Assessing the Natural Regeneration Potential of *Senegalia senegal*by rejection in Chad : Implications for Sustainable Management

Abstract

The study of the potential of natural regeneration assisted by weaning of white gum was carried out in Mandalia, a locality located about 50 km from N'Djamena and its surrounding area. Inductions of shoots by weaning were carried out at two sites, one a *Senegalia senegal*Park and the other a grazing area. In the *S. senegal* parks, most of the shoots were underground. On the other hand, on the grazing land, most of the shoots were stump shoots. There was no significant difference between the number of shoots in the *S. senegal* park and in the grazing land. The survival rate of underground shoots at weaning showed a low value of less than 25%. In the Acacia Park, the correlation between survival and shoot size was 80.28%. However, in the grazing area, the survival rate was 50.69%. These results show that the site does not significantly influence the fate of the weaned underground discharge. It is clear from this study that a sustainable management plan for *S. senegal* is urgently required. To this end, studies on varietal selection and domestication of *S. senegal* should be undertaken as soon as possible. Raising farmers' awareness of the need to protect offshoots in agrosystems and promoting assisted natural regeneration in agrosystems would also enable them to be conserved by local populations and gradually domesticated in the short term.

Keywords: *Senegalia senegal*, rejection, acacia park, Chad.

Introduction

Non-timber forest products (NTFPs) play an important role in improving the living conditions of people in rural areas where poverty is rife with an incidence of around 40.10% (INSD, 2015). These NTFPs include gum arabic, which is produced mainly in the Sahel and Sudan. It is a natural exudate harvested from the trunk and branches of trees in the Acacia family (Ngaryo et al.,2014, 2015). In Chad, traditional gum harvesting is based on anarchic collection, and no forecasts can be made from one year to the next due to the lack of a control structure capable of guiding the efforts of producer farmers to increase their production, and encouraging the constitution of buffer stocks capable of making up for the shortfall in merchandise between seasons (FAO, 2000). The gum trees grown in Chad, in particular Senegalia senegal and Vachellia seyal, form more or less extensive stands of varying density, either mixed or pure (Deppierre, 1969). At five years old, a gum tree can be bled, and will produce gum as regularly as the climate will allow for a dozen years (Abdou et al., 2013).It is only recently that Chad has become aware of the importance of this product for its national trade (FAO, 2000). The first exports only date from 1956-1957, with less than 60 tones controlled (Giffard, 1975). Current production is estimated at 12,000 tones (Jamin and Seiny Boukar, 2002). In Chad, *S. senegal*is found mainly in the Ouaddaï, Biltine, Batha, Salamat and Guéra regions (OSS, 2015; Melom et al., 2015; Ngarnougber et al. 2017). Drought years have allowed its range to shift southwards, particularly in Chari-Baguirmi, Lac and Kanem (Mbayngone et al., 2017). The droughts of the 1970s led to the decline of gum trees, a reduction in gum production, the weakening of the commercial structures set up for this purpose, and the abandonment of certain demobilised producers to private economic operators who were more voracious than ever (Carette and Gaverns, 1999). Recently, there has been a resurgence of economic interest and speculation in gum production (FAO, 2000). This has led to land disputes between natives and immigrants in certain favored areas.

White gum, *Senegalia senegal*, regenerates by seed with difficulty despite its abundant fruiting (Joke, 2000). According to Joke (2000), around 85% of the seeds that fall to the ground are destroyed before germination because of irregular and poorly distributed rainfall, competition from herbaceous cover and insect attacks. However, thanks to the phenomenon of natural vegetative propagation, large areas of land can be colonised. This dynamism is passed on through successive generations and can help combat erosion and desertification. Rejection can rejuvenate certain stands. The main objective of this study is to contribute to the domestication of *S. senegal*, with a view to optimal revegetation of the Sudano-Sahelian environment and rational use in agrosystems. The specific objectives are to (i) assess the potential for natural regeneration by budding; (ii) assess the ability of *S. senegal* to bud after induction.

