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REGENERATION OF SOME FUELWOOD TREE SPECIES OF HUMID SAVANNA OF ADAMAWA, CAMEROON: EFFECTS OF SEASON AND CUTTING HEIGHT

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Abstract

Six most widely used tree species of fuelwood (*Daniellia oliveri, Entada africana, Hymenocardia acida, Lophira lanceolata, Piliostigma thonningii* and *Terminalia macroptera*) were studied in three suburban localities of Ngaoundere (Bini, Borongo and Dang), for two seasons (rainy and dry seasons). Four cutting levels (0, 20, 35 and 50 cm from soil surface) and two cutting modes (horizontal and oblique) were achieved in each season in each locality and for each species. The experimental method was a split-plot with three replicates (localities). The main factors were fuelwood tree species and the under-factors were represented by the seasons, the cutting mode and the cutting height. The experimental unit was constituted by five trees. Data of shoot number, shoot height and diameter were recorded. Results showed that all species produced at least one shoot since the first month, excepted *L. lanceolata* in rainy season. The mean number of the shoots produced at the end of 3 months varied from four (*L. lanceolata*) to 11 (*H. acida* and *E. africana). D. oliveri*, *L. lanceolata* and *P. thonningii* significantly produced the greatest number of shoots in the dry season than in the rainy season. The other species had an opposite behaviour. The shoot number varied very significantly with the cutting height, but not with the cutting mode. The shoot growth in height and in diameter were not similar among species in any season, and the cutting height and the season did not influence the shoot growth of any species. The results would contribute to sustainable management of Adamawa savannas that are now under multiple anthropic pressures.

Résumé

IBRAHIM, A., MAPONGMETSEM, P. M., BOUITANG, D. & HASSANA, B.: Pour contribuer à la compréhension de la régénération des espèces énergiques des savanes de l'Adamaoua, six essences (*Daniellia oliveri*, *Entada africana*, *Hymenocardia acida*, *Lophira lanceolata*, *Piliostigma thonningii* et *Terminalia macroptera*), les plus utilisées comme bois de chauffe ont été mises en étude en milieu naturel dans 3 localités périurbaines de la ville de Ngaoundéré (Bini, Borongo et Dang), pendant 2 saisons (saison des pluies et saison sèche). Quatre niveaux de coupe (0, 20, 35 et 50 cm du sol) et deux modes de coupe (horizontale et oblique) ont été réalisés à chaque saison, dans chaque localité et pour chaque espèce. La méthode expérimentale est un *split-plot* à 3 répétitions (localités). Les facteurs principaux sont des espèces et les sous-facteurs sont représentés par les saisons, les modes et la hauteur des coupes. L'unité expérimentale est constituée par 5 plants. Les données portaient sur le nombre, la hauteur et le diamètre des rejets. Les résultats ont montré que toutes les espèces ont initié la formation d'au moins un rejet dès le premier mois, exceptée *L. lanceolata* en saison des pluies. Le nombre moyen des rejets produits au bout de 3 mois varie de 4 (*L. lanceolata*) à 11 environ (*H. acida* et *E. africana*). On note une disparité saisonnière entre les espèces. *D. oliveri*, *L. lanceolata* et *P. thonningii* produisent significativement le plus grand nombre des rejets en saison sèche qu'en saison des pluies. Les autres espèces présentent un comportement opposé. Le nombre de rejets varie très significativement avec la hauteur des coupes, mais non avec le mode des coupes. Les croissances en hauteur et en diamètre des rejets ne sont pas uniformes entre les espèces quelle que soit la saison. La hauteur des coupes et la saison n'influencent pas les croissances des rejets chez toutes les espèces. Ces premiers résultats contribueront à la gestion durable des savanes de l'Adamaoua, qui subissent actuellement des multiples pressions anthropique.

Introduction

Traditional systems of extensive exploitation are founded on shifting cultivation and long duration of fallow (15-30 years or more) (Zoumana Coulibaly, 1993). According to the results of Piéri (1989), these systems don't seem to provoke the deterioration of the environment (soil degradation, biological unbalance, etc.). Besides, they consolidate biodiversity. These systems were previously in balance with the natural habitats in which populations lived and obtained the greatest part of their subsistence (Agbahungba *et al*., 2001). This balance resulted from the harmonious relations in which the quantity of harvested products was sufficiently weak in relation to the production of natural savannas. Currently, this situation is in the process of changing negatively and in a drastic manner because of the multiple pressures exerted on these surroundings by human population increase (Tchotsoua *et al*., 2000).

Fuelwood cutting occupies an important place in underdeveloped countries where wood is the main source of energy (Agbahungba *et al*., 2001; Agbo *et al*., 1993; Aoudou Doua, 1999). The increased need for wood and charcoal has led to an unprecedented crisis, so that in some countries like India, Pakistan, Bangladesh, Bolivia and Peru, the populations have taken to using cow dung or Lamaos as a source of energy (Eckholm, 1987).

