

Influence Of Site Factors On The Performance Of Natural Regeneration Of *Cupressus Lusitanica* In Beldong Forest

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Abstract— The study was carried out on *Cupressus lusitanica* plantations at Beldong Forest, Jebel Marra, Western Sudan to evaluate the performance of the natural regeneration of *Cupressus Lusitanica* as affected by various local site factors (Plateau, Slope and Depression). Growth and survival rates of natural regeneration were determined and analyzed to determine the most suitable measures to be adopted in such conditions in favor of natural regeneration compared to the nursery seedlings produced at relatively high cost.

For natural regeneration trials, the sample plots were selected from all over the forest using completely Randomized Block Design. The study showed that, site significantly affects the depth to which roots can penetrate, hence has significant effect on the growth and survival of *Cupressus Lusitanica* regeneration. The analysis showed that, there is an increase in organic matter content as moving from the top to the bottom of the plateau in depression areas. This has resulted in a good performance in height growth and rate of survival of the natural regeneration from ridges towards depression. The same holds for the old plantations. Natural regeneration of *C. lusitanica* in plateau occurs in patches and in very dense clusters, but mortality rate was very high, almost about 75% died because of shallow soil and high competition between seedlings. The study recommended that, seed-tree method for *C. lusitanica* in the area is the suitable method for the natural regeneration together with prescribed burning.

Index Terms— Competition, *Cupressus Lusitanica*, Depression, Natural Regeneration, Plateau, Slope. Seedling survival.

I. INTRODUCTION

In the Sudan, areas that are classified as mountainous include Jebel Marra in the west, Red-Sea hills in the East. Jebel Marra is the only site where soft wood tree species,

namely *Cupressus. Lusitanica* and *Pinus radiata* are planted. This study was carried out in Jebel Marra Mountain with a natural habitat recognized as a unique intact ecosystem and a national priority area for biodiversity conservation and sustainable management as was stated by [2]. In Jebel Marra Forest Circle (JMFC), reforestation has rapidly been gaining importance as the natural forests receded from the urban centers. Since reforestation with indigenous species has met little success in the high lands, reliance was placed on exotic Coniferous and *Eucalyptus* spp. *C. lusitanica* was introduced to Jebel Marra more than forty four years ago. It is the most important species for plantations in Jebel Marra, accounting for about 85% of the annual planting program of Jebel Marra Forest Circle. *Cupressus lusitanica* contributes about 90% of the sawn timber produced in Beldong sawmill [3]. The area planted annually by *C. lusitanica* in Beldong forest is very small due to the high cost of seedlings production, transportation and planting operations which are carried out during the short rainy season, when most of the people around the forest work on their own farms.

In 1985, *Cupressus Lusitanica* started to regenerate naturally within and under its canopy of different age classes. Regeneration involves both the physiological developments, which are inherited as well as external ecological factors such as interactions with other plants and animals, climate and disturbances like fire or landslide [6]. Natural regeneration can be described as renewal of forests by means of natural process of seed dispersal, germination and establishment [1]. Natural regeneration is a site-specific ecological process [4]. The appearance of the natural regeneration; according to [5], this could be due to the adaptability of the species to the site. The natural regeneration which occurs under canopy will eliminate the cost of seedlings production and increase the productivity of the species in terms of commercial thinning, if properly managed. The early plantations were established without previous, well designed trials concerning availability of land and water resources for nursery establishment. One of

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reasons of the study is to make use of this natural regeneration through possible manipulation of the local site factors and management strategies.

II. MATERIALS AND METHODS

For experimental layout, the forest was divided on the basis of altitude into three strata, namely, depressions (less than 2100 m), slopes (between 2100 and 2300 m), and plateau greater than 2300 m above sea level. In this study, Complete Randomized Block Design was used to locate blocks within a site and plots within the blocks.

In each stratum there were three blocks each of which was divided into four plots. Within each block three plots were located under the canopy of *C. lusitanica* and the fourth one was located on open area (no seeds). Figure 1 shows the

distribution of the sample plots over the three sites. Various factors were found to have direct influence on the location of the sample plots in the different sites. The variation in topography within each site was taken into consideration when locating the sample plots within each block. In site preparation, the gradient was also taken into account as it affects the amount of water in the soil and the stability of the soil itself in addition to distribution of the seeds in or on the soil. Different degrees of shading from mother trees were also considered as it may have influence on growth rate of the regeneration. The distribution of the old trees was not systematic (irregular), although the initial spacing of plantations in the forest was 2.5 X 2.5 m. This may be due to the improper selection system practiced when harvesting the forest.

