EXTENT, DISTIBUTION AND CAUSES OF DEFECTS IN SOFT WOOD PLANTATION IN KENYA

Muthike G.*[1], Karega S.[2] and Githiomi J.[1]

[1]Kenya Forestry Research Institute, P.O. Box 64636-00620. Nairobi, Kenya, [2]Kenya Forest Service, P.O.Box 30513-00100, Nairobi, Kenya.

ABSTRACT

This paper reports on the magnitude of defects in *Cupressus lusitanica* and their distribution. The study analysed data collected from all forest regions where defects were identified. Results indicated that defects in sawn timber were reported in most *Cupressus lusitanica* (Cypress) plantations, ranging between 23% and 37%. On the average, over 91% of all the defects observed were a combination of heart rot and *oemida gahani,* a common pest in Cypress wood. Peculiar cases (0.4%) involving termite attack on standing trees was observed in western region. The magnitude of the defects significantly differed among different regions. Much of the damage was attributed to monkeys, particularly in Mau and central Kenya, while in Mt. Kenya and Aberdare, damage to trees were associated with buffaloes and elephants. The age of the trees had a significant influence on the magnitude of defects even within the same region. The study recommended need to develop strategies to reduce the primary causes of defects and increase the quality of raw materials available for the wood industry. Further, there is need to improve silvicultural treatment and harvest trees at optimum rotation age to avoid extended damage of the wood in case there is initial attack causing any of the defects. The study further recommends diversification of species and introduction of bamboo as an industrial material particularly in high altitude areas.

Key words: soft wood, defects in timber, wood industry, heart rot

Introduction

Kenya's forest cover is currently estimated at about 7.4% of the total land area (KFS, http://www.kenyaforestservice.org/) below the recommended global minimum of 10%. The country's closed canopy forest cover currently stands at about 2% of the total land area, compared to the African average of 9.3% and a world average of 21.4 per cent (FAO, 2017). Most of the closed canopy forests are *montane* forests that are also the main water towers (KFS, http://www.kenyaforestservice.org/). The Constitution of Kenya requires a minimum tree cover of 10% of the total land area, a vision that is likely to be a tall order to attained if adequate methods to improve forest products processing and utilization efficiency are not urgently deployed. A key one here is improving the quality of round wood the available to the industry.

Timber processing, especially from plantation forests plays a major role in Kenya's development (GOK, 2016). Sawmilling provide employment directly and indirectly to many people in forested rural areas (KFS, 2014; Muthike, 2016). During the 1999-2011 ban that locked out the wood industries from state forests, wood supply to wood industries was reduced and most of the timber industries, particularly those in the Small and Medium Enterprise (SME) category closed down (Ref). This adversely affected socio-economic development with reduced employment opportunities especially in areas where the local economies depended on the industry (Muthike *et al*. 2010).

The period of the ban posed more than a decade of minimal management inputs into forest plantations and low harvesting. This resulted in poor stocking levels of forest stands and low quality wood for the industry (Muthike and Githiomi, 2017). Currently, plantation forests are not optimally distributed due to a large gap between over mature and very young plantations. In addition, there had been inadequate silvicultural operations leading to poorly formed mature stems and prevalence of pests, diseases and game damage, which caused heart rot in wood (ref). With the steady increase in demand for round wood from the expanding industry, there is already a general decline in supply of mature round wood for specialised uses like plywood and sawn timber for structural use. This shortage is likely to increase and affect many other uses due to the

*Corresponding author: www.kefri.org, www.kenyaforestservice.org, gmuthike@kefri.org/ muthikegm@gmail.com

skewed tree population distribution (IUCN, 2001). To date, the inventoried plantation forest land base covers 134,861 ha, of which 95,027 ha is stocked (MEWNR, 2013).

Additionally, according to correspondences between Forest Industry Investor and KFS, there has been numerous complaints of defective logs at varying magnitudes in some plantations, further reducing the available quality round wood. The main defects reported include presence of *Oemida gahani* (Dist) attacks and by extension heart rot. These are highly associated with mechanical damage on the trees particularly during early stages of growth (Webster and Osmaston, 2003). Mechanical damage of trees involves bruising or stripping of the stem bark or breaking tree tops and branches. This exposes the wood material, allowing rain water and microorganisms to penetrate into the wood cells. Most of the mechanical damage of trees in plantations is associated with wild animals and particularly elephants and buffaloes. Similarly, smaller mammals including sky monkeys break tops and branches of young trees in search for food. Domestic animals mainly cattle and goats can also contribute to damage to young trees through brousing, where grazing is allowed in forest plantations.