In Africa, the problem of fuelwood is very acute because 80 per cent of the energy used on the continent is provided by wood according to Baumer (1987) and Sokpon *et al.* (2001). Fuelwood has become a rare and expensive product in the Sahel. A further rise in the deficit of firewood in this zone would be alarming (Baumer, 1987). In Benin, Sokpon *et al.* (2001) have shown that the quantity of firewood used daily varies between 0.9 kg/person and 1.7 kg/person according to localities. In Niamey, for example, a working class family head spends close to a quarter of his income on fuelwood (Eckholm, 1987). Agbo *et al.* (1993) have found out that the quantity of fuelwood used was highly correlated to the number of inhabitants. In this rhythm of deforestation, MINEF (1994) estimates that some indigenous tree species are threatened with extinction if the situation does not change.

The Sudano-guinean region of the Adamawa (Cameroon) is not spared from this fuelwood crisis as testified by the numerous points of fuelwood retail in the region. Indeed, the situation of fuelwood availability has considerably worsened these six last years with the multiple crisis that the country is undergoing (local currency devaluation, reduction of salaries, etc.), and has provoked an increase in kerosene and domestic gas prices and a drastic decrease of the people's purchasing power. The above situation has led to a high demand in fuelwood and in charcoal, and has provoked an increase in the extraction of quantities of wood from the natural ecosystems (Aoudou Doua, 1999, Tchotsoua *et al*., 2000). The increase extraction does not allow these ecosystems to regenerate, thus, fuelwood has become so rare that one has to trek long distances to find fuelwood tree species (Tchotsoua, 1999).

The utilisation of wild fruit trees as fuelwood is an indicator of the rarity of fuelwood in the suburban savannas because these trees were reserved for food and income. With regard to these alarming situations, research on the management of the indigenous tree species for fuelwood and their regeneration deserves particular attention. However, these aspects are not taken into account in the present research programmes of the area, with the exception of the study by Mapongmetsem & Akagou (1997) that was only limited to the inventory of tree species having a potentiality as fuelwood and to the proposition of research perspectives concerning the regeneration of these species.

The objective of the present work is to study the regeneration of indigenous tree species in the ecological conditions of the Sudano-guinean savanna of Adamawa, in order to provide adequate tools to contribute to understanding the regeneration of multipurpose tree species. Thus, based on the six most widely used tree species by the peasants as fuelwood (Mapongmetsem & Akagou 1997), the research team attempted to answer the following questions:

1) What was the regenerative potential of these six indigenous tree species after felling? 2) Taking into account the fact that most fellings are oblique and close to the soil without choosing a particular period of the year, do the number and the growth of the produced coppice shoots vary according to tree species? and 3) Do the seasons, the mode and the height of cutting have any effects on the number and the growth of coppice shoots?

Experimental

Study area

The study sites are located in the Adamawa region (6-8° N, 12-15° E, altitude 1200 m asl). This geographical situation gives at this region a Sudano-guinea climate with one dry season (November-March) and one rainy season (April-October) (Fig. 1). The mean annual rainfall is about 1500 mm, the mean annual temperature is approximately 22 °C and the mean relative humidity about 69 per cent. The seasonally arid situation of Adamawa is due to the influence of the harmattan which recalls the harsh climatic conditions of the Sudano–sahelian savanna, while its rainfall and its thermal amplitude recall the humid subequatorial regions (Hengue, 1994). The rock is constituted of a metamorphic pedestal composed of granites and Pan-African gneiss cut up by syenites and the volcanic formations of mio-pliocène period, leading to formation of various soil types [Bachelier, 1957; Eno Belinga, 1984). This region singles itself out in latitude due to two cuts: in the north, the limit of the area is the extension of the Sudanian savannas and in the south, the forest formation belonging to semi-deciduous forest of Guinean type. The interval between the two limits corresponds to the typical