Materials and methods

Presentation of the study area

The investigations were carried out in Mandalia, a rural sub-prefecture of Chari-Baguirmi located about 50km south-east of N'Djamena, between latitudes 11° 25' and 11° 52' North and longitudes 15° 00' and 15° 25' East (Figure 1). The climate is characterised by two contrasting seasons (a dry season from November to May and a rainy season from June to October). According to Aubreville (1950), such rainfall is characteristic of the Sudano-Sahelian environment, with isohyets ranging from 400 to 700mm. The average annual temperature is around 35°C, with variations between 10 and 45°C. hydromorphic soils-vertisols and the hydromorphic soils-holomorphic soils complex (OSS, 2015). The vegetation has three main physiognomic types, often closely intermingled (OSS, 2015):

- the steppe type, which is most common on arid sites for climatic or edaphic reasons;
- the savannah type, which occupies most of the "average" sites for the same reasons, where plant species such as *Ziziphus mauritiana*, *Mitragyna inermis*, *Vachellia nilotica*,*V. seyal*,*S. senegal* and *Bauhinia rufescens* thrive;
- the "prairie" type, always hydromorphic, which can be assigned to one or other of the 2 previous types depending on whether the grass cover consists mainly of annual or perennial grasses such as *Eragrotis avirensis*, *Sporoberolus* sp...

Depending on the topography, the following dominant species remain: *Hyphaene thebaica*, *Anogeissus leiocarpus*, *Balanites aegyptiaca*, *Ficus microcarpa*, *Combretum glutinosum*, *Guiera senegalensis*, *Vachhellia sieberiana*, *Tamarindus indica* and *Sclerocarya birrea*, found on sandy to sandy-loam soils in exposed areas. These trees make up the plant formations corresponding to tree savannas (Ngarnougber et al. 2017).

