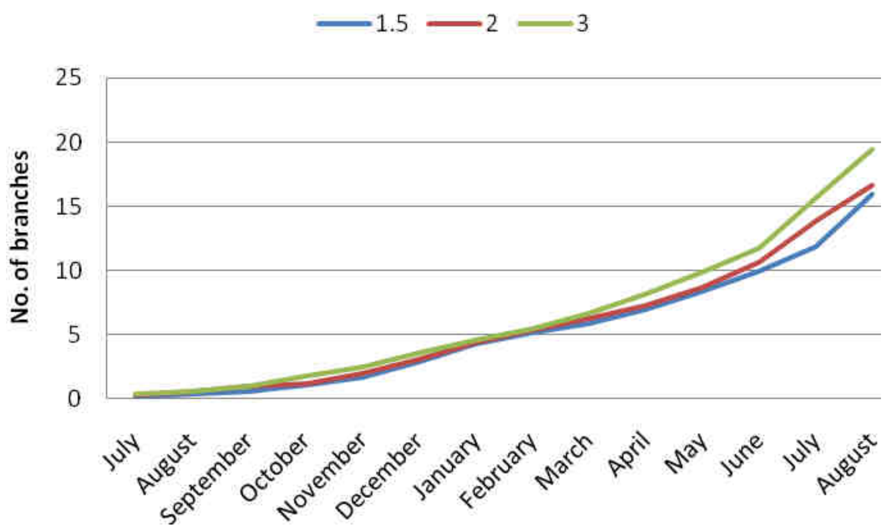

Figure 5: Branching rates of *C. procera* under different spacing levels

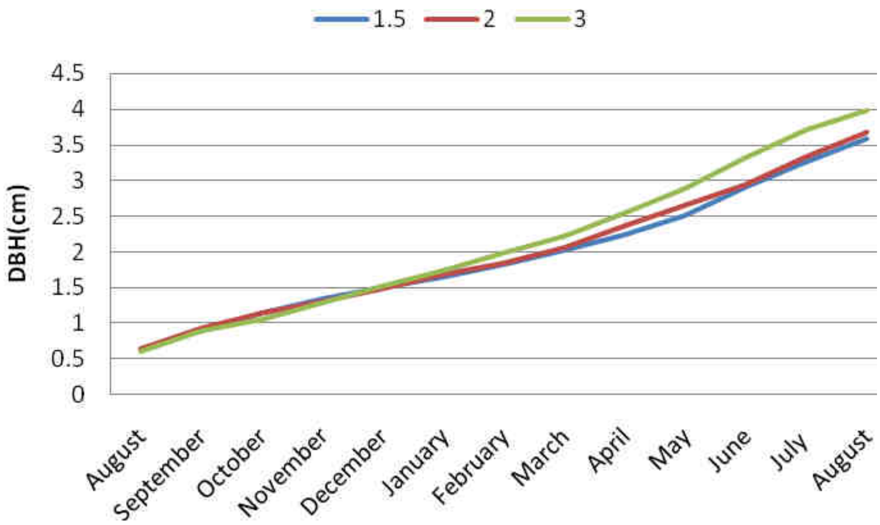

Figure 6: Diameter increment of *C. procera* under different spacing levels

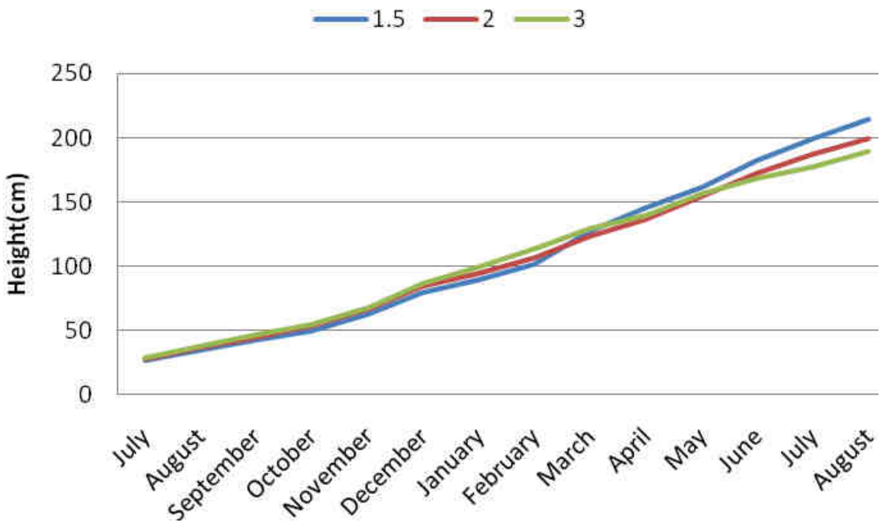

Figure 7: Height growth of *C. procera* under different spacing levels

5 *DISCUSSION*

5.1 Field survival

The observed high field survival of the three provenances can be attributed to the fact that the study site represents a typical arid and semi-arid land hence favoring the species. Good species site matching translates to better field survival and establishment. According to Galal et al (2015), *C. procera* is hardy xerophytic plant, which is distributed globally in many countries. Separately, in a study of drought tolerance of *C. procera* in deserts of Saudi Arabia, Ramadan et al (2014) document impressive drought tolerance by the species. Cutworms mainly attack juvenile seedlings before the stem or root collar has hardened up to withstand attack. This explains why the initial field establishment was mildly affected but the attacked ceased as the plants became hardy and established. Similar attacks have been reported by Verma and Parma (2006) who document considerable damage of *Calotropis* by cutworms. Some of the cutworm species known to cause such damage include *Agrotis ypsilon* and *Agrotis flammatra.* Attack by aphids (*Aphis nerii*) and stem canker seems to be some of the normal pest and pathogenic infestations under field conditions. Spot checks on *C. procera* plants growing in the wild showed similar infestations. The attacks are in consistence with Marugan et al (2000) who document attacks by *Aphis nerii* causing defoliation, death of branches, and