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Natural and Artificial Regeneration of *Boswellia papyrifera* in the Blue Nile State – Sudan

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Abstract: *Boswellia papyrifera* is an important resource in the dryland of the Blue Nile State. However, its population is declining due to many biological and environmental factors. Moreover, there was hardly any regeneration of the species in its natural habitat. The objectives of this study were to count the new regeneration of seedlings, before and after rainfall, to assess the viability of *B. papyrifera* seeds in the soil seed bank, to detect the effect of soil types on seedlings' growth and to determine the optimum diameter and time of cutting. Natural regeneration surveys were carried out in the field by counting the young seedlings at different elevations before and after the rains. Soil samples from plots 2x2 metres were randomly collected. *B. papyrifera* seeds were sown in two types of soil mixes namely, 1 sand: 2 silt by volume; and in soil collected from the site where *B. papyrifera* trees are growing. Branch cuttings of one meter length and 4-5cm and 6-7cm in diameter, each, were taken at three different dates, namely first of April, mid of April and first of May and planted in the nursery. The results showed that *B. papyrifera* produced plenty of seeds that were stored in the soil seed bank. However, seedlings were almost absent after the dry season. A significant ($P<0.05$) difference was found between the mean number of seedlings growing at the foot of the mountain and the slope as compared to those growing on top of the mountain. A significant ($P\leq0.05$) difference was found between the mean height of seedlings raised in the two types of soils. There was no significant difference between the number of survived branch cuttings due to planting date and/or branch diameter, but large diameter cuttings showed better results. These results suggest that additional management interventions, such as artificial regeneration, to support early seedlings

survival or planting of large diameter cuttings at the proper time will positively affect the restoration of the species in its natural habitat.

Key words: *Boswellia papyrifera;* dry lands; seed bank; seedling

INTRODUCTION

Boswellia is one of the 17 genera described in the family Burseraceae, in the order Spindales (Vollesen 1989).The genus is composed of 20 species extending from the Ivory Coast to the Horn of Africa and southwards to northern Madagascar. It is also found in the Middle East as well as India. The centre of the diversity of the genus is located in the northeast tropical Africa within the dry low land areas, where more than 75% of the species are endemic (Vollesen 1989). Members of the genus are usually shrubs or small to medium trees, characterized by woody habit, with compound or slice leaves, and flowers with two whorls, 10 free stamens, a well-developed nectar disk and a syncarpous ovary (Cronquest 1981; Elamin 1990).

The species covers large areas in different parts of the Sudan, south ltitude 14ºN. In the Blue Nile State, it occurs in Jebel El Garri, Ingasana hills and Sudan borders with Ethiopia. In northern Kordofan, it grows gregariously on mountain slopes on shallow soils underline rocks (Saad 1979; Elamin 1990). In Western Darfur State it grows in Jebel Marra, Zalingi, Elgeneina and along the border with Chad (Khamis 2001). In South Darfur State it grows along the border with the Republic of Central Africa. In the Republic of South Sudan, it grows in Bahralghazal, Upper Nile and Equatoria (Thirakull 1984).

The natural regeneration of *Boswellia* in dry lands is seriously limited by wildfires, overgrazing and other anthropogenic matters. Suitable management intervention, such as conservation of the species, artificial regeneration securing survival of seedling or planting large diameter cuttings at the optimum time will positively enhance the restoration of the species in the natural habitat. The objective of this study is to test the viability of seeds contained in the soil seed bank under *B. papyrifera* and determine a suitable management practice to solve the regeneration problem of the species, by seeds and by branch cutting.

MATERIALS AND METHODS

Study area

The study was conducted in the Blue Nile State which is located in the south-eastern part of the Sudan, between Lats. 9°30′ and 12°30′ N, and Longs. 33°5′ and 35°3′E. The total area is about 38500 square kms. It is characterized by mountain series of which Ingassana is the main geographical feature which extends about 72 km (BNSI 2004).