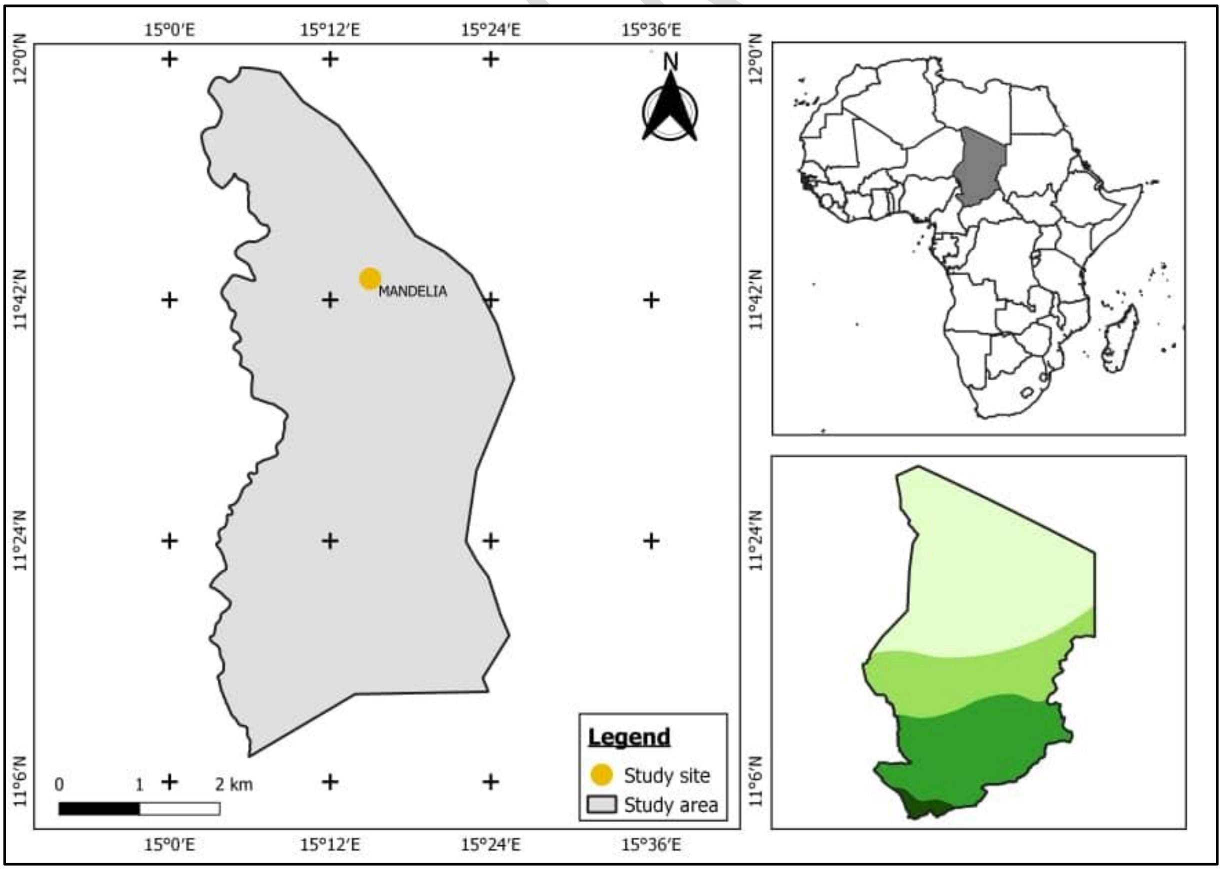

Figure 1: Map showing location of study area

Monographic study of *Senegalia senegal*

A deciduous shrub 2 to 6 m in height and, rarely, a tree, up to 8 m, *Senegalia senegal* is a spiny sarmentose tree in its young age (Arbonnier, 2019). Like most Acacias, it develops according to the Troll architectural model (Muthana, 1988). The acquisition of an orthotropic trunk is achieved by the oblique straightening of the plagéotropic axes (Vassal, 1998). The crown is a ball or a parasol. Twigs with monopodial growth have alternate spiral phyllotaxis and lateral sexuality (Diallo, 1994 ; Muller, 2004; Arbonnier, 2019). The biparipinnate, small leaves (1 to 8 cm long) have 3 to 8 pairs of pinnules. Each pinnule bears 7 to 25 pairs of leaflets. At the base of the petiole are 3 stipules, which are transformed into blackish spines that are grouped together and curved in the shape of hooks. The median spine faces the base of the branch, while the other two diverge laterally. The inflorescence is spike-like. According to Arbonnier (2019), their white to yellow flowers (3 to 12 cm) are all sessile and complete hermaphrodites. The yellow to brown fruit is a dehiscent, oblong, flat pod 2 to 19 cm long. It contains 3 to 6 flattened, reticulated seeds (Photo 1). *S. senegal* belongs to the Fabaceae superfamily and the Rosales order (Joke, 2000). Assoumane (2011) distinguishes five varieties, one of which has not been described. These are: var. *senegal*, var. *rostrata*, var. *kerensis*, var. *leiorhachis*. Each of these varieties is characterised by its floral axis, which may be glabrous or sub-glabrous (var. *leiorhachis* and var. *senegal*), or densely or sparsely pubescent (var. *kerensis* and var. *rostrata*).

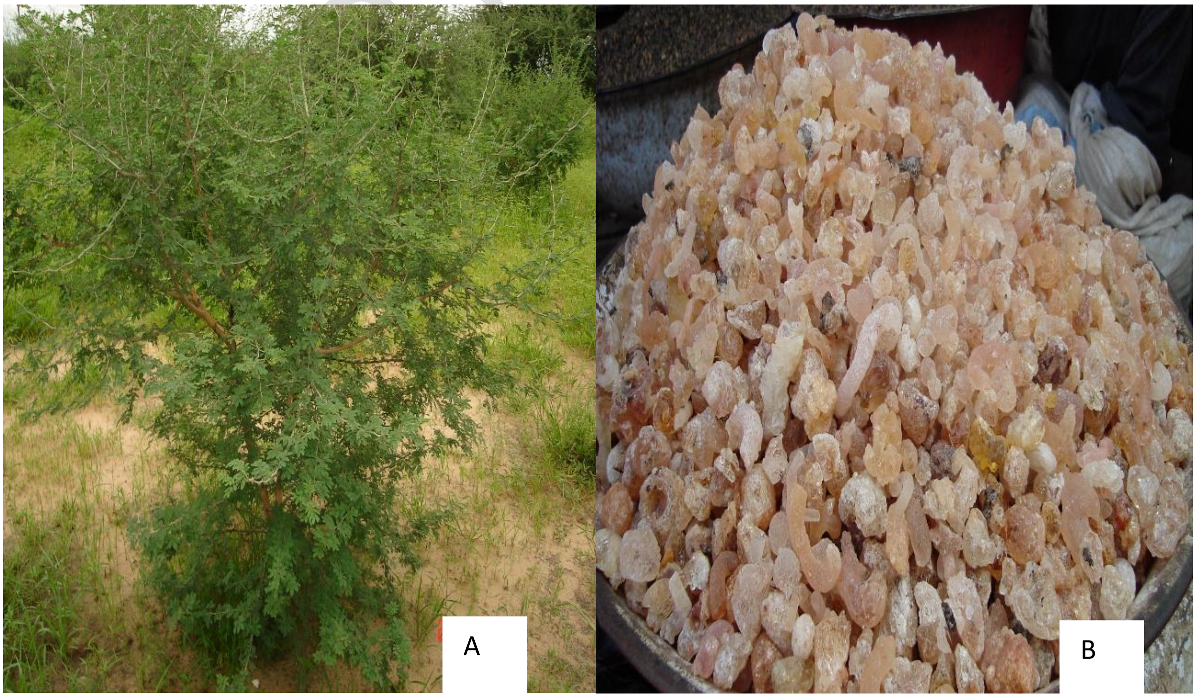

Photo 1: Young *Senegalia senegal* plant (A) and *Senegalia senegal* gum arabic (B)