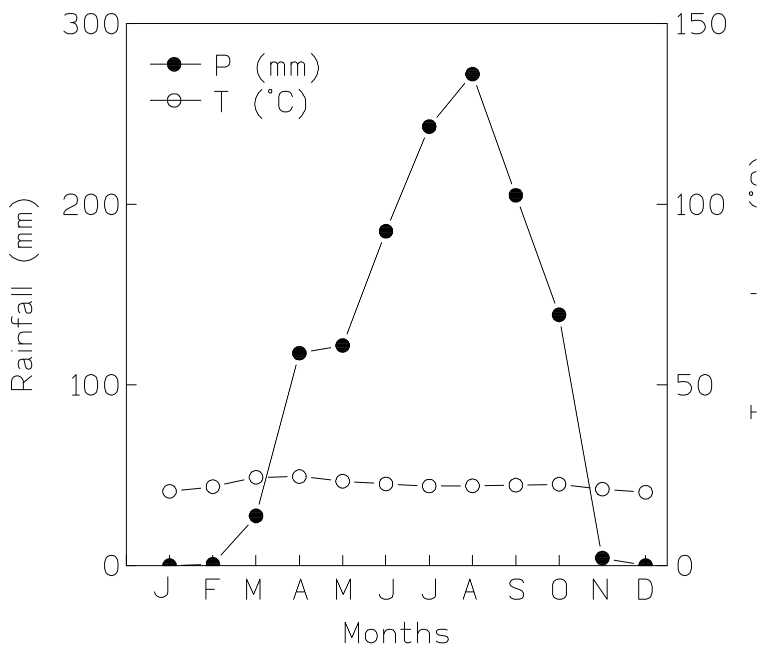

Fig. 1. Ombrothermic diagram of Ngaoundere City (from Meteorological Station of Ngaoundere Airport, 1985-2000)

area of Sudano-Guinea, covered with either the shrub savannas or the tree savanna, *Daniellia oliveri* and *Lophira lanceolata* (Letouzey, 1968). This vegetation aspect is maintained by zoo-anthropic factors such as bush fires and grazing (Rippstein, 1885).

The six most characteristic tree species of the Adamawa savannas and the most appreciated by the peasants as fuelwood (Mapongmetsem, 1995; Aoudou Doua, 1999) were chosen. These are *Daniellia oliveri* (Rilfe) Hutch., *Piliostigma thonningii* (Schum.) Milne-Redh (Caesal-piniaceae), *Entada africana* Guile. and Perrot (Mimosaceae), *Hymenocardia acida* Tul (Hymenocardiaceae), *Lophira lanceolata* Van Tiegho ex keay (Ochnaceae), *Terminalia macroptera* Guile. and Perrot. (Combretaceae). The regeneration experiment was conducted on the field, around Bini, Dang, and Borongo villages located, respectively, at 15, 15 and 20 km from Ngaoundere city. The regeneration experiment was conducted on tree species whose trunk diameter varies between 5 and 10 cm. In order to determine the influence of season and cutting mode, two periods (rainy and dry seasons) and two cutting modes (horizontal and oblique line = traditional cutting) were chosen.

Four cutting heights (0, 20, 35 and 50 cm from the soil) were chosen for five trees of each species. The cutting was carried out with machete. The traditional cutting level is achieved at 0 cm from soil. Coppices were labelled. The experimental method at each season was a split–plot with three replicates (localities). The main treatment was constituted by the tree species, the under–treatments were the cutting height (0, 20, 35 and 50 cm) and the cutting mode (horizontal and oblique line). The experimental unit was constituted of five trees. The recorded data were the number, height and diameter of shoots. The shoot number was determined after 3 months per season. The diameter and height of shoots were measured after the third month. Analyses of variances and Student's t-test were used to compare tree species, and between seasons and between cutting modes. Linear regression was used to determine the relationships between cutting height and regeneration parameters (number, height and diameter of shoots).

Results

Regenerative capacity

Production of shoot number with time. Coppices of all tree species gave at least one shoot after the first month except *L. lanceolata* in rainy season where the first shoots appeared after the second month (Fig. 2a and b). The shoot number in the first month varies generally among tree species in the two seasons according to the order: *H. acida* > *E. africana* > *D. oliveri* > *P. thonningii*, and *T. macroptera* > *L. lanceolata* in the rainy season and *E. africana* > *H. acida* > *D. oliveri* > *P. thonningii* > *L. lanceolata*, and *T. macroptera* in the dry season. This was not consistent through time. Three groups of tree species were distinguished: tree species of which the maximum number of the produced shoots was reached after the first month, then this number remained constant in the rainy season (*H. acida* and *E. africana*) or decreased in the rainy season (*D. oliveri*) or in the dry season (*E. africana*). For the second group of tree species, the maximum number of the shoots produced was reached after the second month, either this value remained unchanged during the rainy season (*P. thonningii* and *T. macroptera*) and the dry season (*H. acida, D. oliveri* and *T. macroptera*), or else it decreased significantly during the dry season (*P. thonningii).* The third group constituted of *L. lanceolata* of which the produced shoot number continued to increase until the third month in the two seasons.

Interspecific variation of the shoot number at the end of seasons. Average shoot number differed significantly among tree species ($F = 25.23$ and $P < 0.001$). This average number varies from four (*L. lanceolata*) to about 11 (*H. acida* and *E. africana*) at the end of the third month (Fig. 3). Two groups of tree species appeared according

