Stump diameter and height effects on early sprouting of three common firewood species used in the coastal zone of Benin in West Africa.

Short title: Stump dimensions effects on resprouting.

Augustin Orou MatiloT.B[1]., Gaston S. Akouehou[1], Brice SINSIN[2]

Abstract

The cutting of exotic plants for wood and charcoal is a frequent practice in the south of Benin. The capacity of each tree to regenerate has not until now been considered as a determinant subject in the management of planting forests of Benin. This research analyzed the effects of abiotics factors especially the diameter and height of cutting on the sprouting capacity of three species (*Acacia auriculiformis, Eucalyptus camaldulensis* and *Tectona grandis)* used as fuelwood in the south of Benin Republic in West Africa. A total of 90 trees of *A. auriculiformis, E. Camaldulensis* and *T. grandis* have been selected and cut on three classes of diameter (10-20 cm, 30-40cm, 40-60cm) for 30 trees per each.

Results indicated that *E. Camaldulensis* had yielded the highest number of sprouts (7 and 6), the highest height (435 cm and 621 cm) and diameter growth of lead sprout (3.50 and 5.04 cm) in both the first and the second season. Considering the relationship between stump characteristics and sprouting ability, the number of sprouts increased with the basal diameter for *E. Eucalyptus* and *T. grandis*. In opposite, for *A. auriculiformis*, when the diameter increased, the height of spouts decreased. Interactive effects for species, class height of cutting and stump diameter indicated significant effect on number of sprouts, height and diameter of lead sprouts. We therefore suggest that *A. auriculiformis* and *E. Camaldulensis* had determinant indicators for fuelwood usage and for short rotation.

Key words: Coppicing; Savanna; Firewood; Non-native species; Resprouting.

Résumé

Titre: Effets de la taille et du diamètre des souches sur les rejets de trois espèces utilisées comme bois de feu dans les régions des côtes du Bénin en Afrique de l'Ouest.

Titre court : Effets des dimensions de souche sur la régénération.

L'exploitation des espèces exotiques à croissance rapide pour le bois de feu est une pratique courante au Bénin. La capacité des espèces à régénérer n'a pas été considérée jusque là comme important dans la gestion des plantations au Bénin. La présente étude vise à analyser les effets des facteurs abiotiques spécifiquement les effets du diamètre et de la hauteur de coupe sur la capacité de régénération de trois espèces (*Acacia auriculiformis*, *Eucalyptus camaldulensis* et *Tectona grandis*). Un total de 90 plants, soit 30 de chaque espèce ont été sélectionnés dans trois sites différents mais localisés dans la zone Guinéenne du Bénin parmi trois classes de diamètres (10-20 cm, 30-40 cm, 40-60 cm).

Les résultats obtenus ont montré que après les coupes *E. camaldulensis* fournit le meilleur nombre de rejets (7 et 6), la meilleure hauteur (435 cm et 621 cm) et le meilleur diamètre des rejets les plus longs (3.50 cm et 5.04 cm) pendant la première et la seconde saison. Considérant la relation entre la dimension de la souche et la capacité de régénération, le nombre de rejets augmente en fonction du diamètre de la souche pour *E. camaldulensis* et *T. grandis*. Contrairement, quand le diamètre de la souche augmente la hauteur de rejets diminue. L'effet interactif des espèces, de la classe de hauteur de coupe et du diamètre du rejet a montré un effet significatif sur le nombre de rejets, la hauteur et le diamètre du rejet le plus long. Nous avons alors suggéré que *E. camaldulensis* et *A. auriculiformis* possèdent des indicateurs déterminant pour la production du bois de chauffe et ainsi une courte rotation dans le processus de régénération.

Mots clés : Taillis ; Savane ; Bois de feu ; Espèces non autochtones ; Régénération

[1]Centre d'Etudes de Recherches et de Formation Forestières, Ministère du Cadre de Vie et du Développement Durable, 06 BP 707 Cotonou, Benin,

[2]Laboratory of Applied Ecology, Faculty of Agronomic Sciences, University of Abomey Calavi, 01 BP 526 Cotonou, Benin. Corresponding author. Email: matilorou@yahoo.fr

INTRODUCTION

Foresters and harvesting contractors refer to various techniques to optimize forest regeneration. These techniques cover a large range of stages from internal to external factors linked to plant which manipulation help to maximize subsequent regrowth. Regeneration methods as germination and vegetative reproduction of forest (Atwood et al. 2009) are known as the most spread tree management techniques in forest restoration. Vegetative propagation, especially resprouting after disturbance (cutting, firing, hurricane, etc) constitutes a possibility for natural forest resilience in tropical forests (Nyland1996, Kaewkrom 2005, Ky-Dembele 2007) and might contribute to the protection and conservation of biodiversity. In the process of planting forest management, the regeneration of trees used for fuelwood request an appropriate knowledge for an optimum production of wood and biomass.

