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VEGETATIVE PROPAGATION BY SUCKERING OF *CROSSOPTERYX FEBRIFUGA* (AFZEL. EX G. DON) BENTH. IN THE PRODUCTION SYSTEMS OF PENDÉ (CHAD)

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ABSTRACT

The Pendé ecosystems are home to an exceptional plant biodiversity, representing an inestimable potential for the socio-economic development of the said locality. Among the emblematic species of these Pendé ecosystems, *Crossopteryx febrifuga* occupies a special place due to its multiple socio-economic and medicinal uses. Anthropogenic pressures and climate change pose an increasing threat to this species. This study aims to contribute to the domestication of *Crossopteryx febrifuga* by suckering. An analysis of its natural regeneration mode in different land-use units was carried out, and the effect of induction type and root exposure mode on the suckering of this species was tested. Characterization analyses and root system excavations enabled us to identify the mode of regeneration by seed propagation, coppice shoot and suckering. Suckering density was estimated at 1±0 suckers/ha in savannah, 2.37±1.18 suckers/ha in fallow land and 2.2±0.83 suckers/ha in fields. As for suckering induction, complete root sectioning was more effective

(40.47±24.82%) than partial sectioning (12.66±6.41%). Roots exposed to the open air showed greater suckering capacity (41.33± 32.88%) than those covered with original soil (23.33± 8.16%) and aluminium foil (11.66± 2.35%). None of the induced suckers developed their own root system. Nevertheless, these results confirm that complete root sectioning and exposure to the open air, combined with optimal environmental conditions, is a promising method for maximizing suckering potential in *Crossopteryx febrifuga* and other woody species to revegetate severely degraded ecosystems in Chad.

Keywords: *Crossopteryx febrifuga*, Savannah, domestication, Induction mode, suckering, Sudano-Guinean, Chad

INTRODUCTION

Natural ecosystems are of paramount importance to human societies, supplying an invaluable wealth of essential resources, for sustenance, materials for handicrafts, medicinal remedies or spiritual enrichment [1]. These ecosystems are home to exceptional biodiversity, representing invaluable potential for socio-economic development. In this context, many species exploited in the wild by rural populations are of major socio-economic interest [2]. Knowing the flora and vegetation of a given locality is thus an indispensable tool for supporting sustainable development policies, particularly in Africa, where plants play a predominant role in human nutrition and health [3,4]. *Crossopteryx febrifuga* occupies a special place among the emblematic species of Chad's ecosystems, due to its numerous socio-economic and medicinal uses. This species, which is widely exploited, illustrates the fragility of Chad's biodiversity. Several high-value plant species are traded on local and regional markets, contributing significantly to household incomes generation [5]. In Chad, studies conducted in the southern region have documented 1.445 species across 600 genera and 145 families, illustrating a remarkable floristic diversity [6]. However, the majority of these botanical inventories were conducted prior to 1973 [7]. Since then, anthropogenic pressures and climate change have increasingly threatened these species, particularly *Crossopteryx febrifuga*, resulting to overexploitation of natural resources and degradation of ecosystem [8,9].

Crossopteryx febrifuga, often referred to as “African cinchona”, is highly value for its medicinal properties in traditional African medicine. Its roots, bark and leaves are used to treat a a range of ailments, including fever, parasitic infections, joint pain and gastrointestinal disorders [10,11]. Its bark is particularly known for its antipyretic and antimalarial properties [12]. However, the extraction of bark and roots, often involving the destruction of the tree or serious damage to its vital tissues, prevents the natural regeneration of the species. In addition, large-scale leaf collection, although apparently less destructive, can also impair photosynthesis and weaken the tree. Beyong its medicinal uses, *Crossopteryx febrifuga* plays a crucial role in local economies in Chad. The trade of this species in derived product in local and regional markets is an essential

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source of income for rural households. However, increasing anthropique pressure, combined with population growth, is leading to overexploitation of this species. The expansion of agricultural land coupled with the increasing demand for energy wood further exacerbate this situation [8,9]. These practices have caused a significant decline in the natural population of *Crossopteryx febrifuga*. The excessive harvesting of essential plant parts, such as roots and bark, poses a major challenge for its regeneration, conservation and domestication. In addition, the limited availability of specific knowledge about its natural regeneration methods in Chad also limits the development of effective conservation and restoration initiatives. Nevertheless, the establishment of low-cost and sustainable regeneration strategies remains an indispensable prerequisite for simultaneously addressing the livelihood needs of vulnerable populations and ensuring the long-term conservation of biodiversity." [13]. In this context, agroforestry initiatives are being implemented to integrate trees of socio-economic interest into existing production systems [14]. However, there is a lack of detailed scientific data on the natural regeneration of tree species in Chad in general, exception made for *Ziziphus mauritiana* suckering [15], constituating a major obstacle to their domestication and to the implementation of sustainable conservation strategies [16]. Thus, this study aims to contribute to the domestication of *Crossopteryx febrifuga* by suckering in Pendé production systems. Specifically, the aim is to determine the modes of natural regeneration in different land-use units and to assess the effect of induction type and root exposure mode on the suckering of this species.