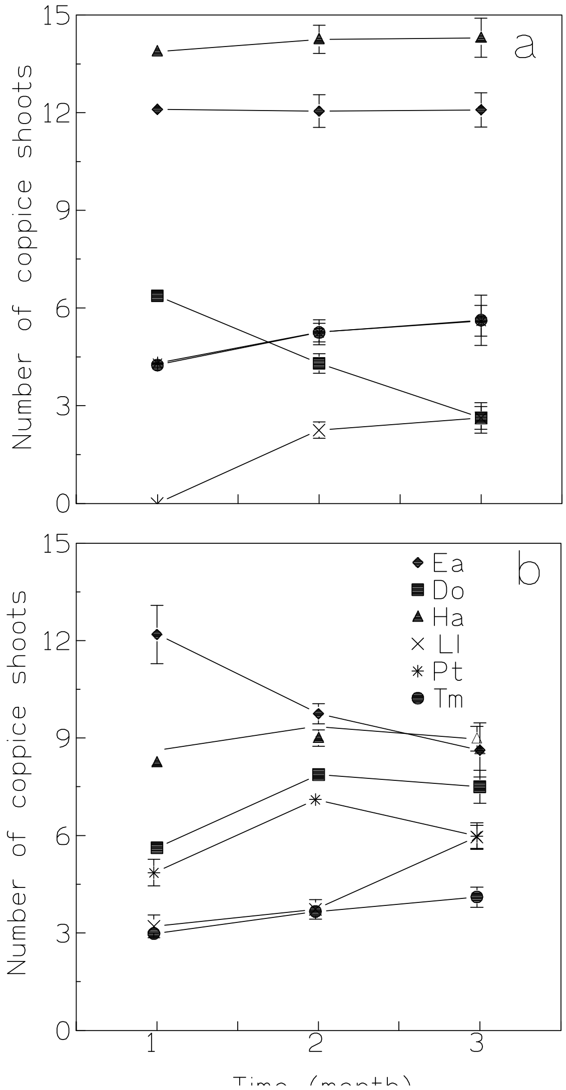

Fig. 2. Temporal changes of coppice shoot number in rainy season (a) and in dry season (b). Ea, *E. africana*; Do, *D. oliveri*; Ha, *H. acida*; Ll, *L. lanceolata*; Pt, *P. thonningii* and Tm, *T. macroptera*.

to comparisons of the means using LSD: *H. acida* and *E. africana* constitute a group that produced a greater number of shoots than the other tree species at the end of the third month.

Tree species also differed significantly by the number of shoot produced at the end of the third month, in the rainy season (F = 23.69 and $P < 0.001$) and in the dry season (F = 11.74 and $P < 0.001$). LSD test distinguished three groups of tree species in both seasons (Table 1). But the groups were constituted of different tree species: *E. africana* and *H. acida* have formed a group producing the highest number of shoot in the both seasons; *D. oliveri* in rainy season and *T. macroptera* in dry season have the lowest number of shoots and the other tree species have formed an intermediate group whatever the season.

Influence of season, cutting height and cutting mode on shoot number. If one considers data for all tree species, season did not have an effect on the shoot number (t = 0.35 and $P = 0.73$). On the other hand, shoot number varied significantly between seasons for each tree species (Table 1). One noted a seasonal disparity among tree species: *D. oliveri*, *L. lanceolata* and *P. thonningii* produced higher shoot numbers in dry season than in rainy season. The other tree species presented an opposite behaviour. Analyses of variances show that only interactions between tree species and season (F = 14.41 and $P < 0.001$) on data of all tree species, between tree species and cutting mode (F = 3.25 and $P < 0.05$) and between tree species and cutting height (F = 2.46 and $P < 0.05$) in dry season were significant. But no interaction was significant in the rainy season.

Shoot numbers varied significantly with cutting height on data of all tree species in the rainy season than in dry season (Fig. 4a, b and c). Contrarily, cutting mode (horizontal and oblique line) did not have any effect on the shoot number, nor on data of all tree species (t = 0.96 and $P = 0.33$), nor according to seasons (t = 0.2 and $P = 0.85$; t = 1.74 and $P = 0.085$). Interaction between tree species and cutting mode (F = 0.72 and $P = 0.616$) and between season and cutting mode (F = 1.22 and $P = 0.278$) have not influenced the

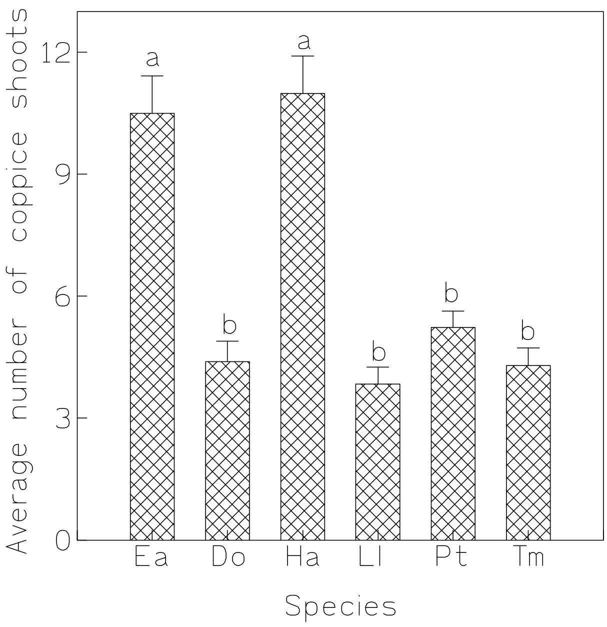

Fig. 3. Average number of coppice shoots all seasons including. Different letters indicate that the values are significantly different. Standard error in bar. Ea, *E. africana*; Do, *D. oliveri*; Ha, *H. acida*; Ll, *L. lanceolata*; Pt, *P. thonningii* and Tm, *T. macroptera*.