Methodology

Induction of shoots by weaning

Induction of shoots by weaning was carried out at two sites: a *Senegalia senegal*Park more than 20 years old and a grazing area with Balanites aegyptiaca, Ziziphus mauritiana, Borassus aethiopum and Calotropis procera as the dominant species, in order to assess the ability of S. senegal to produce shoots. A total of 130 mother plants of *S. senegal* were inventoried for frequency assessment. 24 underground shoots on healthy trees, including 12 in a *S. senegal*Park and the other 12 in a grazing area, were monitored. The trees and shoots under study were labelled beforehand. Total of 12 underground shoots (one shoot per mother plant) were removed from each site. The experimental design was a 2 x 12 factorial block with 2 blocks (sites) and 12 replicates (*S. senegal* plants). Excavation was carried out using a baramine to ensure that we were dealing with a subterranean shoot that had not emerged naturally. The survival of freed shoots was noted after 30 days following weaning.

Evaluating the frequency of disking

To assess the frequency of budding, a double decameter was used to mark out a 10,000m² plot (100m x100m) at each site in which *Senegalia senegal* plants were counted. Those with shoots were identified and counted. The frequency of sprouting is assessed by the ratio of the number of plants with underground sprouts to the total number of plants counted.

Characterisation of sprouting

This was carried out on emerged shoots. The number of shoots per mother plant and the size of the largest shoot were taken at each site. The size of the smallest shoots was not taken into account (< 20cm).

Statistical analysis

Descriptive statistical methods, in particular comparison of means and percentages, analysis of variance and study of correlations, were used to interpret the results. Analysis of variance was used to assess the different quantitative variables between individuals. Relationships between characteristics were studied using correlation tests. The software used was MINITAB 14.

Results and discussion

Characterisation of rejection in *Senegalia senegal*.

Type of discharges

In *Senegalia senegal*Parks, most of the shoots encountered are underground (Photo 2). This implies that their appearance is due to endogenous and exogenous factors favourable to their development. This zone is also protected from animals and certains types of farming. However, on the grazing land, most of the sprouts encountered are stump sprouts. The high number of stump sprouts can be explained by the combined actions of man and livestock. Stump sprouts generally come from the cutting of a branch or trunk. On the other hand, underground sprouts exist on uncut trees, which confirms the work of Poupon and Bille (1979).

Photo 2: Stand of *Senegalia senegal* (A) and emerged underground shoots of *S. senegal* (B)

Rejection frequency

Of the 130 *Senegalia senegal* mother plants studied, we found that 40 had at least one shoot. The suckering frequency was 30.77%. This is comparable to the suckering frequency in certain leguminous plants (Bellefontaine et al., 2005 ; Kosma, 2005).

Number of shoots per plant

In the *Senegalia senegal* park, the average number of shoots per plant was 2.92. This figure is also 2.83 on the grazing land. This difference can be explained by the actions of livestock and the uncontrolled exploitation of firewood. The difference between the two averages is not significant.

Average shoot size

The size of the largest shoot was between 0.68 and 3 m, with an average of 1.35 m, in the S. *senegal* park, whereas in the grazed area it was between 0.32 and 2.30 m, with an average of 0.84 m. The difference between the two averages is significant. The difference between the two averages is significant. So we can say that the size of a reject depends much more on the environment and environmental conditions. To this we can also add the impact of human activity and livestock on this species.

Reaction of shoots to weaning in the *Senegalia senegal*Park

Table 1 summarises the results obtained on weaning of *Senegalia senegal* at site 1. The average number of shoots per plant was 2.92 ± 1.75 with a coefficient of variation (CV) of 60.13%. The average size of the largest shoots was 1.35 ± 0.65, with a CV of 48.13%. However, the correlation coefficient r between the number of shoots and the size of the shoots was 43.57%, which was not significant at the 5% threshold. On the other hand, it was clearly significant between size and survival rate (SR), with a value of 80.28%. This means that the survival rate is highly dependent on the size of the freed reject.