MATERIALS AND METHODS

Description of the study area

The work was carried out in the Sudano-Guinean savannah of the eastern Logone region, precisely in the locality of Mbo-Nya (8º40'24,10968"N; 16º44'57,70824"E; Alt: 388m), an area carefully selected because of the abundant presence of the studies species. The landscape is dominated by broad plateaus punctuated by peaks and depressions and dominated by flood plains [17]. The climate is Sudano-Guinean, with annual rainfall ranging from 900 to 1.200 mm. There are two seasons: a rainy season from May to November (6 to 7 months), and a dry season from November to April (5 to 6 months). Maximum temperatures peak at 38°C in March and April, while minimums stabilize at around 20°C on average [18]. Hydrographically, the region is fed by the Logone River, whose source lies at an altitude of 1.200 m on the heights of the Adamawa plateau, near Ngaoundéré [19,20]. From a pedological point of view, the province of Logone Oriental is characterized by deeply impoverished soils, the result of intensive and repeated cultivation practices. This phenomenon is reflected in erosion exposing lateritic cuirasses on the surface [21]. The soils encountered include more or less leached tropical ferruginous soils, ferralitic soils, hydromorphic soils and vertisols (tropical black clays).

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Characterization of natural regeneration

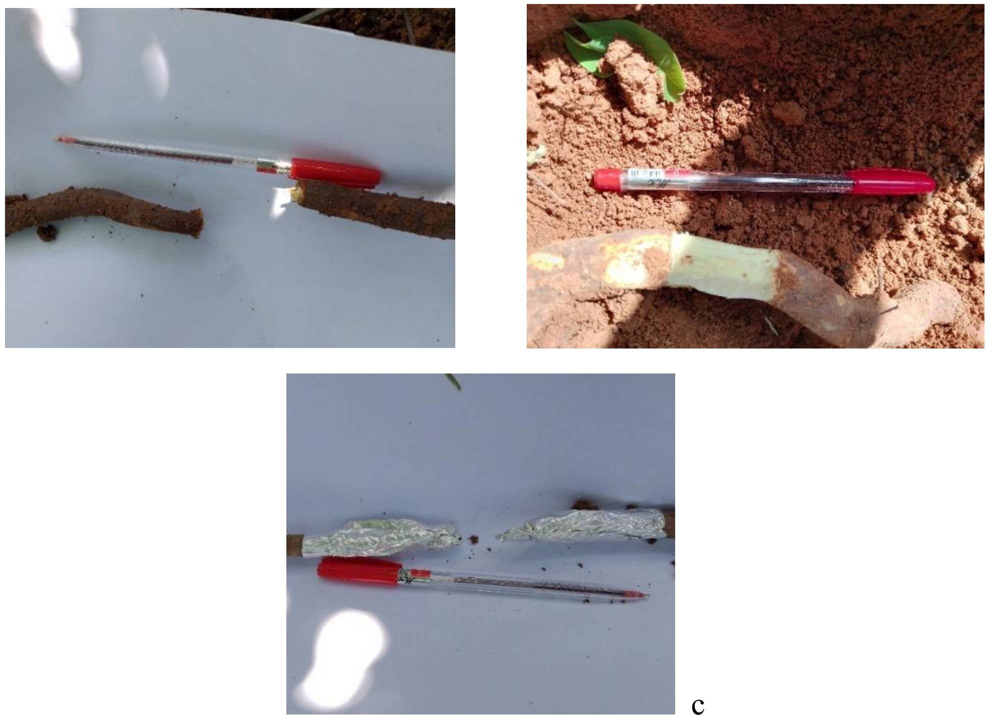
The sampling method adopted to characterize natural regeneration was inspired from previous research conducted in the Guinean savannah's highlands of Cameroon [22]. It is based on the random delimitation of 30 plots of 100 x 100 m² each, equally divided between savannahs (10 plots), fields (10 plots) and fallows (10 plots). The plots were established using a decameter and string, according to the presence and density of the species studied. In each plot, as well as around each adult individual of *Crossopteryx febrifuga*, all seedlings and saplings were counted within a 5 m radius. A seedling or stump sprout is considered mature once it has a diameter at 1.3 meters from the ground greater than 3 cm and/or a minimum height of 2 meters [5]. Natural regeneration, made up of seedlings and suckers, thus encompasses all plants with a diameter at breast height of less than 3 cm and/or a height of less than 2 meters. In addition, a stump sprout is classified as mature as soon as at least one of its sprouts exceeds a diameter of 3 cm. A methodical and progressive excavation of the root systems of each visible leafy axis was carried out using suitable tools (hoes and picks). This step prevents any confusion between a seedling and a sucker, and allows us to determine the origin [5,23]. Indeed, natural seedlings are distinguished by a taproot system, while suckers retain a morphological connection with the mother root [23,24].