Assessment of seed viability of the soil seed bank

Soil samples were collected during the dry season after the dispersal of seeds in a natural stand of *B. papyrifera.* Eight sample plots 2x2 m were randomly selected and arranged in eight replications. The soil sample plots were irrigated every two days to enhance germination; the emerged seedlings were counted to assess the viability of seeds contained in the soil seed bank.

Viability and germination of seeds

A composite of *B. papyrifera* seeds was collected in February, from 5 to 10 mature, untapped trees. Random samples were then taken to test the viability of seeds. The first viability test was conducted immediately after collection of the seeds. The second was conducted on seeds stored for one year in bags at room temperature. Each of the two tests comprised seeds treated by overnight soaking in water and untreated seeds. A randomize complete design was used for germinated seeds at two tests. At the first viability test, 800 seeds were sown at four replications; each one contained 200 seeds *i.e* 100 seeds for each of the two treatments, two treatments (soaked and dry seeds). This test of viability was also conducted after one year of seed collection. The germination test was conducted in the nursery of Damazin Tree Seed Center.

Survey of natural regeneration and seedlings assessment

A reconnaissance survey of *B. papyrifera* was done at Jebel El Garri (40 km east of Damazin) to collect information about the study site, including species density, age and stem diameter. The natural regeneration survey of the species was assessed by counting the young seedlings grown in the field before the onset of the rainy season and at the end of it. Five transects, each of which was 350 m in length, were laid out randomly.

Each transect accommodated 35 sample plots of 4x4m; the space between sample plots was 10 m; the area of sample plots on each transect was 0.056 ha and the total area surveyed was 0.28 ha for each period.

Assessment of the effect of soil type on growth of *B. papyrifera* seedlings

B. papyrifera seeds were sown in the nursery during the first week of March in two types of soils; namely 1 sand: 2 silt by volume and in a soil collected from a site where *B. papyrifera* trees are naturally growing. Each type of soil was represented by 40 bags (20 x 10 cm) replicated four times and arranged in completely randomized design. Plant height was recorded for two seasons (2008 and 2009) starting from the fourth week after sowing.

Effect of size of branch cuttings and planting date on survival of the species

Branch cuttings of one metre length and 4 to7 cm diameter, divided into two treatments.4-5cm and 5-7cm, were taken in three different dates; first of April, mid of April, and first of May. The cuttings were collected from trees showing vigorous growth and were planted in the same day in the nursery. A completely randomized design was used. The number of cuttings per each planting date was 40, *i.e.*, a total of 120 cuttings. The cuttings were planted in four replications, four rows spaced two metres apart and interspaced one metre along rows. The planting depth was 30 cm, and the upper end of each cutting was smeared with paint**.** The survival of cuttings was recorded weekly for five weeks during the rainy season starting from mid of May.

Data analysis

The data were analyzed using MSTATC and JMP statistical soft wares. The means were separated using LSD.

RESULTS

Assessment of the seed viability of soil seed bank

Only two seeds have germinated per sample plot. However, given the total area of sample plot which was 0.0032 ha, this indicated that the germinated seeds per hectare were 625 seedlings. Therefore, the viable seeds stock in the soil seed bank was very low.