The general average of height obtained at the end of the third month was about 50.28 cm. Shoot growth in height was not similar among tree species (Fig. 5a). According to ANOVA, tree species effect was significant on shoot height (F = 111.32 and $P < 0.001$). Mean comparison by LSD test has also shown that tree species differ significantly by their shoot height except *H. acida* (37.9 cm) and *T. macroptera* (39 cm) which had a similar growth. The most elevated growth in height was recorded for *E. africana* (94 cm) and the lowest for *L. lanceolata* (8.2 cm).

Tree species have shown significant variations of shoot growth in height in both seasons (Table 2). In the rainy season, it was *E. africana* which produced the longest shoots (about 92 cm) and the shortest shoots were recorded by *L. lanceolata* (4 cm) which was not significantly different from *D. oliveri* (9 cm) according to mean comparison by LSD test. In the dry season, it was *E. africana* and *P. thonningii* which produced the longest shoots, the shortest shoots were produced by *L. lanceolata* and *D. Oliveri* and

TABLE 1

Comparison of the number of coppice shoots between tree species at each season and between season for each specie

Species	*Rainy season*	*Dry season*	*Student's t*
E. africana	12.25 (1.52)a	8.59 (0.83)a	2.06 *
D. oliveri	1.83 (0.35)c	6.96 (0.59)ab	7.41 ***
H. acida	13.17 (1.54)a	8.59 (0.72)a	2.61 *
L. lanceolata	3.12 (0.47)bc	5.07 (0.73)b	2.35 *
P. thonningii	4.13 (0.47)bc	6.33 (0.58)b	2.97 **
T. macroptera	5.50 (0.77)b	3.08 (0.28)c	2.96 **
F	23. 69***	11.74***	

Different letters indicate the values are significantly different. Standard error in brackets. * $P < 0.05$, ** $P < 0.01$ and *** $P < 0.001$.

production of shoot number.

Shoot growth

Interspecific comparison of the shoot height.

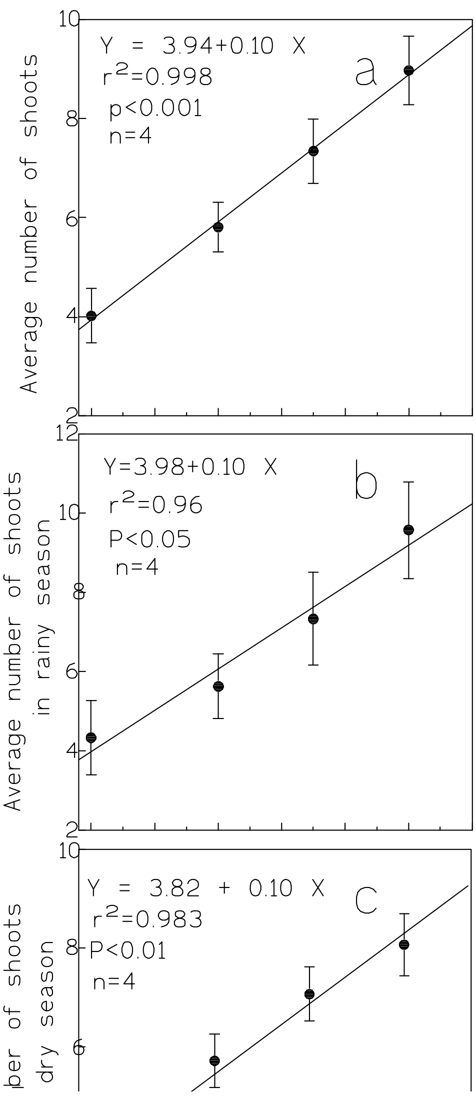

Fig. 4. Relationship between mean number of coppice shoots and cutting heights on all seasons including (a), in rainy season (b) and in dry season (c).