Data were collected on the total number of suckers produced by the mother root, their distance from the base of the mother tree trunk, their height and diameter at ground level, as well as the presence or absence of neoformed root system at the base of each sucker. At the same time, trees that had been cut and rejected were noted, as were the height and diameter of the stump.

The experimental design used was entirely randomized. The factor studied corresponded to land-use types: fields, fallow land and savannah, and the number of repetitions was 10 plots per land-use unit.

Induction of suckering

Excavations process targeting one to two superficial roots, with diameters ranging from 1 to 4 cm, were carried out at the base of each adult tree. A total of 540 roots were selected from 286 adult *Crossopteryx febrifuga* plants, most of which were multi-celled. Two root induction techniques were used: complete induction and partial induction by light root injury [23, 25]. A complete sectioning (Fig 1.a) of 270 roots was carried out using pruning shears and/or a knife, with the removal of a segment 2 to 4 cm long [25]. Of these severed roots, 90 were kept covered with their original soil, another 90 were left exposed to the "open air" at a distance of 5 to 10 cm from the induced root, and the last 90 were wrapped in aluminium foil (Fig.1.c) [26]. At the same time, light wounds (Fig.1.b) were applied to 270 roots. Of these, 90 were covered with their original soil, 90 were exposed to the open air, and 90 were covered with aluminium foil, following the same procedure.



a b c

Figure 1: Sucker induction mode: full section (a), partial section (b) and full section covered with aluminium foil (c)

These light wounds, made with a knife, consisted in removing a segment 2 to 4 cm long from the upper half of the root, depending on its diameter [25]. The experimental design is a split-plot with three replications. The first factor refers to the type of induction, while the second relate the mode of root exposure. Each experimental unit comprises 30 induced roots, repeated three times.

Data were collected on a monthly basis, from the date of appearance of the first sucker to the end of the rooting experiment. Data were collected on the position of emergence of the induced sucker, whether proximal (close to the point of attachment to the mother plant) or distal (far from its point of attachment), the height of the suckers emitted, the number of leaves per sucker, the diameter of the sucker at ground level, and rooting and/or emancipation.

Data analysis

The data collected were subjected to an analysis of variance. Results are presented as means plus or minus standard deviations. Significant means were separated using the Duncan Multiple Range Test. The statistical program used for the analysis of variance is Statgraphics plus 5.0. Microsoft Office 2013 Excel spreadsheet was used to plot the graphs.

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RESULTS AND DISCUSSION

RESULTS

Natural regeneration of *Crossopteryx febrifuga*

Characterization analyses and excavations of *Crossopteryx febrifuga* root systems revealed a total of 330 adult individuals, mostly multi-celled of various ages, representing an average density of 12.22±7.96 individuals/ha. This density varies according to land-use unit. 67 seedlings were identified, representing a density of 4.18±2.00 seedlings/hectare, and 192 sprouts, representing a density of 8.34±5.47 sprouts/hectare. As for suckers, 36 were identified at the base of 30 mother trees, or a density of 1.85±0.67 suckers/hectare.

Natural suckers

Sucker density ranged from 1±0 suckers/ha in savannah to 2.37±1.18 suckers/ha in fallow land (Table 1). This observed variation is corroborated by the analysis of variance, which revealed a significant difference between the studied environments (0.0283 < 0.05).

The percentage of adult plants sucker ranged from 3.06±2.94% in savannahs to 31.98±29.82% in fields (Table 1). The number of suckers varied from 1 to 3. Analysis of variance shows a significant difference (0.0060 < 0.05).