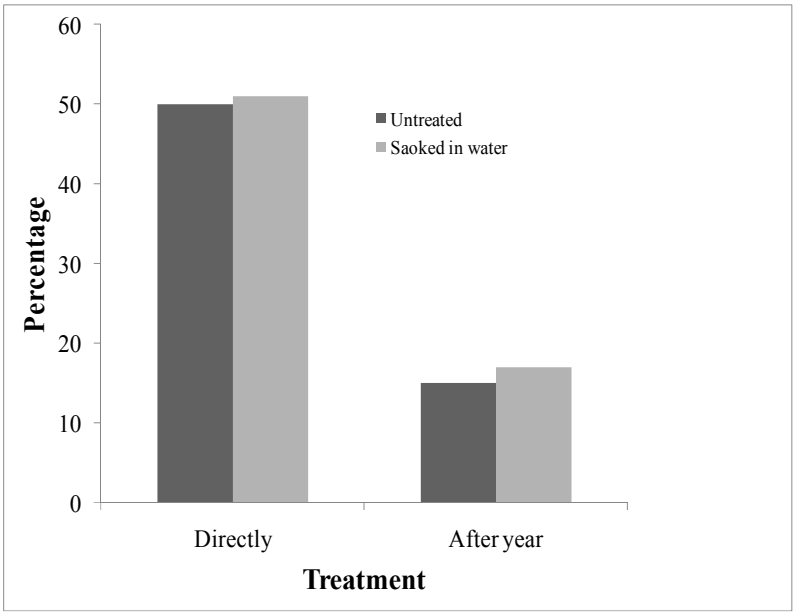

Fig. 1. Effect of seed storage and treatment on seed viability germination of *B.papyrifera*

Germination of seeds sown immediately after harvesting

No significant difference was obtained between the germination percentage of untreated seeds and the seeds soaked in water after three weeks from sowing. The germination percentage of the treated seeds was 51%, and that of the untreated ones was 50% (Fig.1)

Effect of storage on germination of seeds

The result of the two experiments revealed that the seed storage had a significant (t-Test, t=18.15; P< 0.0001) negative effect on *B. papyrifera* seed viability. Soaking seeds in water had no significant difference as compared to untreated seeds. The germination percentage of freshly collected seeds was 50% and that of the ones stored for one year was only 16.5% and14.5% respectively for treated and untreated seeds (Fig. 1).

Natural regeneration and seedlings assessment

The first assessment of the natural regeneration, before the rains, gave zero seedlings. The second assessment was carried out after the rainfall and the mean number of seedlings along each transect is presented in Table 1. The results showed that there was no significant difference between the mean numbers of seedlings in the first four transects. However, a significant difference (P<0.05) was found between the mean numbers of seedlings in the foot of the hill and slope as compared to the top of the hill. The number of seedlings per ha in the foot of the hill was 1000 and 1071 for transects number one and three, respectively. On the other hand, the number of seedlings recorded on the slope of the hill was 946 and 875 for transects two and four, respectively. The number of seedlings in the top of the hill was 571 seedlings per ha.

Table 1. Number of regenerating seedlings per hectare after the rainy season

Site	Mean number of seedling/sample plot	Number of seedlings/ha
Foot hill	1.6 a	1000
Slope	1.5 a	946
Foot hill	1.7 a	1071
Slope	1.4 a	875
Top hill	0.9 b	571
Mean	1.4	893
SE±	0.09	

Number of seedlings /transect =mean number of seedlings per sample plot x 35

Effect of soil type on growth of *B. papyrifera*

Highly significant (P<0.0001) difference between the mean height of seedlings raised in the two types of soils was recorded. In the first season, seedling height and growth rate were 4.2 cm and 0.15 cm receptively, for forest soil, for mixed soil they were 3.7 cm and 0.13 cm. In the second season, they were 6.5 cm and 3 cm for forest soil and 5.2 cm and 0.2 cm for mixed soils (Table 2).

Table 2. Mean height (cm) of seedlings and growth rate/week in the first and second seasons

Soil type	First season		Second season	
	Seedling height(cm)	Growth rate(cm)	Seedling height(cm)	Growth rate(cm)
Forest soil	4.2	0.15	6.5	0.3
Mixed soil	3.7	0.13	5.2	0.2
SE±	0.09		0.02	

Effect of planting date cutting diameter on survival of *B. papyrifera*

The cuttings planted at the first and mid of April showed better survival as compared to those planted at the first of May. Cuttings' diameter taken at mid of April gave 85% survival rate, compared to 70% and 53% for first of April and first of May, respectively (Fig. 2).

The diameter of branch cutting showed no significant effect on survival of the branch cuttings. However, the cuttings of thick (6cm-7cm) diameters produced a higher survival rate (58%) compared to cuttings of thin (4cm-5cm) diameters (42%) (Fig. 3).