Recently, West African forests encountered various disturbances primarily due to clearing for agriculture, recurrent fires for hunting and also fuelwood cutting for domestic use (Lachat 2006). In Benin, located in semi-arid area, 4,070 hectares of exotic species such as *Acacia auriculiformis, Casuarina equisetifolia, Tectona grandis, Eucalyptus camaldulensis, Terminalia superba* and *Cacia siamea,* have been established in purpose to supply firewood and to conserve natural forest (PBF I Report1995). Firewood is the dominant source for both domestic and commercial energy required by Benin rural populations. It used for food preparation, beer brewing, tobacco curing, brick firing, fish and meat smoking as well as heating and lighting in rural households. Therefore firewood has social, economic (Kataki & Konwer 2001, Lemenih & Bekele 2004) and geographic effects (Turker & Kaygusu 2001) in West Africa in general but in Benin in particular. This area encounters a strong insufficiency of firewood according to the warning recent report of FAO (2007).

After a first logging, the re-establishment of new plantation demands much efforts, money and time. Therefore the knowledge about the vegetative regeneration capacity of these species is an advantageous necessity to maximize the production of firewood in the zone. Otherwise, an optimum production of wood biomass might be connected with the resprouting capability of each species and an appropriate rotation system. This resprouting ability is also favored by specific conditions.

It's a common knowledge in forestry that sprouting of trees after disturbance contribute more largely to the regeneration of natural forest than seed regeneration in tropical forest (Ky-Dembele 2007). Tree ability to resprout might therefore play a key role in such mechanism. The ability of tree to resprout after disturbance especially cutting is not only related to its biological factors, but depend on external factors (abiotic factors) such as diameter of the stumps (Shackleton 2001), the height of cutting (Khan & Tripathi 1986; Tiwari & Das 2010), the slope of the area (Gracia & Retana 2004), the grazing capacity of the area (Sawadogo et al. 2005; Orou Gaoue & Ticktin 2008), the period of fire (Sawadogo 2005; konstantinidis et al. 2006), the cutting method (Ducrey & Turrel 1992) and the cutting season (Figuieroa 2006; Xue et al. 2013). For example, cutting performed during the dormant period of plants result in the minimum stool mortality and the maximum new sprouts number (Culvenor 1993). Also larger stems produced more coppices, greater mean and cumulative coppice shoot lengths than smaller stems (Mwavu & Witkowski 2008).

Moreover the capacity of each tree to regenerate has not until now been considered as a determinant subject in the management of planting forests in Benin. Also, the interactive influence of stumps sizes especially of stump height and diameter in forest regeneration is still not well known.

The objective of this study is therefore to examine in the planting forest, the effects of external factors, especially the influence of diameter and height of stump cutting, on the resprouting capability of three exotics species (*Acacia auriculiformis*, *Eucalyptus camaldulensis* and *Tectona grandis*) currently used as fuelwood in the south of Republic of Benin. This study addresses the following question: Does the diameter and height of stumps influence the resprouting ability of exotic plant? The results may provide reliable scientific support for foresters and farm managers in the process of exploitation, rotation and management of planting forests

MATERIAL AND METHODS

Study site

The study was undertaken in the south of Benin Republic, one of the Golf of Guinea a West Africa Coastal Zone countries (Figure 1). In this country, vegetation distribution showed 70% of savanna and 30% of semi-deciduous forest. The most extensive soil types are sandy and clay in the south and ferralitic in the north. The study has been carried out in the coastal agro-ecological zone which is one the eight zones encountered in Benin. The rainy season, from April to November is bimodal in the study area (April-June and August-November), with a peak in August. August is the wettest month of the year with the average of 170 mm to 200 mm. The mean annual rainfall is between 1,000 mm and 1,400 mm in the study area. Temperatures ranges from 17°c in January (the coolest month) and 35°c in April (the hottest month) resulting in aridity of the period in the study area. Humidity ranges from 65 to 95%. This climate supports a regular rain-fed cropping regime. The three sites are similar in terms of temperature, rainfall and soil characteristics.