Growth parameters of natural suckers

The average height of suckers varies according to the environment. It ranges from 57.39±11.22 cm in the fields to 74.75±29.10 cm in the savannahs (Table 1). However, this variation remains apparent, as the analysis of variance shows no significant difference between environments (0.3141 > 0.05).

The average diameter of suckers at ground level varied between environments, ranging from 1.80±0.45cm in the field to 2.70±0.31cm in the fallow (Table 1). No significant differences was found by the analysis of variance (0.0069 < 0.05).

The mean distance of suckers from the mother tree fluctuated from 110.16±12.77 cm in the field to 119.91±22.59 cm in the fallow (Table 1). Analysis of variance revealed no significant differences (0.7937 > 0.05).

Finally, the diameter of suckering roots varied from 4.64±1.04 cm in savannahs to 5.23±0.78 cm in fields (Table 1). Analysis of variance showed no significant difference between environments (0.6030 > 0.05).

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Table 1: Natural suckering in different land use units

Parameters/ land use system	Density of suckers	Diameter of suckers (cm)	Height of suckers (cm)	Distance (cm)	Sucker root diameter (cm)	Parameters/ Units land use
Savannah	1±0	3.06±2.94	2.64±0.59	74.75±29.10	119.91±22.59	4.64±1.04
Fallow land	2.37±1.18	13.97±10.85	2.70±0.31	70.71±11.84	114.66±28.64	4.85±0.98
Fields	2.2±0.83	31.98±29.82	1.80±0.45	57.39±11.22	110.16±12.77	5.23±0.78
Mean	1.85± 0.67	14.60±19.53	2.38 ± 0.45	67.61± 17.38	114.91± 21.33	4.90±0.93

Seedlings

Observations on *Crossopteryx febrifuga* seedlings show an overall average density of 4.18±2.00 seedlings/hectare. This density varies slightly according to the environments studied (Table 2). It ranges from 3.0±1.0 seedlings/hectare in the fields to 5.2±1.64 seedlings/hectare in the savannahs. However, analysis of variance revealed no significant difference between these environments (0.3233 > 0.05).

Growth parameters of seedlings

Average seedling height ranged from 48.22±6.37 cm in savannah to 64.45±16.64 cm in fallow (Table 2). Although these values showed some variation, analysis of variance revealed no significant difference between environments (0.4713 > 0.05).

The average diameter of seedlings fluctuated from 2.49±1.09 cm in the fallows to 3.17±0.21 cm in the savannahs (Table 2). Analysis of variance showed no significant difference between these environments (0.3707 > 0.05).

Table 2: Characteristics of wild boars according to land use units

Land use system	Density	Height (cm)	Diameter (cm)
Savannah	5.2±1.64	48.22±6.37	3.17±0.21
Fallow land	4.0±2.32	49.74±23.88	2.49±1.09
Fields	3.0±1	64.45±16.64	2.60±0.40
Mean	4.18±2.00	52.02±18.77	2.72±0.83

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Stump shoots

The density of stump sprouts varied according to the environment. It ranged from 5.87±2.47 shoots/hectare in the fields, to 12.0±7.43 shoots/hectare in the savannah (Table 3). Analysis of variance revealed no significant differences between these environments (0.0811 > 0.05).

Stump shoot growth parameter

Depending on the land-use unit, the average height of stump sprouts ranged from 42.71±7.96 cm in the fallows to 47.15±13.33 cm in the fields (Table 3). However, analysis of variance revealed no significant difference between these environments (0.6214 > 0.05).

The mean diameter of stump sprouts also fluctuated from 2.19±0.68 cm in the fallows to 2.62±0.27 cm in the fields (Table 3) despite these observations the analysis of variance did not indicate significant variations (0.2131 > 0.05).

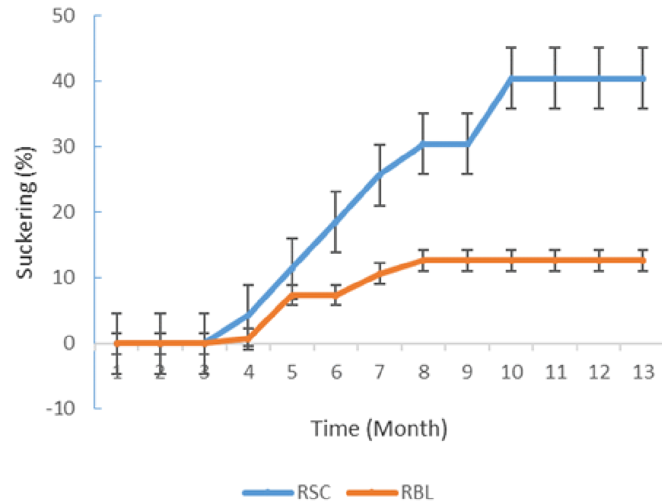
Table 3: Characteristics of stump shoots according to environment