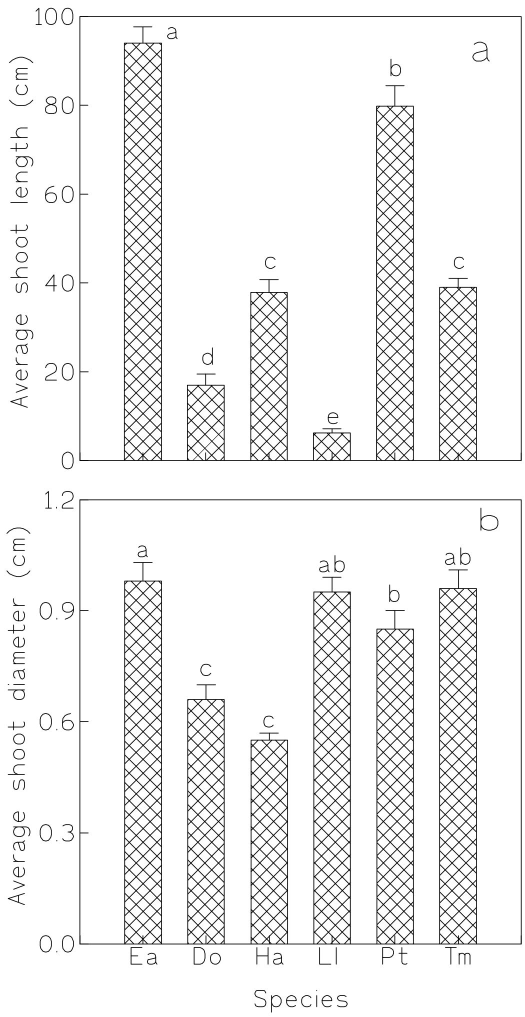

Fig.5. Average length (a) and average diameter (b) of coppice shoots at the end of the 3rd month, all seasons included. Different letters indicate values are significantly different. Ea, *E. africana*; Do, *D. oliveri*; Ha, *H. acida*; Ll, *L. lanceolata*; Pt, *P. thonningii* and Tm, *T. macroptera*.

the other tree species displayed an intermediate behaviour.

Interspecific comparison of shoot growth in diameter. Concerning shoot diameter, general average value was about 0.83 cm at the end of the third month. Tree species effect was always significant ($F = 17.45$ and $P < 0.001$) on data of all

TABLE 2

Comparison of the shoot length among species at each season and between seasons for each species

Species	*Rainy season*	*Dry season*	*Student's t*
E. africana	92.42 (4,8)a	95.62 (5,40)a	0.44ns
D. oliveri	8.92 (1,32)e	24.08 (3,83)c	3.57 * * *
H. acida	25.67 (2,65)d	50.14 (3,71)b	5.38 * * *
L. lanceolata	3.72 (0,45)e	12.20 (1,89)c	6.79 * * *
P. thonningii	64.25 (5,60)b	95.43 (6,02)a	3.79 * * *
T. macroptera	37.26 (2,80)c	40.79 (2,91)b	0,87ns
F	86.58 * * *	52.27 * * *	

Different letters indicate the values are significantly different. Standard error in brackets. *** P < 0.001 and ns: non significant.

tree species. Average shoot diameter varied from 0.98 cm for *E. africana* to 0.55 cm for *H. acida* (Fig. 5b**).** According to mean comparison by LSD test, three groups appeared: on the one hand, *E. africana* with the thickest shoot, on the other hand *D. oliveri* and *H. acida* with the smallest shoot diameter, and the other tree species had a diameter situated between the two previous tree species. Interspecific variations of shoot growth in diameter have been observed in rainy and dry seasons (Table 3). The composition of groups varied according to the seasons. *L. lanceolata* had the thickest shoot (1.01 cm) and the smallest shoot diameter was produced by *D. oliveri* (0.48 cm) and *H. acida* (0.57 cm) in the rainy season. While in the dry season, it was *E. africana* which had the thickest shoot and *H. acida* (0.54 cm) the smallest shoot diameters.

Effect of season, cutting height and cutting mode on shoot growth. Growth in height (t = 4.20 and $P < 0.001$) and in diameter (t = 4.75 and $P < 0.001$) varied significantly with seasons. The effect of seasons on the height of the shoots for *E. africana* and *T. macroptera,* and on the diameter of the shoots for *H. acida was* not significant (Tables 2 and 3). For the other tree species, it was in the dry season that the greatest growths in height and in diameter were recorded except for *L. lanceolata* where the growth in diameter was faster in the rainy season than in the dry season.

TABLE 3

Comparison of the shoot diameters among species at each season and between season for each species

Species	*Rainy rain*	*Dry season*	*Student's t*
E. africana	0.78 (0.05)b	1.18 (0.07)a	4.53***
D. oliveri	0.48 (0.04)c	0.81 (0.05)c	4.95***
H. acida	0.57 (0.03)c	0.54 (0.03)d	0.68ns
L. lanceolata	1.01 (0.05)a	0.83 (0.07)c	2.03*
P. thonningii	0.71 (0.04)b	0.98 (0.07)bc	3.22***
T. macroptera	0.78 (0.06)b	1.14 (0.05)bc	4.23***
F	14.03***	17.49***	

The different letters indicate the values are significantly different. Standard error in brackets. * $P < 0.05$, *** $P < 0.001$ and ns: non significant.