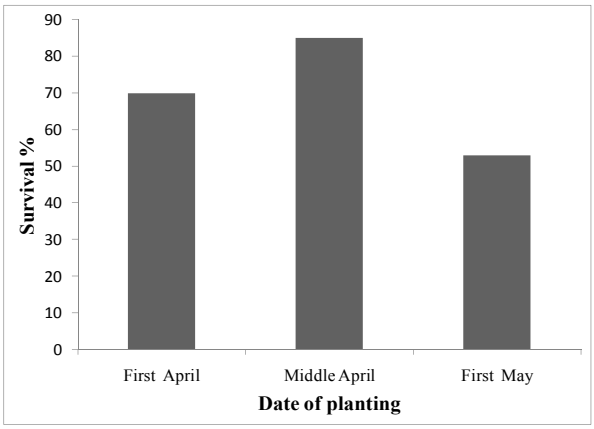

Fig. 2. Effect of planting date on survival of branch cuttings of *B. papyrifera*

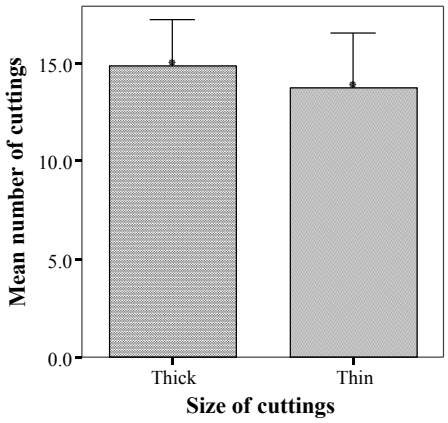

Fig. 3. Effect of diameter (cm) of branch cuttings on the survival of *B. papyrifera*

DISCUSSION

Assessment of seed viability of *B. papyrifera* in soil seed bank

The result indicated that *B. papyrifera* produced plenty of viable seeds to secure its natural regeneration, but there were some factors that hindered seed germination and their growth and development, (Abuelgasim and Abdalla 2008a; Thornner 1962). These are empty or sterile seeds, certain insects attack large quantities of seeds, grazing animals destroy the germinated seeds and seedlings through trampling. Moreover, Nomads, especially cattle herders, cut down the branchs of *Boswellia* trees to feed their animals in the late dry season, seedlings in areas inaccessible to livestock are threatened by annual wild fire and seeds as well as seedlings in steep areas are washed by rain water. All these factors hinder the natural regeneration of the trees. These factors interact singly or jointly leading to poor regeneration of *B. pap*yrifer.

In addition to the above mentioned factors many researchers have shown that intensive tapping of *Boswellia* trees for frankincense leads to production of large quantities of empty and non-viable seeds (Ogbazghi 2001).

Assessment of natural regeneration of *B.papyrifera*

In this study, the mean number of seedlings/ha was 893, which is less than what reported by (Abuelgasim and Abdalla 2008a) who indicated that the mean number of seedlings/ha was 2886 and 929 in July and September, respectively. On the other hand, Adam (1998) and Khamis (2001) found almost zero regeneration during the dry season in Gebel Marra area of western Sudan. In Ethiopia, Negussie *et al*. (2007) reported 8331 seedlings/ha of *B. papyrifera* surviving in enclosures and 3325 seedlings/ha in an open grazed woodland during the rainy season, while in dry season there were 28.2% (2344 seedlings/ha) and 22.4% (744 seedlings/ha) survived in the enclosures and grazing woodland, respectively. In the second season, the survival rate dropped to 18.5% (434 seedlings/ha) and 11% (82 seedlings/ha) in the enclosures and grazing woodland, respectively. Moreover, in Ethiopia Abeje *et al*. (2005) have reported only 85 to 175 seedlings per hectare in two sites.