Land use system	Shoot density	Height (cm)	Diameter (cm)
Savannah	5.87±2.47	47.15±13.33	2.62±0.27
Fallow land	7.62±4.43	42.71±7.96	2.19±0.68
Fields	12.0±7.43	43.49±4.75	2.48±0.34
Mean	8.34±5.47	44.49±9.32	2.42±0.49

Suckering induction

Effect of induction type on suckering rate

The first suckers were observed four months after root induction. Thirteen months after induction, completely section roots showed a significantly higher suckering rate (40.47 ± 24.82%) than roots those of the partial section (12.66± 6.41%) (Fig 3). The analysis of variance indicates a significant variation (0.0363 < 0.05).

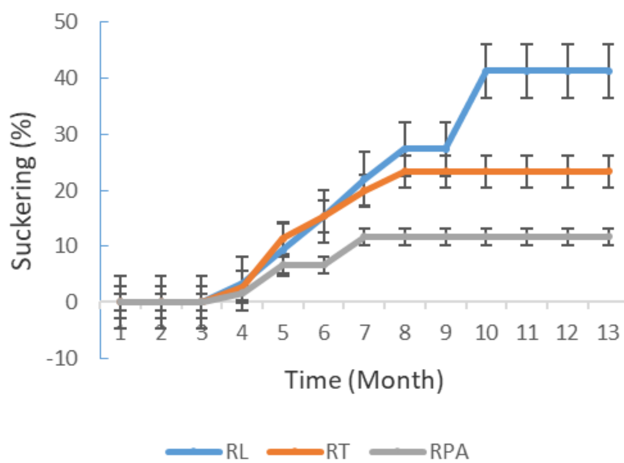


RSC= root completely severed, RBL= root slightly wounded

Figure 3: Influence of induction mode on suckering rate evolution

Influence of root exposure mode

Roots exposed to the open air (41.33 ± 32.88%) showed a higher suckering capacity than those covered with original soil (23.33 ± 8.16%) and aluminium foil (11.66 ± 2.35%) (Fig 4). However, statistical analysis revealed no significant difference between the various root exposure methods (0.2762 > 0.05).



RL= Roots left in the open air, RT= Roots covered with original soil,
RPA= Roots covered with Aluminium foil.

Figure 4: Effect of exposure mode on suckering rate

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Effect of the induction type*exposure method interaction on root suckering

The suckering rate ranged from 8.33±1.67% for roots that had been lightly wounded and left in the open air, to 63.33±15.15% for roots that had been completely severed and exposed to the open air (Table 4). These variations are corroborated by the analysis of variance, which shows a significant difference (0.0337< 0.05). Roots that had undergone complete sectioning had a higher suckering rate than roots that had been lightly wounded. This result indicates that complete sectioning is a stimulator of sucker development in *Crossopteryx febrifuga*, and the open-air exposure mode is the best.

Table 4: Percentage of suckering as a function of induction mode and exposure type interaction

Induction mode	RT (%)	RL (%)	RPA (%)	Moyenne (%)
Complete section	27.77±3.14	63.33±15.15	10±0	33.7±6.09
Partial section	16.66±6.66	8.33±1.67	13.33±0	12.77±2.77

RL= Roots left in the open air, RT= Roots covered with original soil, RPA= Roots covered with aluminum foil.

Growth parameters of induced suckers

Influence of induction types

Crossopteryx febrifuga suckers from partially sectioned roots attained a a mean height of 61.81±20.19 cm, compared with only 42.24±7.51 cm for those from fully sectioned roots (Table 5). This difference was significant as confirmed by the analysis of variance, (0.0386 < 0.05).

As for the basal diameter of the suckers, a substantial variation was also observed. It varied from 2.18±0.49 cm for suckers derived from completely severed roots, to 2.27±0.69 cm for those derived from partially sectioned roots (Table 5). The analysis of variance did not reveal a significant difference (0.8034 > 0.05).