abortion of fruits. The observed lady bird beetle seems to be the main natural enemy of the aphids (*Aphis nerii*). Marugan et al (2000) reports similar observation of the lady bird beetle (*Menochilus sexmaculatus*) as the main predator of *Aphis nerii*. Similarly, Dhafer et al (2012), in a study in Saudi Arabia, found out that the carpenter moth, *Semitocossus Johannes* (Staudinger), scale insect *Contigaspis zilla* (Hall) and milkweed aphid *Aphis nerii* (Boyer de Fonscolombe) were pests attacking the plant. According to Salau and Nasiru (2015), key insect associated with C. procera are *Trichius fasciatus, Apis mellifera, Anthophora species, Componotum perrisi, Physopelata famelica, Dysdercus chrypsippus, Musca domestica, Antherenus scrophulariae* and *Cerceris spincaudata.* The observed quick recovery from pest and pathogenic agents can be attributed to the strong regeneration of new shoots from the stem or root stock following attack. This mechanism of resistance to attack is referred to as tolerance whereby a plant is in a position to withstand attack by rapidly replacing the lost/damaged tissue. Singh (2010), also demonstrated the excellent resprouting ability of *C. procera* after cutting or burning. Our findings are also in consistence with Hassan et al (2015) who asserts that *C. procera* has a deep tap root and an ability to resprout from lateral roots. Similar sediments are shared by Orwa et al (2009) who documents that *C. procera* has a taproot 3–4m deep, and a secondary root system with woody lateral roots, which may rapidly regenerate adventitious shoots when the plant is injured. Similarly, Francis (2004) reports that even after senescence and the aerial parts die, the plant will re-sprout immediately from the rootstock.