Effect of soil type on growth of *B. papyrifera* seedlings

The mean growth rate of *B.papyrifera* seedlings ranged between 0.15 and 0.3 cm per week for the first and the second seasons, respectively. This is equivalent to growth rate per year of 7.7cm to 15.4 cm, provided that the conditions in the nursery are optimum. Though these rates were low, they were higher than those reported by (Abuelgasim and Abdalla 2008b).

Research on *B. papyrifera* in the same area as this study, (Khan 1962) reported that the growth rate for two seasons was generally low as compared to other species. He speculated that *B. papyrifera* seedlings remain in a stagnant situation without developing to saplings or mature trees for up to 10 years.

Effect of date of planting and diameter of branch cutting on survival of *B. papyrifera* branch cutting

The best time for planting branch cuttings was mid of April. This is in line with the findings of Khan (1967) who indicated that planting of branch cuttings should be during April and May, however preferable in April.

Furthermore, a relationship between the rooting of branch cuttings and diameter of the branch cuttings existed. Khamis (1997) and Khan (1967) reported that long and medium cutting diameter of 10 cm girth without irrigation gave high rate of sprouting and survival in the field at Jebel Mara.

CONCLUSIONS

- *B. papyrifera* produces plenty of viable seeds which are added to the soil seed bank that secures the natural regeneration of the species.
- Storage of seeds of *B. papyrifera* results in loss of seed viability.
- The natural regeneration of *B. papyrifera* after the rainy season is higher in the low lands compared to the top of the mountains.
- Low lands are best for natural regeneration of *B. papyrifera*.
- Large diameter branch cutting (6cm-7cm) can be adopted for vegetative propagation of *B. papyrifera*.
- Forest soil, obtained from the natural habitat of the species, is the best potting medium for producing *B. papyrifera* nursery stock.

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التوالد الطبيعي والإصطناعي لشجرة صمغ اللبان بولاية النيل الأزرق – السودان

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المستخلص: تعد شجرة صمغ اللبان من المصادر المهمة بولاية النيل الأزرق ، ولكن هنالك نقص فى كثافة أشجارها. ويعود النقص في كثافة الأشجار إلى عدة عوامل إحيائية وبيئية لذا فان تكاثر الأشجار فى مواقعها الطبيعية قليل جداً . الهدف من الدراسة حساب نمؤ البادرات الجديدة للشتلات قبل وبعد موسم الخريف ، حساب البذور الحية بمخزون التربة ، التربة المناسبة لنمو البذور ، ميقات زراعة العقل ، والسمك المناسب للعقل . أُجرى مسح بمواقع مختلفة للتكاثر الطبيعى قبل وبعد موسم الخريف . تم أخذ ثمانية عينات عشوائياً من سطح التربة تحت الأشجار بمساحة 2x2م ، وأيضاً جمعت بذور الأشجار من الغابة وتم زراعتها في نوعين من التربة ، الأولى خليط من الرمل والطمي بنسبة 2:1 والثانية من تحت أشجار صمغ اللبان . وأيضاً زرعت العقل بالمشتل بطول واحد متر وسمك 4-5سم و 6-7 سم في ثلاثة مواقيت مختلفة هى الأول من أبريل ، منتصف أبريل والأول من مايو .
أظهرت النتائج أن أشجار صمغ اللبان تنتج كميات وفيرة من البذور التى تخزن فى بنك البذور فى التربة ، إضافة إلى عدم وجود شتلات حية في موسم الجفاف ، وجدت إختلافات معنوية بين عدد الشتلات النامية في أسفل ومنحدر الجبل مقارنة بالتي تنمو بأعلى الجبل . وجدت اختلافات معنوية بين متوسط طول الشتلات التي زرعت في النوعين من التربة . لا توجد إختلافات بين نسبة العقل الحية وميقات الزراعة وسمك العقل ولكن العقل ذات السمك الكبير أعطت نتائج أفضل . خلصت الدراسة إلى أن الإكثار الإصطناعي لأشجار صمغ اللبان وزراعة العقل في مواقيت مناسبة تؤثر إيجاباً في الحفاظ على نوعية الأشجار في موقعها الطبيعي .