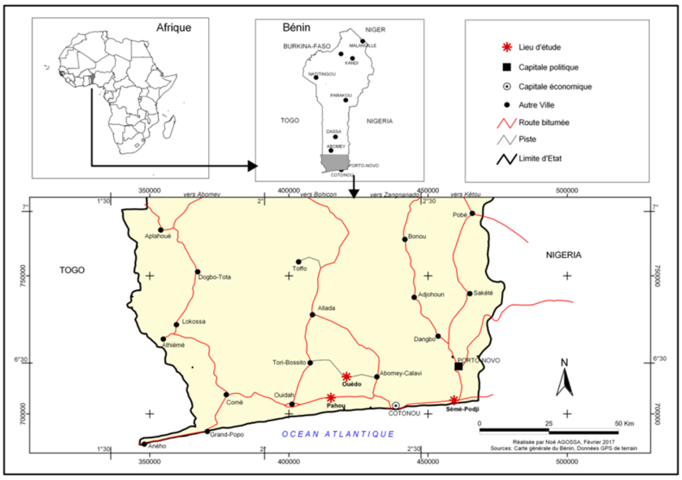

Figure 1 : Carte de localisation des sites d'études

The most three exotic species used as fueldwood are targeted in this research: *Acacia auriculiformis* (auri in English), *Eucalyptus camaldulensis* (commonly called eucalyptus) and *Tectona grandis,* vulgarly called teak (Table 1). Although these species are exotics in Benin area, *A. auriculiformis*, *E. Camaldulensis*, and *T. grandis* are currently the main source of firewood in the south of Benin (PBFI Report, 1995). Three sites (Ouedo, Pahou and Sèmè) located around the most populated city (Cotonou) of Benin provide mostly firewood for population. The three plantations of these species have similar age (fifteen years old) and planted with similar density of 100 individuals per hectare.

Experimental designs

A total of 90 trees of *A. auriculiformis,, E. Camaldulensis* and *T. grandis* have been selected on three classes of diameter (10-20 cm, 30-40 cm, 40-60 cm) for 30 trees per each and three sizes of height (20 cm, 30cm and 60 cm). The cutting of individuals has been held in February 2014 in dry season in purpose to ensure to have the maximum resprouting (Figuieroa 2006 ; Petrice & Haack 2011). The experimentation consisted in two rainy growth seasons from February 2014 to November 2015.

Table 1. Species Identification

Species	Family	Native area	Year of introduction in Benin
Accaciaauriculiformis	Fabaceae	Australia, Indonesia	1985
Eucalyptus camaldulensis	Myrtaceae	Australia	1985
Tectonagrandis	Lamiaceae	Southeast Asia (India, Indonesia, Sri Lanka)	1948

In purpose to better understand the growth mode (shape especially) of each species per year before the cutting, height and diameter of trees (DBH) have been recorded. After the first stage, individuals have been cut by using axe as the common tool used in the area. Ducrey and Turrel (1992) have also proved that the cutting with axe has a significant resprouting effect among many species. In purpose to avoid any mistakes, each stump has been painted on a remarkable color. At the end of a rainy season i. e. the seasonal growth, the following variables number of sprouts, the height of lead sprouts, the diameter of sprouts, the number of desiccation, the height and diameter of stumps have been recorded. In purpose to avoid any mistake, sprouts on each of the marked stumps were labelled till the end of the second growth season. The similar variables have been collected at the end of the second growth season.

Statistical analysis

In purpose to better understand the structure of each woodland and analyze the shapes statement of trees before cutting in planting stand, we applied Weibull distribution on diameter and height of trees by calculating form parameter following Glèlè (2009).

In purpose to evaluate the growth of trees before cutting, we considered diameter and height of trees as independent variables. We used ANOVA and Tukey HSD test to compare the growth of three species for each variable. Concerning the resprouting growth (number, height and diameter of sprouts), we first used ANOVA followed by Tukey HSD to compare in each season the three species growth of sprout and used Wilcox test to compare the growth of sprouts from first to second season (Dagnelie 2008).

As observations of the data in this study are continuous variables, regression analysis was performed to test the relationship between the diameter of stumps and the number of sprouts, the height of lead sprouts and the diameter of lead sprouts. Wilcox test was used to test the significance of theses correlations. The Spearman's rank correlation coefficient (r) was used to evaluate the robustness of the correlation, as the number of observations for each variable is less than 30.

The full model including species, diameter and height has been used to check the effect of each variable on the growth. That effect helped to make a clear decision on the effect of each variable first as independent variables but also as interactive variables. Two way-Anova is used to assess the effect of height and diameter but also whether there is an interaction between height and diameter on the dimension of sprouts. A generalized linear model was used to evaluate the effect of diameter and height size class of stump on the number of sprout with Poisson error distribution because these are counted data obtained and on the height of sprout with Gaussian error distribution because height and diameter are continuous data. In the analysis of number of sprouts, the species, the class of stump height and diameter of stumps were included as explanatory variables. The number of stems, the height of lead sprouts and the diameter of lead sprouts at the end of the second seasons were used as response variables. The contribution of interaction terms was tested for their significance and than the species effect. All statistics analyses were conducted using R

RESULTS

Distribution and growth before cutting

Weibull distribution for stem diameter and also for height indicated similar shape planting trees before cutting (Figure 2).