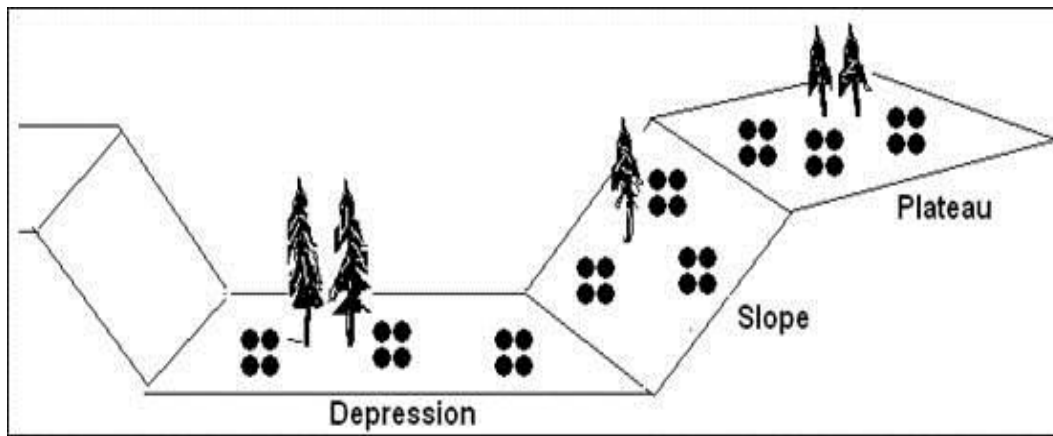


Figure 1: Layout of regeneration sample plots in Beldong Forest

A Total of 36 permanent sample plots (six meter radius (0.01 ha. area each) were located to cover the whole forest with 12 sample plots in each stratum. The four sample plots selected in each stratum were located together as a cluster so that each stratum was covered in terms of age, canopy closure and bare land. These clusters were then treated as follows: the first sample plot was located on bare land, where soil preparation was carried out through clearing, ploughing followed by seed broadcasting; this sample plot was denoted as A₁. The other three sample plots were located under canopy of *C. lusitanica* plantation with following treatments. Sample plot A₂ received the same type of treatment given to sample plot A₁. For sample plot A₃, seed broad casting was done after superficial clearance, while sample plot A₄, was demarcated without any treatment (controlled sample plot). The above treatments were replicated three times in each stratum as in Table 1.

Soil analysis was carried out in the experimental area to determine the controlling factors affecting the growth of the seedlings. The experiment was conducted at the beginning of the rainy season in June with the same amount of seeds in

each sample plot. The variables recorded in each sample plot were germination time, total survival of seedlings, mortality and total heights of 20 seedlings in the first and the second seasons.

Table 1
Experimental sample plots

Stratum	Treatments			
	A ₁	A ₂	A ₃	A ₄
Plateau	P ₁ A ₁	P ₁ A ₂	P ₁ A ₃	P ₁ A ₄
	P ₂ A ₁	P ₂ A ₂	P ₂ A ₃	P ₂ A ₄
	P ₃ A ₁	P ₃ A ₂	P ₃ A ₃	P ₃ A ₄
Depression	D ₁ A ₁	D ₁ A ₂	D ₁ A ₃	D ₁ A ₄
	D ₂ A ₁	D ₂ A ₂	D ₂ A ₃	D ₂ A ₄
	D ₃ A ₁	D ₃ A ₂	D ₃ A ₃	D ₃ A ₄
Slope	S ₁ A ₁	S ₁ A ₂	S ₁ A ₃	S ₁ A ₄
	S ₂ A ₁	S ₂ A ₂	S ₂ A ₃	S ₂ A ₄
	S ₃ A ₁	S ₃ A ₂	S ₃ A ₃	S ₃ A ₄

Where: P = plateau, D = depression, S = slopes

III. RESULTS AND DISCUSSION

Effect of site and treatment on survival of Natural Regeneration

On the three sites of the study area [plateau (P), slope (S), and depression (D)], the number of germinated seedlings was found to vary from one site to another. Analysis of Variance (ANOVA) and the pair comparison according to Duncan Multiple Range Test (DMRT) were used to separate the difference between them (Tables 2 and 3). It is clear from the results that the total number of seedlings in six months period was higher in the plateau site compared to the other two sites. The average survival per plot was 626, 217 and 51 seedlings in the sites of plateau, slope and depression respectively. The survival in plateau was significantly different from that of slope and depression; whereas the difference between slope and depression was not significantly different at $P \leq 0.05$. The high density of seedlings in plateau site may be due to the occurrence of seeds in clusters which caused by wind and

water movement and also due to the topography of the site.