Table 1: Reaction of seedlings to weaning in the *Senegalia senegal* nursery

Produced rejets	Number of shoots per plant	Size of largest reject (m)	Rejections after weaning
P1	5	1,08	D
P2	2	0,68	D
P3	1	1,05	D
P4	3	1,28	S
P5	6	3,00	S
P6	2	2,50	S
P7	5	1,30	D
P8	2	1,10	D
P9	1	0,90	D
P10	5	1,18	D
P11	2	1,00	D
P12	1	1,15	D
Average	**2,92 ± 1,75**	**1,35 ± 0,65**	**TS = 25%**

D = death, S = survivor, SR = survival rate

The curves below show the curve of variation in the size of shoots in relation to the number of shoots (Figure 2) and the curve of variation in survival in relation to the number and size (Figure 3), the regression line between the number of shoots and size (Figure 4) and the regression line between size and survival of shoots (Figure 5).

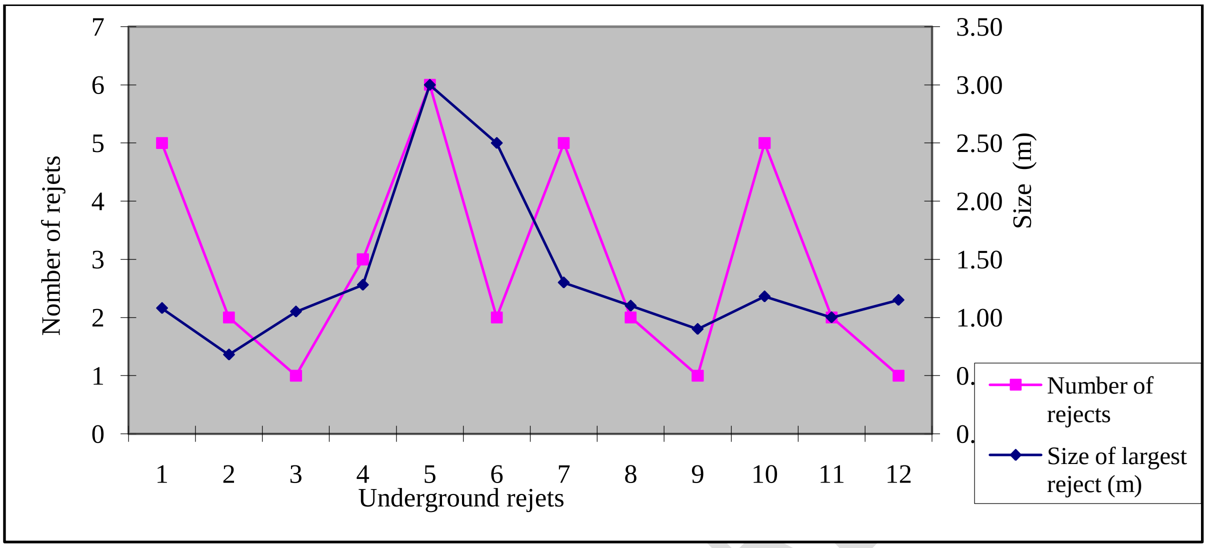

Figure 2: Variation curve for size versus number of shoots

At this site, the largest number of shoots was 6, with the largest size being 3m, and the smallest number was 1, with the smallest size being 0.68m.