When one considered data of all tree species, shoot diameter varied significantly with cutting height (F = 2.86 and $P < 0.05$), but not in both seasons (F = 1.28 and $P = 0.285$; F = 2.09 and $P = 0.104$). This influence of cutting height on shoot growths in diameter was only significant for *D. oliveri*, *L. lanceolata* and *E. africana* (Annex 1). In the same way, shoot growth in height was not influenced by the cutting height (F = 0.08 and $P = 0.964$) and in both seasons (F = 0.07 and $P = 0.972$, and F = 0.29 and $P = 0.831$), except for *L. lanceolata* ($r^2 = 0.226$ and $P < 0.05$) (Annex 2).

Discussion

Variation of shoot number and shoot growth among tree species

Most tree species have the potential to form at least one shoot in the first month, independent of season, except for *L. lanceolata* in the rainy season where the appearance of shoot only occurred in the second month. In his work conducted in the savannas of South Africa, Shackleton (2001) found that for *Terminalia sericea* the shoot appeared after 3 months of tree cutting and the shoot number varied from 7 to 9 per stump. The fast appearance of shoot has shown that all tree species have the necessary capacity to quickly initiate at least one shoot, even though this capacity varied according to tree species. In fact, the shoot number for some tree species reached its maximum in the first month and it was maintained throughout the experimentation process, while for the other tree species, particularly *L. lanceolata*, this number increased progressively to reach its maximum at the end of the second and the third months. This has suggested that most tree species have a very high regenerative capacity. For these tree species, capacity for the latent buds were important enough to produce all shoots in the first month. However, energetic nutrient contained in stumps for the growth of all shoots were not sufficient to maintain all shoots during the whole season. Then competition occurred among different shoots, leading to the death of some shoots and maintenance of others. The influence of the phytohormones is highly marked in *D. oliveri* and *E. africana*. Otherwise, both tree species, *E. africana* and *H. acida,* are polyseasonal and could be especially cut in all seasons, even if their regeneration occurred faster in rainy seasons.

With regard to their growth, tree species have shown variable strategies for growth of their shoots (in height and in diameter). Among these tree species, *E. africana* and *P. thonningii* have shown a high growth potential of their shoots and an interesting perspective for the exploitation of their wood as fuelwood because their fast growth enables them to reach exploitable ages quickly and to conserve other tree species. Thus, Mapongmetsem and Akagou (1977), Yonkeu *et al.* (1998), and Mbatchansie (2001) have shown that *L. lanceolata*, *H. acida* and *D. oliveri* were the most exploited tree species for fire wood and charcoal in the Adamawa area, due to their high energy potential for the peasants.

Effect of season on shoot number and growth

In general, shoot apparition is not influenced by season, but shoot number obtained depends on season. With the exception of the three characteristic tree species of the Adamawa savannas (*L. lanceolata*, *D. oliveri* and *H. acida*), the shoot number produced was higher in the rainy season than in the dry season. This influence of season on shoot number was found on other tree species and other ecosystems. Heth *et al.* (1998) have shown that emergence and maximum shoot number of *Ecalyptus camaldulensis* in Israel varied strongly with cutting season. Spring is the best period to reach maximum shoot number after wood cut. Cauvin (1982) has also shown on other *Ecalyptus* that the best season to have maximum shoot number was the end of spring. According to the results, the best cutting period was generally the rainy season, because in the dry season, tree species have difficulty to get necessary substances for shoot production, due

ANNEX 1

*Results of the linear regressions between shoot diameters (cm) and cutting heights. * P < 0.05, ** P < 0.01 and *** P < 0.001; ns: non significant; F: Fisher values*

Species	*a*	*b*	*F*	r^2	*N*	*P*
			Both seasons included			
E. africana	0.859	0.005	3.18	0.063	48	0.084ns
D. oliveri	0.506	0.005	5.06	0.137	34	0.031*
H. acida	0.549	0.0001	0.00	0.0001	48	0.948ns
L. lanceolata	0.750	0.007	12.73	0.272	36	0.001***
P. thonningii	0.847	0.0001	0.00	0.0001	48	0.959ns
T. macroptera	0.885	0.003	1.23	0.026	48	0.274ns
			Rainy season			
E. africana	0.766	0.0009	0.09	0.004	24	0.772ns
D. oliveri	0.388	0.004	4.04	0.224	16	0.064ns
H. acida	0.571	0.0002	0.02	0.0008	24	0.899ns
L. lanceolata	0.790	0.008	15.92	0.420	24	0.001***
P. thonningii	0.701	0.001	0.09	0.004	24	0.763ns
T. macroptera	0.742	0.002	0.22	0.01	24	0.644ns
			Dry season			
E. africana	0.951	0.009	7.35	0.250	24	0.013*
D. oliveri	0.658	0.0052	2.49	0.135	18	0.134ns
H. acida	0.527	0.0004	0.05	0.002	24	0.833ns
L. lanceolata	0.611	0.007	3.71	0.27	12	0.083ns
P. thonningii	0.994	-0.0004	0.01	0.0004	24	0.926ns
T. macroptera	1.028	0.004	2.16	0.089	24	0.156ns

to water deficiencies, except *L. lanceolata*.