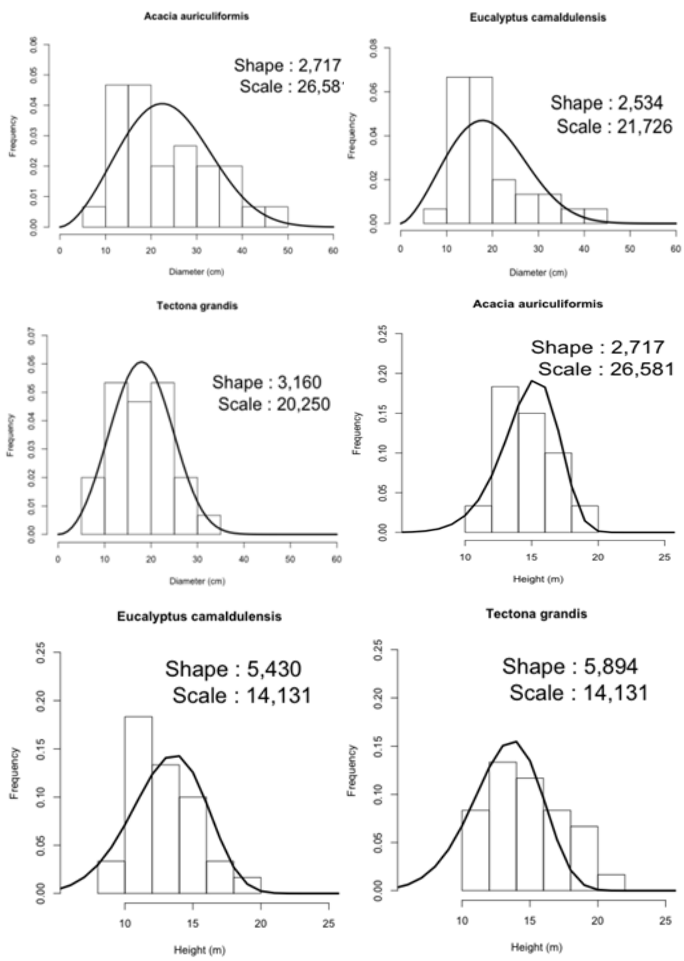

Figure 2. Distribution des plants de *Acacia auriculiformis, Eucalyptus camaldulensis*, *Tectona grandis* avant la coupe

The largest diameter was recorded for *E. camaldulensis* about 45.4 cm in 15 years growth. For the same period, *T. grandis* has shown the most inferior stem diameter about 8.2 cm. The mean growth per year showed that *A.auriculiformis* have about 1.57±1.74 cm per year when *E. camaldulensis* and *T. grandis* has respectively 1.28±1.92 cm and 1.21±2.95 cm per year (Figure 3).

Relating to the height growth before cutting, *E. camaldulensis* have got 20.5 m and under bad situation had less than 9.5 m for 15 years. Considering the growth per year, *T. grandis* yielded height growth of 99.53±12.09 cm per year and *E.camaldulensis* and *A. auriculiformis* showed

87.31±14.35 cm and 98.22±24.58 cm (Figure 3).

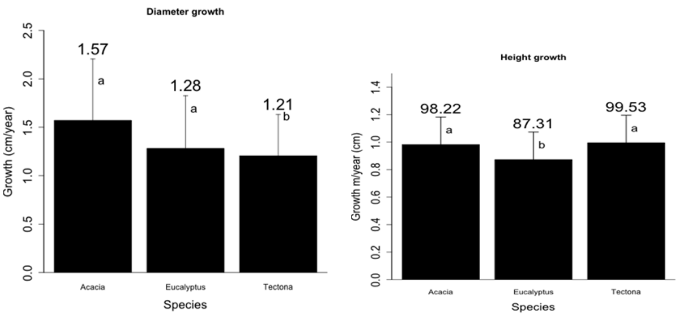

Figure 3. Diameter and height growth rate per year before cutting. *NS means Non significant; Different alphabet letters mean significance for ANOVA, Tukey HSD test, P<0.05*

The comparison of the pre-cut ting data about species diameter and height growth (Figure 3) of the current study population showed that the difference between height growth and diameter growth are completely different. *A. auriculiformis* indicated the highest diameter growth (1.57cm/year) whereas *T. grandis* indicated the highest height growth (99.53 cm/year) in natural state coming from seed banks.

First and second season's growth

The number of sprouts, the height of sprouts and diameter of sprouts in the first and second rainy growth season indicated differences in growth for the same species between seasons. The first season indicated higher number of sprouts, higher height of sprouts and higher diameter of sprouts taken separately.