Finally, the number of leaves shows a remarkable disparity according to the type of induction. Suckers from fully severed roots produced an average of 7.65±1.82 leaves, compared to 11.52±2.68 for those from partially sectioned roots (Table 5). The analysis of variance revealed a significant difference (0.0135 < 0.05).

Table 5: Effect of induction type on growth parameters

Induction type	Height (Cm)	Diameter (Cm)	Number of leaves
Complete sectioning	42.24±7.51	2.18±0.49	7.65±1.82
Partial section	61.81±20.19	2.27±0.69	11.52±2.68
Means	52.02±13.85	2.22±0.59	9.58±2.25

Influence of exposure mode

The average height of *Crossopteryx febrifuga* suckers ranged from 38.72±14.22 cm in roots covered with aluminium foil to 56.54±15.65 cm in roots covered with original soil (Table 5). , Despite this fluctuation the analysis of variance showed no significant difference between exposure types (0.4738> 0.05).

Basal diameter ranged from 2.11±0.71 cm in suckers left in open air to 2.56±0.64 cm in suckers covered with aluminium foil (Table 6). No significant difference is revealed by statistical analysis (0.6580 > 0.05).

The number of leaves fluctuated from 7.39±0.72 in suckers formed from roots covered with aluminium foil to 9.64±2.64 in those left in open air and those covered with original soil (Table 6). Analysis of variance revealed no significant difference between the exposure modes (0.6501> 0.05).

Table 6: Effect of exposure mode on growth parameters

Exposure mode	Height (Cm)	Diameter (Cm)	Number of leaves
Roots left in the open air	48.93±18.92	2.11±0.71	9.64±2.64
Roots covered with original soil	56.54±15.65	2.19±0.39	9.64±3.73
Roots covered with aluminium foil	38.72±14.22	2.56±0.64	7.39±0.72
Means	48.06±16.26	2.28±0.58	8.39±2.36

Effect of induction*exposure interaction on growth parameters

The sucker height fluctuated from 28.66±0 cm for sucker from partially sectioned roots covered with aluminium foil to 72.51±5.18 cm in suckers from partially sectioned roots covered with original soil (Table 7). Analysis of variance showed a significant difference (0.0215<0.05). The induction type*exposure interaction significantly affected the height of *Crossopteryx febrifuga* suckers.

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The diameter at base level ranged from 1.98±0.21 cm for suckers obtained from complete sectioned roots and covered with the original soil, to 3.02±0 cm for those obtained completely sectioned root and covered with aluminium foil (Table 7). Statistical analysis showed no significant difference in the interaction of induction type*exposure method on sucker diameter at ground level (0.4447 > 0.05).

The number of leaves per *Crossopteryx febrifuga* sucker ranged from 6.88±0 in *Crossopteryx febrifuga* suckers from lightly wounded roots covered with aluminium foil to 12.99±0.22 in those from partially sectioned roots covered with original soil (Table 7). With variability established, statistical analysis indicates no significant difference (0.1848 > 0.05).

Table 7: Influence of induction*exposure interaction

Parameters /Induction-Exposure	Height (cm)	Diameter (cm)	Number of leaves
RSC / RT	45.89±5.04	1.98±0.21	7.40±2.45
RSC / RPA	48.78±0	3.02±0	7.9±0
RSC / RL	36.41±5.10	2.10±0.39	7.82±0.74
RBL / RT	72.51±5.18	2.50±0.27	12.99±0.22
RBL / RPA	28.66±0	2.11±0	6.88±0
RBL / RL	67.7±9.5	2.11±0.89	12.38±0.83
Means	49.99±4.13	2.30±0.29	9.22±0.70

RL= Roots left in the open, RT= Roots covered with original soil, RPA= Roots covered with aluminium foil RSC= Root completely severed, RBL= Root slightly injured

Rooting of suckers

In the natural *Crossopteryx febrifuga* suckers inventoried, only 10.78% of suckers developed their own roots, although they remained dependent to the mother tree (Fig 5). Of the induced suckers, none initiated their own root system after formation and remained connected to the mother tree.

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a b

Figure 5: Natural root suckers (a) that have formed their own adventitious roots and artificial root suckers (b) that have not.

Pole of sucker emergence

Induced suckers emerged more proximally (48.33%) than distally (7.5%). No observations were made on suckers emerging on both the proximal and distal poles.