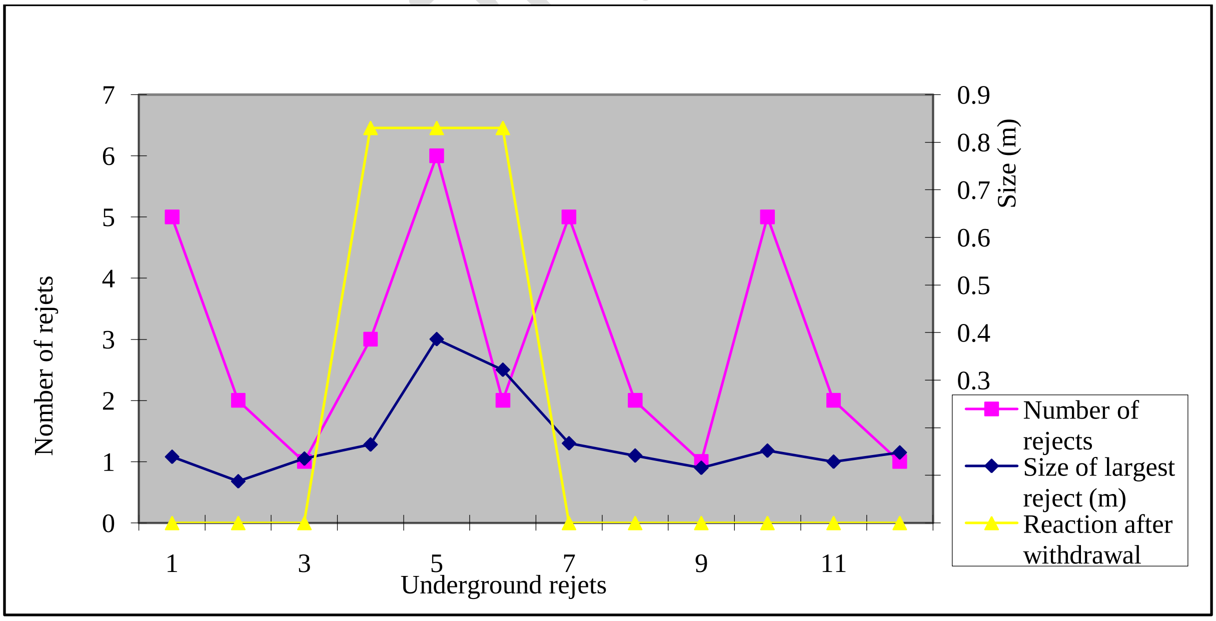

Figure 3: Variation curve for survival in relation to the size and number of rejections

Each survival corresponds to a rate of 0.83%. For the three survivors we have a survival rate of 25% at this site.

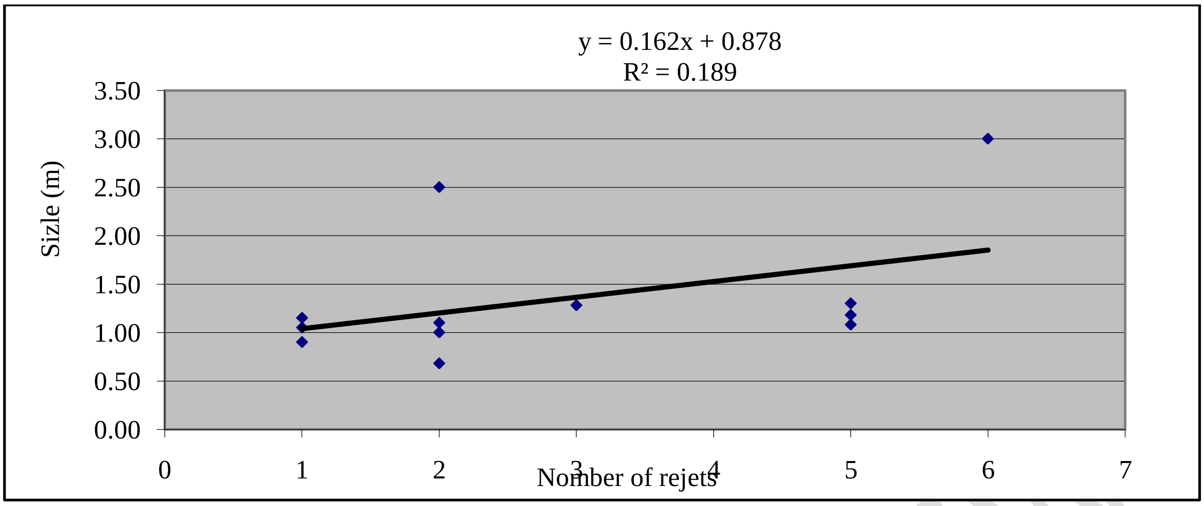

Figure 4: Regression line between number and size of rejects

The regression equation shows a positive correlation between the number and size of rejects (y =0,4417x-0,3895; R^2 = 0,6445). This implies a certain dependence between these two parameters.The correlation between survival and number is positive. In this site, survival is also a function of size.

Reaction of shoots to weaning in the grazing area.

Table 2 summarises the results of weaning at site 2. The average number of shoots per mother plant was 2.83 ± 1.46, with a CV of 51.59%. The average height was 0.84 ± 0.52 with a CV of 61.90%. However, the correlation coefficient between number and size is 10%, which is not significant at the 5% level, and the correlation between size and survival is 50.69%, which is also not significant at the 5% level. The survival rate (SR) at these sites was not size-dependent.

Table 2: Reaction of offspring to weaning in the grazing area

Postage-paid originating rejects	Number of shoots per plant	Size of largest (m)	Reaction after weaning
P1	2	0,70	D
P2	1	0,80	D
P3	3	0,60	D
P4	3	0,67	D
P5	4	0,30	D
P6	5	1,20	S
P7	2	0,32	D
P8	6	0,40	D
P9	3	2,30	S
P10	2	0,70	D

P11	2	1,20	D
P12	1	1,00	S
Average	**2,83 ± 1,46**	**0,84 ±0,52**	**TS = 25%**

D = death, S = survivor, SR = survival rate

The curves below show the variation in size versus number of shoots (Figure 5), the variation in survival versus size and number (Figure 6), the regression line between number of shoots and size (Figure 7) and the regression line between size and survival of shoots.