At the end of the first season, we found that *E. camaldulensis* has yielded the highest number of sprouts (7.16 sprouts), but with a remarkable decrease a second year till 6.06 sprouts (Figures $4A_1$ & $4A_2$). Difference of the number of sprouts was significant from *A. auriculiformis* to *E. camaldulensis*. In opposite, there was no significant differences between *A. auriculiformis* and *T. grandis* during the first season (Figure $4A_1$) and second season between species (P<0.05).

On the other hand, we found that the number of sprouts decreased the second season for *E. camaldulensis* and *T. grandis*, when the number of sprouts increases for *A. auriculiformis* (Figure $4A_1$ & $4A_2$).

About the height growth of lead sprouts (Figure $4B_1$& $3B_2$), *E. camaldulenis* offered the highest growth (H=435±95.22 cm) after the first season with a significant difference with other species. The same trends have been showed in the second season growth, where *E. camaldulensis* indicated higher height sprout with significant differences with others. In the other hand, *A. auriculiformis* and *T. grandis* have no significant differences (P <0.05).

Concerning the growth of lead diameter sprouts in the first season, *E. camaldulensis* offered the highest growth (D=3.49±0.58 cm) with a significant difference (Figure $3C_1$), while *A. auriculiformis* and *T. grandis* showed no significance differences between them (P< 0.05). The diameter's growth in the second season was similar to the first where *E. camaldulensis* had also the largest stem sprout D= 5.04±0.65 cm.

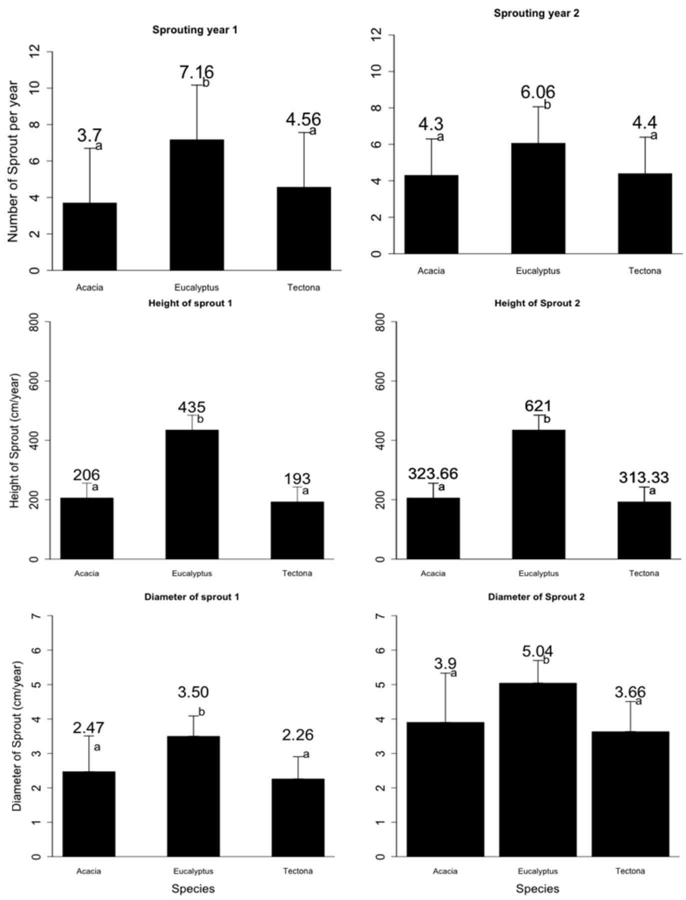

Figure 4. Number, growth height and diameter of sprouts during the first growth season (A_1 B_1 C_1) and the second season (A_2 B_2, C_2) in plantation areas of Benin. Different alphabet letters mean significance for ANOVA, Tukey HSD test, P<0.05.

Relationship between stump dimensions and sprouting ability.

Influence of basal diameter

In this study, basal diameter of species is ranging from 8 cm to 45 cm. We found that the number of sprouts increased with the basal diameter of stumps for all species *A. auriculiformis, E. camaldulensis*, *T. grandis* (Figure 5).The results also showed in the case of *A. auriculiformis* that, three stumps had not sprouted and only one stump had not sprouted for *T. grandis*, while all stumps of *E. camaldulensis* had sprouted during the two growth seasons. The deletion of dead stumps of *A. auriculiformis* resulted a considerable change and then the influence of basal diameter was uniform for the three species. The dead individuals affected enormously the number of sprouts/stumps.