There was a gradual decrease in the number of seedlings of *C. lusitanica* from plateau to depression over slope, which might be due to the topography of the different sites in relation to the stability of the seeds on / or in the soil. The plateau is flat to some extent especially in the center, which forms a suitable media for the stability of the fallen seeds mostly in cluster form. As such, the seedlings were found in high densities. Such high densities, on the other hand, are to be taken as a disadvantage as it leads to high competition for survival among the seedlings themselves and between them and the other weeds. Most of the dead seedlings in the plateau site were found erect in their original normal form, which gives an indication of limited effect of water run-off and other disturbing factors. In contrast, seedlings inspected in the sites of slope and depression were found to be fewer in number compared to those of plateau, but were healthier and better distributed.

Table 2
Effect of Site and Treatment on Survival of Seedlings after 6 months

Source of variation	DF	MS	F	P-Level
Site	2	680913.5	4.236854*	.029232
Treatment	3	79925.9	.497324	.688291
Interaction	6	99642.3	.620005	.712120
Error	20	160712.1		

* Significant at a probability level of 0.05

Table 3
DMRT for survival rates (According to Table 2)

Site	Mean number of seedlings
Plateau (ridge)	626 ^A
Slope	217 ^B
Depression (valley)	51 ^B

*Means sharing at least one letter in the superscript are not significantly different at probability level of 0.05

In plot P₁A₁ located on the bare land with normal soil preparation, the average number of seedlings per plot was 69 with good growth and healthy seedlings. Such performance might point to the soil preparation as a controlling factor. The few seedlings per plot could be related to the scarcity of seeds since the plots were located in bare and open land (not under canopy). The sample plot P₁A₂ which was treated as plot P₁A₁, has an average survival of 877 seedlings, with approximate spacing of 24 cm. The average survivals in plot P₁A₃ and P₁A₄ were 727 and 646 seedlings respectively, which were not

significantly different at $p \leq 0.05$. The *C. lusitanica* natural regeneration was very dense (> 600) and stunted after six months from starting of the experiment.

Tables 4 and 5 show the effect of site on survival of *C. lusitanica* regeneration (saplings) after 12 months (second season). The effect of site on survival has kept the same trend as that of the first six months (first season). There was a decrease in number of saplings per plot because of mortality due to perhaps high competition between the saplings.

Table 4
Effect of Site and Treatment on Survival of *C. lusitanica* after 12 months

Source of variation	DF	MS	F	p-level
Site	1	16864.12	5.784629*	.033207
Treatment	3	2412.02	.827356	.503868
Interaction	3	3037.66	1.041958	.409270
Error	12	2915.333		

* Significant at probability level of 0.05

Table 5
DMRT for survival rates (According to Table 4)

Site	Mean number of seedlings
Slope	81 ^A
Depression	18 ^B

*Means sharing at least one letter in the superscript are not significantly different at probability level of 0.05

Effect of site and treatment on height growth

Tables 6 and 7, show the effect of site and treatment on height growth of six months old *C. lusitanica* natural regeneration. Site has significant impact on height growth, where the average heights were 5 cm, 8 cm and 8 cm in plateau, slope and depression respectively. This might reflect the depth to which the roots can penetrate into the soil. It

could also be related to variation in soil organic matter contents among the different sites. Proceeding from plateau to depression through slope, there was an apparent increase in site quality; which may explain the observation that the average heights in slope and depression were not significantly different at $p \leq 0.05$.

Table 6
Effect of site and soil work on height growth of *C Lusitanica*

Source of Variation	DF	MS	F-Cal.	p-level
Site	2	37.79459	6.845295*	.005435
Treatment	3	14.41433	2.610700	.079725
Interaction	6	5.43082	.983621	.462113
Error	2	5.521250		

* Significant at probability level of 0.05

Table 7
DMRT for height growth rates (According to Table 6)

Site	Mean height (cm)
Slope	8.08 ^A
Depression	7.54 ^A
Plateau	4.88 ^B

*Means sharing at least one letter in the superscript are not significantly different at probability level of 0.05

Tables 8 and 9 show the effect of treatment on height growth of *C. lusitanica* saplings after twelve months (second season). The highest heights were recorded in plots "A₂" which were located under the canopy of the species in the different sites subjected to soil preparation. The highest value of height was found to be 28 cm in slope, followed by 22 cm in depression (A₂). The superior height growth in depression may

be due to soil improvement which facilitated the roots to penetrate deep into the soil, as the soil preparation improves the physical and chemical characteristics of the soil thus leading to availability of water and nutrients which may otherwise be inaccessible for both the delicate regeneration and the old trees as well.