Oemida gahani (Dist) has been documented as an important pest in East Africa (Webster and Osmaston, 2003; Curry, 1965). This is a beetle which inhabits dead wood of mainly *Cupressus* and *Juniperus* species. The beetle lays its eggs on any opening of living trees with large pruning scars, stripped bark or broken tops and branches. The eggs hutch into larvae, which burrow into the wood and restrict themselves in the inner dead part of the stem called the heartwood. As the tree continues to grow, although the entry wound may close up (if it was small), the larvae continue to develop and slowly begin to destroy the wood cells, compromising the structural integrity of the wood material and progressively develop into wood rot.

Apart from the two species mentioned above, several other indigenous and exotic species have been known to play host to *O. gahani*. Some of the known methods used to control the spread of this pest include burning debris of host species in an area before planting, replacing host tree species with non-host ones and controlling animals from particularly young plantations. Timely pruning before the branches mature and treatment of large pruning scars also help to minimize possibilities of entry of the pest (Curry, 1964).

In addition to *O. gahani* attack and heart rots, spiral grains and reaction wood have been reported particularly in areas with strong winds and steep terrains. Peculiar cases of termite infestations on standing *Cupressus lusitanica* trees has also been reported in some drier parts of Western and Lake Victoria as well as Eastern regions. It is probable that the termites find easy entry into the wood of living trees through already destroyed heart wood particularly if that destruction goes down to the base of the tree. This study investigated the extent of these defects, distribution among the main softwood regions and their effect on merchantable wood of the common soft wood timber species.

MATERIALS AND METHODS

The study involved assessment of mature plantations in Central, Abardares, Mt. Kenya, Mau, North Rift, Eastern and Western/Lake regions in Kenya, where complaints of defects in logs had been registered by wood processing industry investors (KFS Reports). The plantation registers were examined in each case to provide information on the history of plantation in terms of silvicultural treatment and any observations made on the onset and cause of damages to the trees. The assessed plantations were classified according to their age, size and region in which they were grown.

Assessment of the defects in wood was done using standard sawmill test procedures and was carried out between the years 2014 and 2017.This period was chosen because it coincided with active operations in the state plantations after the logging ban. The period registered many complaints of defective wood and requests from the wood industry. In each of the identified plantation, trees were randomly sampled, marked, felled and cross cut into commercial log lengths using chain saws. Log diameters were measured to the nearest centimetre at the butt, top and at every 0.5 m intervals along the length using diameter tapes (ISO, 1983). Log lengths were measured to the nearest 0.1 m using a linear tape. The total volume of all the logs in each case was computed using Smalian formula; Equation (1) (ISO, 1983), where V_l is the total merchantable log volume, L is the merchantable log length, D is the log mean diameter and π is a constant with a value 3.142.

$$V_l = \sum \left(\frac{\pi D^2}{4} L \right) \quad (1)$$

Logs were converted into sawn timber using the most commonly used sawing systems in Kenya; circular, broad band or narrow band saws. The total volume of the resultant sawn timber (V_t) was computed as shown in Equation (2) (ISO, 1974), where *b* is timber breadth, *d* is timber depth, *l* is timber length. Timber recovery rate (R %) was computed as a relationship between total log volume (V_l) and total volume of the resultant sawn timber (V_t) as shown in Equations (3) (ISO, 1974).

$$V_t = \sum (bdl) \quad (2)$$

$$R\% = \left({}^{V_t}/_{V_l} \right) 100 \quad (3)$$

The sawn timber was subjected to scrutiny to identify the pieces that are affected by *O. gahani* and/or heart rot and any other pest related defects. Any piece found affected to more than two thirds of its length was rejected, otherwise the defective part cut off and the piece re-assessed again based on the Kenyan grading standards for soft woods (KSO2-711). The total volume of the rejected timber was computed again using formula 2 above and expressed as a percentage of the total sawn timber volume.