DISCUSSION

The results indicate that the distribution of *Crossopteryx febrifuga* plants is not uniform across the different land-use units, reflecting significant variations in their ability to reproduce sexually by seed propagation and asexually by stump sprout and suckering. These observations confirm that natural suckering ability varies not only between species, but also according to environmental conditions. Anthropogenic effects are also significant. The results corroborate the observations of numerous authors [27,28, 29], who have documented the suckering phenomenon in this species. Natural suckering is often triggered by environmental stresses such as fire, drought, wind, altitude or flooding [28]. This adaptive plasticity enables some species to regenerate even under marginal ecological conditions. However, in *Crossopteryx febrifuga*, natural suckering rates remain low compared with other species. For example, *Diospyros mespiliformis* and *Sclerocarya birrea* show significantly higher suckering rates in the Sudano-Sahelian zone of Cameroon, reaching 36% and 49% respectively [23]. Some authors show rate of 7.14% for *Balanites aegyptiaca*, 14.77% for

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Sclerocarya birrea and 12.57% for *Ziziphus mauritiana* in fallow land in the Sahelian zone of Chad [30].

In the Guinean savannah highland of Cameroon, the suckering rates of *Ximenia americana* (3.47%) and *Lophira lanceolata* (17.83%) remain close to those observed for *Crossopteryx febrifuga* [5]. Species such as *Isoberlinia doka* and *Isoberlinia tomentosa*, studied in Togo, show much higher percentages, reaching 83% and 56% respectively in fields and fallows [31]. The same trend was observed in the present study, where field activities and those that existed in the fallow land led to the neo-formation of natural suckers. These interspecific variations highlight the importance of local conditions, particularly climatic and edaphic, as well as the genetic variability of species in their ability to produced sucker.

Sucker emergence distance is another key parameter that varies widely between species. In *Crossopteryx febrifuga*, this distance is relatively limited compared with other species. *Sclerocarya birrea* and *Diospyros mespiliformis* in the Guinean savannah hihglands of Cameroon show emergence distances of 1.7 m and 2.5 m respectively [24], while *Bombax costatum* reaches up to 15 m in Burkina Faso [32]. Some species, such as *Litsea glutinosa*, can generate suckers up to 25 m or more [33]. In Chad, studies have showed that sucker emergence distance ranged from 78.28±6.56 cm in savannahs dominated by *Ziziphus mauritiana* to 102.91±65.54 cm in fallows associated with *Sclerocarya birrea* [30]. These differences are influenced by factors such as root configuration, edaphic conditions and phytohormone transport capacity. Thus, the short emergence distance observed in *Crossopteryx febrifuga* may limit its effectiveness in colonizing surrounding areas.

Observations of seed propagation seedlings and stump sprouts also show significant variability between species and regions. In contrast to our results, studies conducted in Burkina Faso reported the absence of *Bombax costatum* seedlings or stump sprouts over an area of 500 hectares [32]. These results highlight the dependence of vegetative regeneration on both the species-specific trait and the degree of anthropization of the environment. With regard to seedling height, contrasting results have been reported regarding the comparative evolution of the belowground and aerial parts of *Faidherbia albida* seedlings and cuttings [34]. At 7 months, the authors observed a visible block effect on the heights of direct seedlings, however the effect was not statistically significant likely because of substantial measurement variability. Similarly, *Detarium senegalense* seedlings in the nursery attained mean height of 83.8 ± 2.28 cm after eight months in the nursery, and 137.33 ± 7.08 cm in the field, significantly higher than our results [35]. The presence of stump sprouts in *Crossopteryx febrifuga* suggests that this plant is regularly exploited by the local population, favouring a mode of regeneration adapted to anthropic disturbances. In Burkina Faso no significant difference in stump shoot height was observed eight months after a bushfire. on *Detarium microcarpum* shoots there was observed eight months after a bushfire between the burned plot and

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the unburned control plott [36]. In Chad, however, shoot and seedling density varied according to land-use unit [30]. These authors report a density fluctuating from 19.46±9.44 shoots/ha for *Sclerocarya birrea* in savannahs to 44.06±25.45 shoots/ha for *Balanites aegyptiaca* in fallows. Seedlings were 5.25±1.75 semi/ha for *Sclerocarya birrea* and 20.52±3.05 for *Balanites aegyptiaca*.

The low natural suckering rates and short emergence distances of *Crossopteryx febrifuga* underline the need for adapted management strategies to maintain this species in its natural habitat, particularly in ecosystems subject to high anthropogenic pressure. These results confirm the importance of environmental and anthropogenic trauma in stimulating vegetative regeneration mechanisms.