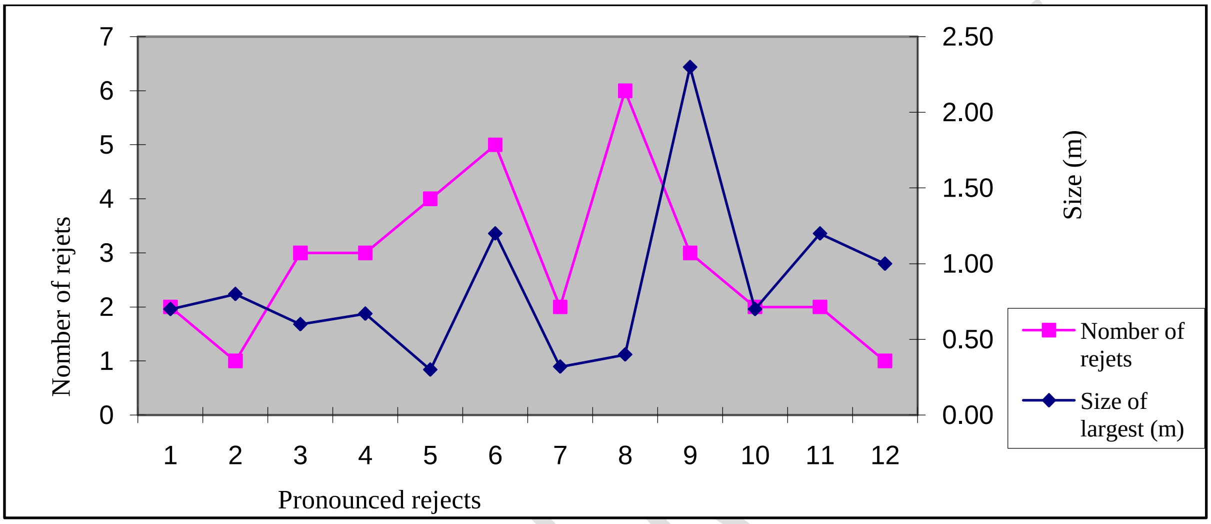

Figure 5: Variation curve for size versus number of shoots.

In the *Senegalia senegal*Park, the greatest number of shoots is 6, with the greatest height 2.30 m, and the smallest number is 1, with the smallest height 0.30 m.

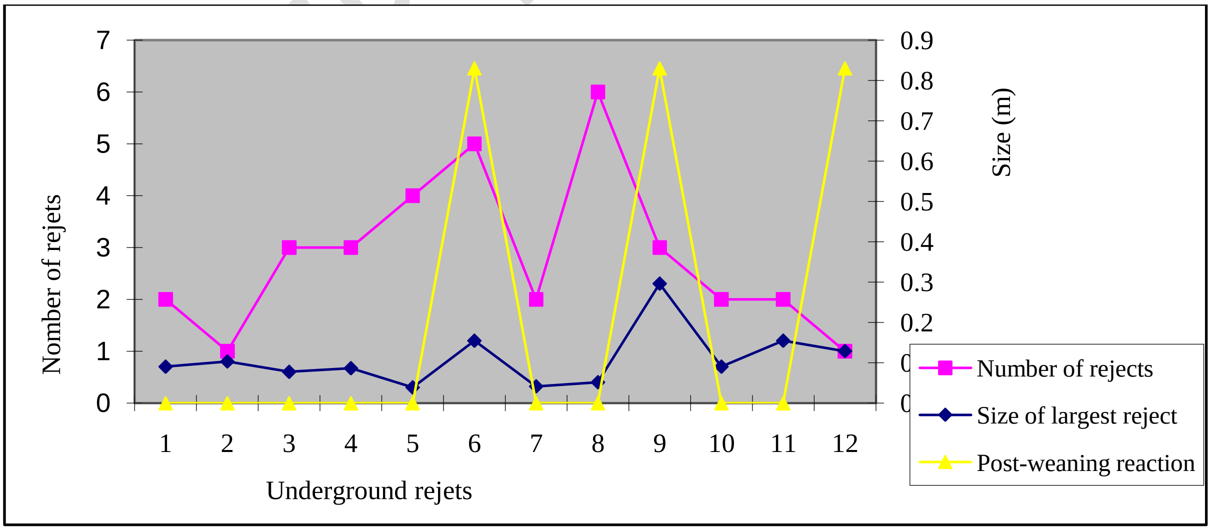

Figure 6 : Variation curve for survival in relation to size and number of rejections.