RESULTS AND DISCUSSION

Regional distribution of defects in softwood plantations

Table I shows the distribution of defects in softwood and their primary causes within various regions as assessed between 2014 and 2017. A total of 622 ha. of *C. lusitanica* plantations were reported to contain wood with defects in the main softwood plantation regions in the country. Visual observation of the plantations under study showed very few signs of damaged stems except for some cases of broken tops and in some cases a few trees with signs of early injuries but recovery of the bark. Majority of the plantations assessed were observed to have characteristically high stocking density and branchy trees of small diameter and poor quality stems. This was an indication that they must have had little or no silvicultural treatment at all.

Of the plantations studied, the largest proportion was assessed in Aberdare, Mau and Mt. Kenya regions with 28.3%, 26.6% and 21.4%; respectively (TABLE I). Relatively smaller areas were found in the other regions, the smallest being in Eastern region, where only one plantation was reported and assessed as defective. This plantation had the highest percentage defect in wood (37%) followed by Aberdare and North Rift (35% and 33%), respectively. The lowest mean defect (22%) was in Central Kenya region.

Records from the forest compartment registers in all the study areas, the main initial cause of defects is injury to the trees particularly at the young age. The injuries were mainly attributed to large mammals in Mt. Kenya region. In Aberdare region, a combination of large and smaller mammals is highly associated with damages to trees especially in Nyandarua. In Central, Mau and North rift regions, injury to trees was mainly as a result of the smaller mammals. During the time of the logging ban, almost no activities took place within the plantation areas. There was neither farming nor silvicultural practices. This scenario could have promoted the presence of smaller mammals within the plantations and damage to young trees in search for food. In areas with larger mammals, the trees had visible damages like broken tops, which is attributed to elephants. Other trees had bruised stems, which is attributed to buffaloes knocking the stems with their horns. The damages reduced after the installation of electric fences, which locked out wild animals from the plantations..

In some cases, damage to trees was attributed to domestic animals (cattle and goats) especially in areas where human populations around the forests was large, leaving little land for animal grazing on private farms. The areas included Koibatek in Mau Region, Lari forest in Aberdare region and Kakamega forest in Western, where animal grazing in the forest has been historically a dominant practice. In such cases, like with damages by wild animals, trees with multiple leads and bruised stems were common.

Injury to trees opens the bark which is technically the protective covering of the tree. Microorganisms gain entry into the wood and become agents of wood cell destruction, targeting the Cellulose fibres and tracheids which are the structural elements of the wood material. At early stages of attack, it is easy to observe cases of *Oemida* attack characteristics (Terry and Curry, 1965). This leads to rotting of the wood elements and hollow parts develop particularly along the stem pith. Stem rot develops either from the bottom upwards or from the top

downwards depending on the part of the tree that was initially injured. In some cases, butt logs were found to be more damaged than the middle and top logs.

Effect of tree age on level of defects in the wood

Table II shows the effect of tree age on defects in forest plantation softwood. Tree age positively influenced defects in the wood. Out of a total of 34 plantations assessed during this study, 27 were above 30 years of age at the time of assessment, which constituted 79.4 % of plantations with defective wood and constituting equivalent of 539.7 ha (72.5%) of the plantation area assessed.

TABLE I -REGIONAL DISTRIBUTION OF DEFECTS IN PLANTATION SOFTWOOD

Region	Number of Plantations	Area (Ha)	Proportion (%)	Mean Defect (%)	Primary Cause
Central Kenya	3	54	8.4	22.3	Monkeys
Aberdare	12	182	28.3	34.6	Elephants
Mt. Kenya	5	137.6	21.4	31	Elephants
Mau	8	171.4	26.6	28.6	Monkeys
North Rift	2	36.5	5.7	32.5	Monkeys
Eastern	1	10.3	1.6	37	Monkeys & Termites
Lake/western	3	52	8	33	Monkeys Termites
	Σ=34	Σ=643.8	Σ=100	μ=31	

In stems where damage was more pronounced from the bottom, termite infestations were also observed, burrowing the centre of the stem upwards and filling the gap with soil. In drier and hot climates like in the case of Eastern and Lake Victoria/Western regions, the tree begins to be destroyed around the butt at early age. This could be the reason why the rate of defects in such wood was quite high (37% and 33%) in Eastern and Western/ Lake regions, respectively.