The results obtained on suckering induction show that complete sectioning of *Crossopteryx febrifuga* roots results in a significantly higher suckering rate than those observed in partialy sectioned roots. This finding can be explained by the increased intensity of the trauma, which appears to induce changes in the biosynthesis and redistribution of signal molecules and phytohormones, such as auxins and cytokinins [37]. These hormones play a crucial role in meristem stimulation and vegetative regeneration. The results obtained are consistent with previous studies conducted in Cameroon [23]. The authors observed that complete sectioning is a more effective stimulator of sucker formation than partial section. The species studied, including *Balanites aegyptiaca* (36.7%), *Diospyros mespiliformis* (66.7%) and *Sclerocarya birrea* (70%), show a similar response to *Crossopteryx febrifuga*. Furthermore, observations by Fawa (2015) in Cameroon [38] confirm the effectiveness of complete sectioning for species such as *Ximenia americana* (86.67%), *Lophira lanceolata* (69.99%) and *Vitex doniana* (60.0%). These results underline a recurring pattern whereby the major trauma induced by complete sectioning favors the mobilization of the biological resources needed for regeneration. In Chad, complete sectioning of *Ziziphus mauritiana*, resulted in a suckering rate of 67.22%, substantially higher than the 15% induced by partial section (15%) [15]. These observations, made in diverse ecological contexts, suggest that complete sectioning acts as a universal trigger for regeneration mechanisms in several woody species of arid and semi-arid zones.

Results obtained on traumatized roots, depending on their mode of exposure (original soil, open air, aluminium foil), show significant variations. Roots exposed to open air show faster sucker development, which could be attributed to increased migration of growth hormones from soil-covered areas to exposed parts [5]. This hormonal redistribution, favored by specific environmental conditions (oxygenation, thermal fluctuations), would stimulate the activation of lateral meristems and initiate sucker growth. In contrast, foil-covered roots, deprived of gaseous exchange and light, show a considerably reduced capacity for regeneration.

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The results obtained on growth parameters highlight the significant impact of induction type on the growth of *Crossopteryx febrifuga* suckers. Sectioned roots promote increased growth, as demonstrated by height, basal diameter and number of leaves [15]. These observations may be explained by the fact that complete root sectioning may stimulate hormonal mechanisms, such as increased production of cytokinins and auxins, responsible for sucker regeneration and growth. Partially sectioned roots, on the other hand, appear to limit the physiological response required for optimal growth. Less invasive induction may not be sufficient to trigger favourable systematic responses, leading to reduced growth. These results underline the importance of the type of root injury in the suckering process [39].

Talking about the poles of sucker emergence, results similar to ours have been reported by several authors. In Chad, *Ziziphus mauritiana* suckers emerged more proximally (73%) than distally (28.3%) [15]. Similarly, in northern Cameroon, they report higher emergence rates of proximal suckers (74.34%) than distal suckers (25.66%) in *Balanites eagyptiaca, Diospyros mespiliformis* and *Sclerocarya birrea* [23].

With regard to sucker rooting, results similar have been reported for *Maerula crassifolia, Ximenia americana* and *Lophira lanceolata*, in which young suckers fail to develop new roots [5,40]. Natural (2.07%) and artificial (4.05%) suckers of *Ziziphus mauritiana* developed their own root system while remaining connected to the mother trees were reported in Chad[15]. Also in Chad, a rooting rate for natural suckers of *Balanites aegyptiaca* (27.32%), *Sclerocarya birrea* (30.50%) and *Ziziphus mauritiana* (37.27%) were reported in the Sahelian zone [30]. For the suckers which did not root, the technique described by these authors consisting of rolling the root with soil before covering it with aluminium foil will be tested in the near future. This domestication technique will stimulate sucker rooting and encourage farmers to vegetalize their homegardens and landscape *in situ*. Suckers of some species in tropical and Mediterranean regions become independent very early on, including *Quercus ilex, Detarium microcarpum* and *Bridelia ferruginea* [33]. The master of rooting and severance will permit to vegetalize the landscape of the area.

CONCLUSION

At the end of this study, it emerged that the distribution of *Crossopteryx febrifuga* plants is not uniform across the different land-use system, reflecting significant variations in its ability to reproduce sexually by seed propagation and asexually by stump sprout and suckering. Complete sectioning revealed a high suckering rate compared with partially sectioned root. Roots exposed to the open air showed faster sucker development than those covered with the original soil and aluminium foil. In the long term, further research could explore specific interventions, such as the introduction of growth regulators or habitat management, to enhance the regeneration capabilities of this species.

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