Relating to the height of sprouts, the increase of basal diameter for *A. auriculiformis* had showed a negative correlation when taking into account the dead individuals. When the basal diameter of stumps increased, the height of sprouts decreased (Figure $5B_1$). The remove of dead individuals has changed the previously negative observed correlation into positive between basal diameter and the height of lead sprouts for *A. auriculiformis*. In the case of *E. camaldulensis* there is a positive but not significant correlation between the increasing of basal diameter and the height of sprouts (Figure $5B_1$). The correlation between basal diameter and the height of sprouts was significant for *T. grandis* (Figure 5C1). The effect of dead individuals was also weak on *T. grandis* height of lead sprout.

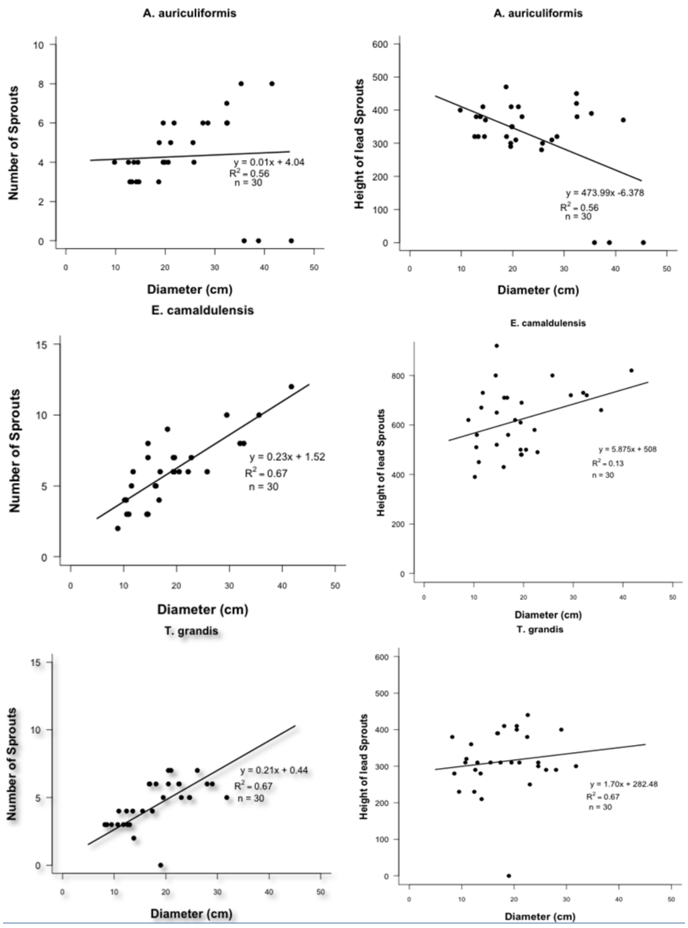

Figure 5. Influence of basal diameter on number of sprouts and height of lead sprouts

Influence of cutting height of stem

The stump height size-classes were named smaller, intermediate and higher i.e. 15-25 cm, 35-45 cm, 55-65 cm. Although there were no significant differences among species, *A. auriculifomis* indicated the highest trend of number of sprouts.

Height of sprouts did not indicate any significant differences among class sizes when considering stump height class has independent factor.

Considering the interaction effect of variables, the results were not uniform (Table 2). For example, the species and diameter, species height class and diameter indicated significant effect on all response variables i.e. number of sprouts, height of sprouts and diameter of sprouts.

Table 2 : GLM examining the effect of predictor variables (Diameter of Stump and height of stump) of three exotic species on the Number of sprouts, Height of lead Sprouts and Diameter of lead Sprouts.

		Number of sprouts		Height of sprouts		Diameter of sprouts	
Source	DF	F value	P	F value	P	F value	P
Species	2	9.96	0.0001***	77.658	0.000***	16.245	0.000***
Class of height	2	2.15	0.123NS	5.169	0.007**	0.999	0.372NS
Diameter of stumps	1	22.88	0.0000***	0.083	0.773NS	4.253	0.042*
Species* Class	4	0.38	0.821NS	0.139	0.967NS	0.268	0.897NS
Species*Diameter	2	7.244	0.0013**	7.218	0.0013**	8.449	0.000***
Class*Diameter	2	4.257	0.017*	1.994	0.143NS	4.217	0.018*
Species*Class*Diameter	4	3.0134	0.0234*	3.01	0.023*	4.849	0.001**

On the other hand Species and height class of stump did not indicate any effect on studied variables. The intermediate result was found on height class of stump and diameter of stump effect where they affected significantly on the number of sprouts and diameter of sprouts (Figure 6).