Trees at age below 30 years were fewer (27.5% of the plantation area assessed). Similarly, the level of defect increased with tree age, being significantly higher in

TABLE II -EFFECT OF AGE ON DEFECTS IN SOFTWOOD FOREST PLANTATIONS

Plantation Age (Yrs)	Number of Plantations	Area (Ha)	Proportion of Area (%)	Mean Defect (%)
< 30	8	104.1	27.5	23
30 - 40	18	323	50.2	31.1
> 40	9	216.7	22.3	35.3
Total	34	643.8	100	29.8

plantations above 30 years than in those below. There was a clear trend of increasing level of defect with increasing tree age. Exceptional cases were observed in Kakamega and Vihiga in Western region where 17-year-old plantations had the highest levels of defects (36% and 30%, respectively) observed in this study. This was however highly attributed to a combination of rot and termite attack on the trees. Most of the other plantations below 30 years of age had lower defect percentages than older ones.

As discussed above, when the trees have had bruised bark or broken tops at early age, microorganisms attack progressively causing damage to the tree structural elements as the organisms feed on the cellulose material in the wood. Over time, further damage is realised upwards or downwards along the stem. If the trees are harvested at earlier age, the level of damage is lower than when the affected trees are left unharvested for a longer period (Muthike and Karega, various reports). Trees continued to grow through the years with neither thinning nor clear fell harvesting. Those plantations that had been damaged and subsequently developed microorganism attack then progressively developed rots, which continued over the years.

The Financial Implications of the Defects in Wood

The results of this study showed 30% of the 643.8 hectares of *C. lusitanica* plantations studied were defective and cannot be economically utilized. This translates to 193 hectares and assuming a normal mean stocking of 266 stems per hectare, a mean merchantable log volume of 1.3 m^3 for a mature *C. lustanica* tree and a total of 66,739 m^3 of round wood is defective. This further translates to a loss of KES 266,957,600 (USD 2,669,576) at a mean rate of about KES 4,000 per cubic meter of *C. lusinatica* round wood, based on the lattest price of wood published by the Ministry of Environment and Forestry in the Kenya Gazette (Supplement No. 16 of 26th February, 2016). More pronounced is the loss the industry suffers when this wood is extracted and sawn because the product is rejected after incurring the logging and processing costs.

CONCLUSIONS

- The presence of wild and domestic animals is a catalyst to tree damage, which eventually become the beginning of defects in the wood. The most affected were mainly *C. lusitanica* plantations were affected by the defects observed.
- Results and observations linked lack of/or delayed silvicultural treatment to development of defects in *Cupressus lusitanica* wood.
- Delayed harvesting of trees beyond the rotation age promotes progression of defects in soft wood.

RECOMMENDATIONS

- Installation of electric fencing continues to keep off large mammals out of forest plantations.
- There is need to develop strategies to deal with smaller mammals especially monkeys in forest plantations areas. Continous activities within the plantation areas like farming and silvicultural activities can minimize the presence of these animals, especially during the growing stage of the plantations.
- Plantations should be well monitored for any signs of attack, especially when they are known to have suffered some damage. Early assessment for defective wood would help identify plantations that may not need to be left until they reach rotation age. In cases where a plantation is observed to have defects at the commercial thinning stage, it would be prudent to clear fell the plantation at that stage to save the wood from further damage as the plantation waits clear felling at rotation age.
- The study strongly recommends replacement of *C. lusitanica* with Pinus species whose quality and strength properties are similar. This is recommended in areas where *C. lusitanica* is more prone to sky monkeys because the same rarely damage pines. Further still, in areas where plantations border natural forests, species that are succeptable to damage by wild animals can be replaced with bamboo, which is currently gaining popularity as a commercial crop and an industrial raw material.

ACKNOWLEDGEMENTS

The authors acknowledge the facilitation received from both Kenya Forestry Research Institute (KEFRI) and Kenya Forest Service (KFS) during data collection and analysis. We also are thankful to the various sawmill

owners who facilitated logging and timber processing exercises.

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