The survival rate for each corresponds to 0.833%, hence the yellow arrows. For the three survivals we have a rate of 25%.

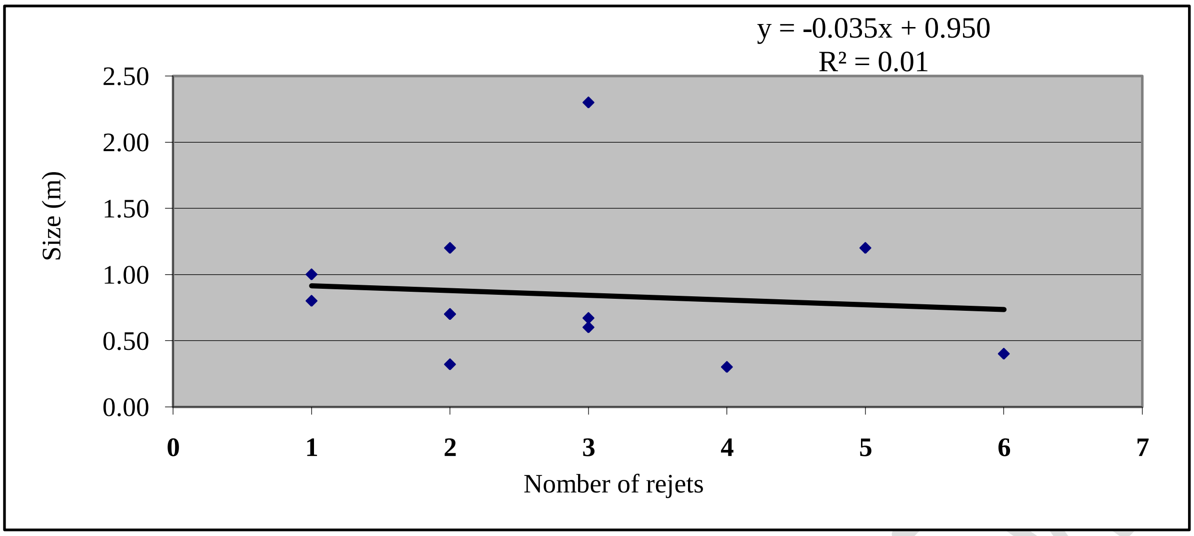

Figure 7: Regression line between size and number of rejects

The regression equation between size and number shows a negative correlation ($y = 0{,}4913x - 0{,}2097$; $R^2 = 0{,}5137$). This implies that in this site there is no dependency between these two parameters.The regression equation shows a positive correlation between survival and size. In this site, survival is a function of size.

Comparison of weaning responses at the two sites

The difference between the average number of offspring in the two sites was not significant ($P>0.05$). The average size of the large offspring was 1.35m in site 1, whereas in site 2 it was 0.84m. This difference is significant. However, the survival rate was 25% in both sites, lower than the average number of weaned offspring. This suggests that the survival rate of weaned shoots depends more on their size and, above all, their ability to form their own root systems.

Implication and endogenous species conservation strategies

In terms of endogenous conservation strategies, only adult shea trees benefit from efficient conservation. Very few juveniles are present due to the multiple anthropic and climatic pressures. Intensive use of a plant species without any prospect of domestication increases its vulnerability. In the long term, the species could become extinct as a result of excessive harvesting and increasing human pressure (Keirungi and Fabricius, 2005). Senegalia senegal is conserved in agrosystems. This demonstrates the contribution of agrosystems to biodiversity conservation in Chad, as illustrated by the work of Salako et al. (2014) and Idohou et al. (2014) in Benin.

Conclusion

Rejection appears to be a process of vegetative propagation whose value for the survival, development and repopulation of semi-arid zones cannot be underestimated, as seedlings and plantations are becoming insufficient and require considerable technical and financial resources. This is a credible alternative insofar as it is simple, economical and replicable, allowing the territorial extension of species with these aptitudes and densifying the plant cover. For livestock farmers, the cuttings provide fodder that is much more appreciated by their livestock. The bleeders find that the shoots can be bled and will produce gum arabic as much as the climate favours. Investigations into the reactions of weaned shoots have shown that the survival rate of weaned shoots compared with suckers is low, and the shoots have poor rooting ability.

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