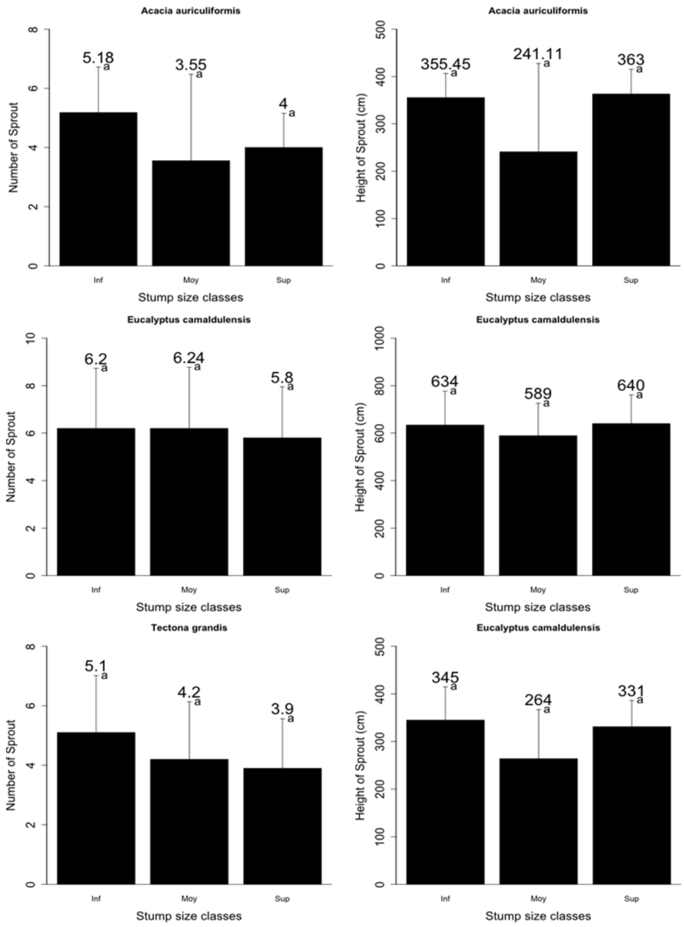

Figure 6. Influence of height of stump on number of sprouts and height of lead sprouts

DISCUSSION

Growth before cutting and after cutting

The results of this research showed that the speed of growth before cutting is always significantly inferior to the growth of sprouts during two growth seasons (Figure 3). Our results agreed with results from previous studies in tropical natural forests (Kruger & Reich 1993), where among savanna species coppices and root suckers sprouts showed higher height and bigger collar diameter compared to seedling sprouts. This ability to regrowth for stumps is related to the capacity for new buds to mobilize and utilize the nutrients (lignotuber) stored which might be slow in the case of seedlings and in natural stands. However the capacity to mobilize carbohydrates for the initial growth depends on the period of cutting (Ducrey Turrel 1992 & Konstandinidis et al. 2006). Cutting made in mid and late summer and in autumn had yielded the best capacity to regrowth and dry season in tropical area was the indicated period. In our case, the cutting has been held in dry season that is indicated as the best period of regrowth. This result helps foresters and forest researchers to take a good decision for better production.

Number of sprouts in relation of the stump diameter and cutting height

When the diameter of stumps increased, the number of sprouts increased for *E. Camaldulensis* and *T. Grandis* (Figure $5B_1$ & $5C_1$). This suggests that the stumps of *E. camaldulensis* and *T. grandis* had sufficient carbohydrates to assume the life of resprouts and therefore while the availability of these nutrients increased the capacity of stump to produce new sprouts also increased (Shacleton 2001, Mclaren & Mc Donald 2003, Mwavu & Witkowski 2008). Instead of diameter of stumps, the plant size or age at the time of cutting may affect the number of sprouts (Shackleton 2001). In addition, the effectiveness of resprouting from stumps varies with species, plant size or age at the time of cutting, stump height, and the percentage of the stand removed (Luoga et al. 2004). The age of cutting in our study was about 15 years which is enable to produce optimal resprouting. The results of our study in tropical area and the results of other in temperate area on downy birch and silver birch (Johansson 2008) are similar and showed that the number of sprouts from stumps mainly depends on the vigor of the tree at the time of the cutting related to its diameter and cutting height. The carbohydrates reserves may determine the growth of new sprouts and then lead to a significant correlation. The effect of the carbohydrates reserves on the growth of lingo tuberous sprouts and true seedlings of *Eucalyptus oblique* after removal of over storey in a native dry forest showed that carbohydrates reserves were higher in coppices than seedlings and may determine the vigor (Walters & Bell 2005).

Looking for the number of sprouts on each stump per year, except *A. auriculiformis*, both *E. camaldulensis* and *T. grandis* decreased from the first growth season to the second growth season (Figure $3A_1$). The similar result has been found in the temperate area where *Betula pubescens* has been studied for five years. Because of the desiccation of old branches and the growing of a plant, the number of sprouts decreased and helped the plant to growth fastly in term of diameter and height (Johansson 1992). Concerning *A. auriculiformis*, our result realized that one season growth is not enough to complete its resprouting that justified the increasing of the number of sprouts till the second year. In addition, *A. auriculiformis* demonstrated a huge capacity of sprouting in Benin area.