5.2 Growth performance of the three *C. procera* provenances

The multiple branches observed in the three provenances are a typical growth characteristic of *C. procera*. Sharma et al (2011) state that *C. procera* occurs as a single or many stemmed soft-wooded shrub, and occasionally a tree reaching to 6m. The heavy branching is important in production of wool since most of these branches become floral in the reproductive phase whereby the inflorescence branch is borne in an extra-axillary position, lateral to the vegetative branch. Similar relationship of branching and reproduction phase is documented by Sobrinho et al (2013) who recorded multi-branching characterized by phenophases of sprouting (leaf flush), flowering (including buds) and fruiting (green or ripe). The good growth performance (branching, DBH and height) displayed by Baringo provenance can be attributed to site condition. Probably, the site conditions at the study site are very close to those at Baringo. However, authoritative conclusion on this can only be arrived at after comparison of key site characteristics such as soils, rainfall, temperature among others is done. It is also early to isolate the best provenance since all growth curves for all the provenances are yet to level off. For instance, the mean height of Baringo provenance is 1.8m with the highest individual reaching 2.6m. Several researchers have recorded different heights of *C. procera* at maturity. Orwa et al (2009) document 2 to 6m while Dietmar (2005) recorded 4m. Separately, Hassan et al (2015) recorded a height of 2-6m and a diameter of 25cm.

5.3 Effects of spacing on growth performance of the three *C. procera* provenances

The reason why the different spacing levels did not reflect major differences in their growth performance in the first ten months was due to the fact that the plants were still young and the different spacings probably offered equal opportunities for growth. After ten months, canopy closure in some of the spacings probably triggered competition for some key resources such as light, nutrient, water amongst others. Normally, wide spacing favors increment in branching and diameter growth while close spacing promotes height growth. This explains the observed heavy branching and highest diameter in 3x3 spacing and highest height in 1.5x1.5m spacing level. Similar relationship between spacing was demonstrated by Mehari and Habte (2006) who found out that increased spacing increased crown diameter and root-collar-diameter. On the other hand, an increase in spacing reduced wood quality because it increased branch diameter (knot size). Similarly, Glencross et al (2012) showed that spacing manipulate branch size, crown rise and stem size. Pretzsch et al (2015) document similar relationship between spacing and growth parameters. However, since domestication of *C. procera* is mainly for wool production, best spacing should strike a balance between good growth and productivity.

Typically, best silvicultural practices advocate maximum space utilization and maximum returns to the land owner. Different spacings have been used in cultivation of *C. procera* depending on the end product. According to Kalita and Saikia (2001), in production of biofuel, spacing of 1 m × 1 m which translates to 10,000 plants/ha can be used where water is not limiting but usually 5,000 plants/ha at 2 m × 1 m is recommended. Elsewhere, Andrade *et al* (2005) used three spacings (1.0 m x 1.5 m; 1.5 m x 2.0 m and 2.0 m x 2.0 m) and found that the spacings did not influence the phenology of the silk flower. According to Sharma *et al* (2000) and Kumar *et al* (2013), *C. procera* has been cultivated in South America and on the Caribbean Islands at a spacing of 1-1.5 m.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the field establishment and growth performance of the three provenances, the study can authoritatively conclude that *C. procera* can be grown in a typical farm setting. Initially, Baringo provenance showed good performance in most the study parameters under monitoring. However, after a year of monitoring, Tharaka provenance seems to take the lead as far as growth increment is concerned. Further monitoring will isolate the best performing provenance. From space utilization perspective and growth performance, 2x2 spacing has proved to be the best. It is important to note that all the growth curves of the study parameters are yet to level off. Further monitoring will show when growth parameters will level off and isolate the best provenance and spacing. Wool productivity analysis will be key in determining the best provenance and spacing. The field growth of *C. procera* is characterized by periodic attack by aphids (*Aphis nerii*) which, coupled with stem canker formation, resulted to loss of apical dominance and massive flower abortion.

6.2 Recommendations

Further monitoring is recommended to establish when the growth curves levels off and isolate the best provenance and spacing. Analysis of wool productivity should be done and results used to further isolate the best provenance and spacing. There is need for further research on the impact of attack by aphids (*Aphis nerii*) on the growth and productivity of *C. procera*. Though lady bird beetle (*Menochilus sexmaculatus*) seemed to be the main natural enemy of the aphids, there is need to establish whether the natural enemy is sufficient in controlling the aphid in a farm setting or other control methods need to be developed. Similarly, Salau and Nasiru (2015) recommend development of *C. Procera* pests management practices to enhance growth and development of the species.

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