Season also has a remarkable influence on shoot growth (in height and in diameter). This appeared in general in dry season, which is the most favourable season for shoot growth. Because of competition among them, shoot number was weak during dry season. This competition eliminated a certain number of shoots. Resources mobilised in the rainy season are allocated to the few shoots that remained. Exceptions do exist. In fact, results in the growth and height for *E. africana* and *T. macroptera* and in diameter for *H. acida* were similar in both seasons. For a better management of the Sudano-guinean savannas of Adamawa in view of the plant species conservation implied in the production of the firewood or charcoal, wood cutting practices must be done more in the rainy season, contrary to the usual practice of peasants who cut them all year round.

Effect of cutting height on the shoot number and growth

Cutting mode did not have any influence on shoot number and growth. It has been observed that the shoots have grown along tree stumps from the bottom to top, with a predominance of shoots between 2 and 3 cm from the point of cut. This parameter must not be considered as an indicator of management for tree species

ANNEX 2

Results of the linear regressions between shoot lengths (cm) and cutting heights. * $P < 0.05$, ** $P < 0.01$ *and* *** $P < 0.001$; *ns = non significant. F: Fisher values*

Species	*a*	*B*	*F*	r^2	*N*	*P*
			Both seasons included			
E. africana	93.485	0.02	0.01	0.0002	48	0.92ns
D. oliveri	9.68	0.26	3.44	0.097	34	0.073ns
H. acida	41.814	-0.149	0.92	0.02	48	0.343ns
L. lanceolata	4.70	0.057	1.26	0.039	33	0.27ns
P. thonningii	79.94	-0.004	0.00	0.00	48	0.988ns
T. macroptera	38.66	0.014	0.02	0.0004	48	0.899ns
			Rainy season			
E. africana	102.75	-0.394	2.26	0.093	24	0.147ns
D. oliveri	7.83	0.042	0.32	0.023	16	0.578ns
H. acida	28.472	-0.107	0.55	0.024	24	0.467ns
L. lanceolata	2.27	0.055	6.43	0.226	24	0.019 *
P. thonningii	58.957	0.02	0.43	0.019	24	0.517ns
T. macroptera	36.87	0.015	0.01	0.0004	24	0.923ns
			Dry season			
E. africana	84.214	0.434	2.34	0.096	24	0.140ns
D. oliveri	11.695	0.409	3.26	0.169	18	0.09ns
H. acida	55.156	-0.191	0.90	0.04	24	0.352ns
L. lanceolata	11.73	0.042	0.13	0.019	9	0.725ns
P. thonningii	100.922	-0.209	0.40	0.018	9	0.532ns
T. macroptera	40.453	0.013	0.01	0.0003	24	0.936ns

regeneration. Peasants are free to practice tree cuttings at different modes (horizontal or oblique line).

Shackleton (2001) has shown that increase of cutting height for *Terminalia sericea* had a positive effect on the shoot number in the savannas of South Africa. These results have been confirmed by studies on other tree species and on other types of vegetation (Harrington, 1984; Khan & Tripathis, 1986; Bowersox *et al*. 1990; Huang, 1990). In this study, the number of shoots has varied very significantly with the cutting height. The more the cutting height increases the more the shoot number become important up to 50 cm of height. These results could be explained by the spatial availability along tree stump, as suggested by Shackleton (2001). Indeed, the more the cut points were high on stump, the more the surface area carrying latent buds was great and the more the number of the shoots produced was high. This was different from the peasant practices of cutting the trunks of trees at the level of the soil. According to Bowersox *et al*. (1990) and Johansson (1992), the survival of the trunk cut was positively correlated to cutting height. That means it would be urgent that the traditional system of cutting the tree for fire wood and charcoal changes if we want to conserve and exploit sustainably without compromising the existence of these tree species in the savannas of the Adamawa.

Conclusion

The study has shown that all tree species, considered as fuelwood in the Sudano-guinean savannas of the Adamawa, have a remarkable regenerative capacity, due to the fast production of the great number of shoots and their growths. However, *E. africana* and *H. acida* were different from the other tree species by their high regenerative capacity and their polyseasonal behaviour. The best period for cutting was the rainy season. It was during this season that the necessary resources to raise the latent buds and their development were mobilised. Over the three month period, the tree cutting at the level of soil generally practised by the peasants was not favourable to the management of the regeneration of the plant species. The traditional practice of tree cutting must, therefore, take into account the seasons and the cutting levels, the savannas of the Adamawa should be preserved, in view of a sustainable production of firewood or charcoals, without compromising the existence of these genetic and economic resources.

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