Relating to the effect stumps of height size-class on the number of sprouts, there was no significant effect. This could inform that the regenerative capacity of stumps for exotic species did not have dependence with the height of stump. The position of active buds and their capacity to regenerate is not likely depended on their position.

Height and diameter growth of sprouts in relation to stump sizes

In this study as in many, only the lead sprouts have been measured. We have separately measured the height and the diameter of lead sprouts. In practice, some studies have assimilated the height and diameter of sprouts to the total biomass of the plant (Guidici & Zingg 2005).

The basal diameters of stumps had showed a negative correlation with a height of sprouts (Figure $5A_2$) for *A. auriculiformis.* The negative correlation between the basal diameter and the height of sprouts (Figure 5A2) may be attributed to the change in physiology of the trees with age (Khan & Tripathi 1986). In general, vegetative reproduction predominates in the juvenile phase and sexual reproduction in the adult phase. Also, when the tree's age increased, the number of dormant buds, which sustain the sprouting, is reduced due to their death. The increasing thickness of the bark with advancing age of trees also offers mechanical hindrance to the resprout height growing.

Concerning a negative correlation between size of stumps and the biomass (height and diameter of sprout), many studies have found a similar result. The study of stump dimensions in the regrowth of an indigenous savanna tree species (*Terminalia sericea*) for fuelwood noted a negative correlation between the stump sizes and the shoot coppice lengths (Shackleton 2001). In a wet hill forest of North-East India, tree regeneration in a disturbed sub-tropical found a decreasing coppicing ability with increasing stems size for four sub-tropical forest species. This has been ascribed to the increased bark thickness of larger stems hindering emergence of the bud study (Khan & Tripathi 1986). For *E. camaldulensis* and *T. grandis*, we found a positive relationship between diameter and height of lead sprouts. This variability among species informed that each species might have differently their capacity to resprouts even located in the same climatic area.

Nature of disturbances and resprouting

In this study, cutting has been carried out by axe and in dry season which is the dormancy period of the plant in this area. Cutting is a kind of disturbances among others. This kind of cutting called coppicing is the common cutting method in Benin. In fact, the cutting regimes (coppicing, crown thinning and pollarding) is related to the intensity of disturbances (Luoga et al. 2004). In our study, although the intensity of disturbance was not evaluated, we found that this type of cutting is convenient for the species because of the weak rate of stump death (only 4 individuals died among 90) although stump survival varied with species (Pyttel et al. 2013; Keyser & Zarnoch 2014).

For fuelwood usage, coppicing is known to be the best (Nygard et al. 2004) to get benefit with all biomass of trees, its determinant to find the positive of coppicing. In this relevance, it may be important in the future to evaluate the disturbance effect of each cutting method (e.g. coppicing, crown thinning and pollarding) on the resprouting of stump.

CONCLUSION

The results from this study revealed that *E. camaldulensis* had a high ability to resprout after a disturbance like cutting. The respouting in terms of number of sprouts had positive relationship with the basal diameter of stumps (until 45 cm) and also with the height of stumps (until 65 cm). In terms of height cutting, *E. camaldulensis* is good when cutting is held between 55-65 cm. We observed also in this study that all the stumps of *E. camaldulensis* could resprout though some individuals of *Auriculiformis auriculiformis* died especially after 35 cm. A positive relationship has been noticed for *T. grandis* but with variation according to the diameter and height of stumps. *A. auriculiformis* has shown a negative and significant correlation between the basal diameter of stumps (height and diameter of sprouts) when taking into account the dead individuals. This suggests that the death of stumps is an important factor to take into consideration to manage *A. auriculiformis* forests and helps in the choice of it rotation in this area.

Regarding the resprouting of *E. camaldulensis* and *A. auriculformis*, the first one showed a better growth and number of sprouts. Considering the ability of *E. camaldulensis* and *A. auriculiformis*, these species had a good capacity for resprouting and were very good for short rotation, therefore they are convenient for ecosystem restoration. *A. auriculiformis* had also indicated dead risk when the diameter is larger than 35 cm.

Although brilliant results in terms of sprouts for *E. camaldulensis* and *A. auriculiformis*, many authors had kept our mind on the importance and considering of other factors like economic factors, ecological factors, fuel production and the use (e.g. timber, pole, fuelwood) for each species to make our last decision. Evaluation of the impacts of these above factors could be determinant to make the last choice. Forest manager will need to take into consideration differential aspects of each species if the diversity of forest is to be maintained.

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