Table 8
Effect of site and soil work on height growth after 12 months

Source of variation	DF	MS	F	p-level
Site	1	10.5967	.225160	.643654
Treatment	3*	186.5097*	3.962997*	.035503*
Interaction	3	41.1865	.875139	.481055
Error	12	47.06278		

* Significant at probability level of 0.05

Table 9
DMRT for height growth (According to Table 8)

Treatment	Mean height (cm)
2	24.10 ^A
1	18.30 ^{AB}
4	12.9 ^B
3	11.8 ^B

*MEANS SHARING AT LEAST ONE LETTER IN THE SUPERScript ARE NOT SIGNIFICANTLY DIFFERENT AT PROBABILITY LEVEL OF 0.05

The following site factors were observed on the three sites when assessing the growth of the natural regeneration of *C. lusitanica*: distance from the nearest ridge and valley, exposure, elevation above sea level, topographic concavity or convexity and slope. The high correlation of *C. lusitanica* regeneration growth and survival with slope and topography raises questions about the causality of the relationship. Obviously, neither of the two variables influences growth directly; but both are factors that are accompanied by a complex configuration of other factors, which affect the physiological processes of the regeneration of the species. In particular, both variables determine the depth of the soil and therefore, the depth to which roots are able to penetrate, the distribution of water on and within the soil, which in turn influences soil development and the availability of nutrients and other processes.

From the observations, site quality as mentioned before increases from the plateau (ridge), over the slopes to the nearby valleys, thus underlining the likelihood of parallel gradient in certain soil properties affecting growth of *C. lusitanica*. The close correlation that was found between the growth of natural regeneration of *C. lusitanica* on one hand and topographic concavity or convexity on the other hand (Figure 2), point out to soil moisture as the main factor limiting growth. However, soil moisture may affect growth through two mechanisms [7]; firstly poor growth may be a consequence of an absolute water scarcity on certain physiographic position, such as on the ridge and steep slopes, due to excessive surface water run-off, rapid internal drainage of the soil, shallow soil or other causes. Secondly, slow growth may be due to the indirect effect of soil moisture, such as excessive leaching of nutrients on the ridges or the impact of soil moisture on pedogenesis.

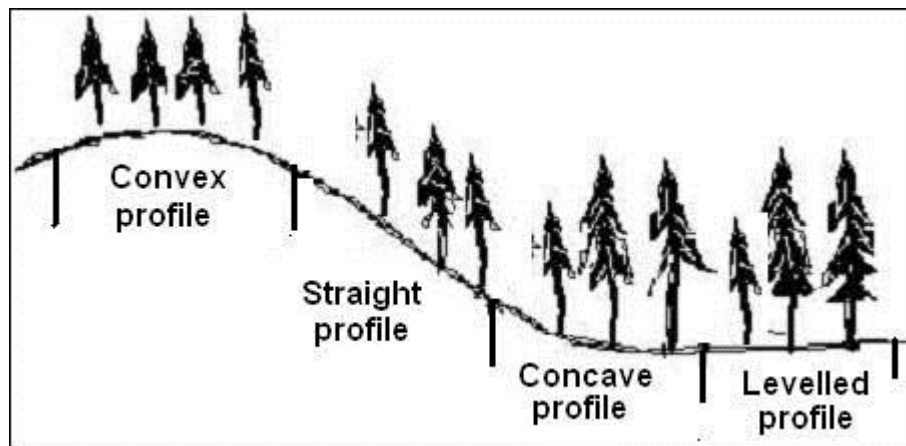


Figure 2: Topographic curvature of Beldong Forest land

IV. CONCLUSIONS

One of the most serious forest management problems in the Jebel Marra Forest Circle (JMFC) is the lack of a proper regeneration method for *C. lusitanica*. This is especially true for Beldong forest due to great variations in the topography of the area that complicate the process of seedlings production and transportation, hence the regeneration cost. The best alternative to the costly artificial regeneration system is the natural regeneration. This alternative is achieved through harvest-regeneration activity in which an appropriate number

of individual trees are left across the area to provide seeds for the production of next generation of trees. The results of this research showed that natural regeneration of *C. lusitanica* is not effective on bare land even with seeds broadcasting. However, the best choice in this case is the adoption of natural regeneration method under canopies of mother trees.

The seed-tree system requires planning and effort from a forest manager before harvest and not just after the cutting of trees. For the method to work well in the area, undesirable

vegetation must be controlled to allow the seedlings of *C. lusitanica* to establish. It is also important to remember that *C. lusitanica* is light-seeded species that requires the mineral soil to be exposed to have proper germination and seedling establishment. Desirable seed-trees should be selected carefully. Perhaps the easiest way to approach the problem of seed-tree distribution is to consider them in terms of rows that run perpendicular to the prevailing wind. The rows can be spaced approximately two times the height of the trees themselves, as the results showed that the maximum distant seeds can fall is twice the tree height. Prescribed burn before seed fall helps to reduce the debris load on the sites. Most of *C. lusitanica* forests in Jebel Marra could be successfully regenerated using this technique; however, the method should not be used in areas that flood frequently (depression) or in areas with steep slope and shallow soils.

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