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REFORESTATION OF LEBANON CEDAR (*CEDRUS LIBANI* A. RICH.) IN BARE KARSTIC LANDS BY BROADCAST SEEDING IN TURKEY

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Abstract

The objective of this article is to explain the application of broadcast seeding method with Lebanon cedar in bare karstic lands with shallow or medium soil depth and with bedrock creaks, which resulted from the destruction of Lebanon cedar since 5000 years in the Taurus Mountain range, Turkey. The idea of planting by broadcast seeding was first recommended by Boydak, in 1983 in Armutkırı, Anamur, Turkey. Based on his report, Turkish Forest Service prepared a reforestation project and broadcast seeding of Lebanon cedar was applied in 300 ha, in the fall of 1984, for the first time. The result was very successful and at the end of fifth growing season an average of one seedling per sqm (9000 seedlings per ha) was obtained. This application was considered a breakthrough and between 1984-2005 Turkish Forest Service has planted 40.457 ha Lebanon cedar by broadcast seeding in bare karstic lands in Taurus Mountains. Research results reveal that the amount of seeds with cone scales to be dispersed varied between 200 kg/ ha and 600 kg/ ha depending on ecological sites, exposures and surface soil tillage (between 10-20 cm; at compact soils). Considering research and application results, recommendations were made for broadcast seeding application of Lebanon cedar in bare karstic lands.

INTRODUCTION

Lebanon Cedar (*Cedrus libani* A. Rich.) is significant from the historical, cultural, aesthetic, scientific, and economic perspectives. It is presently found primarily in the Taurus Mountain range of Asia Minor, Turkey. Historical records indicate extensive and magnificent forests of Lebanon cedar also occurred in Syria and Lebanon; however, heavy cutting, burning, and goat grazing for the past 5.000 years have left only small populations in Syria and Lebanon [1,2,3,4]. Although human impacts have continued in Anatolia for thousands of years, the almost inaccessible topography of the Taurus Mountains has prevented Lebanon cedar from being totally destroyed.

Wood of Lebanon cedar is highly resistant to decay and atmospheric conditions, it has good stability, durable and has a peculiar smell and color. The wood is easily processed by hand and machine tools [5]. Because of these valuable wood properties, Lebanon cedar has always been in demand which caused destruction of its forests.

Lebanon cedar in the Taurus Mountains occurs generally between 800 and 2100 meter elevation, but it can be found at lower (500-600 m) and higher (2400 m) elevations as small populations or small groups and individuals. Some scattered populations can be found in other parts of Anatolia such as Sultanda ı-Afyon and in the Black Sea region (Çatalan-Erbaa and Akıncıköy-Niksar) (Figure 1) [6,7,8,9,4,10]. Presently there are 109.440 hectares of pure natural Lebanon cedar forests either in normal (71.452 ha) or degraded (37.988 ha) conditions [11]. But together with its mixed and/or extremely degraded stands and bare karstic lands occurred after degradation of Lebanon cedar, range of this species covers an area of more than 600.000 ha in Turkey [6,7,4].

Large reforestation efforts with Lebanon cedar are being undertaken both inside and outside its natural range for commercial, soil protection and aesthetic purposes because of its adaptability, high survival rate and unique wood properties either in Turkey [9,4,12,13] or other countries such as Italy [14,15], Iran [16] and Bulgaria [17]. Turkish forest Service has planted about 115.000 ha of Lebanon cedar till the end of 2005, inside (58.500 ha) and outside (56.500 ha) of its range.

In karstic lands with shallow or medium soil depth and with bedrock cracks, seeding (broadcast seeding; full seeding) has many advantages to planting, while in medium-deep or deep soil depth reforesting by planting can be preferable [8,9,4,18].

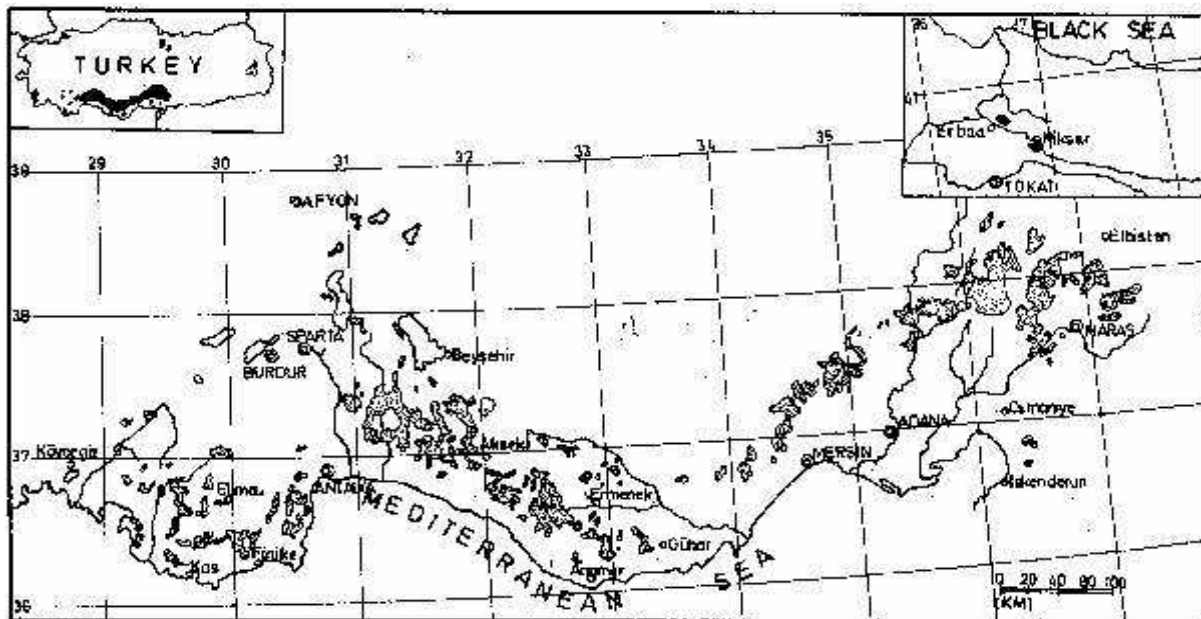


Figure 1. Natural distribution of Lebanon cedar in Turkey [46]

The first comprehensive reforestation project based on broadcast seeding in bare karstic lands was applied in 300 ha, in the fall of 1984 in Armutkiri, Anamur, Turkey [18,19]. As the result was very successful, broadcast seeding method was applied in large areas by Turkish Forest Service and between the years 1984 and 2005, 40.457 ha bare karstic lands were successfully planted.

The objective of this article is to explain the application of broadcast seeding (full seeding) method with Lebanon cedar on bare karstic lands in Taurus mountains range, in Turkey. Moreover, by considering research and application results, to make suggestion to restore and expand Lebanon cedar populations in immense bare karstic lands which resulted from the destruction of Lebanon cedar since 5000 years.

ECOLOGY OF LEBANON CEDAR

Soil

Forests of Lebanon cedar are found on different geological formations (sedimentary, volcanic and metamorphic) and different parent materials on Taurus Mountains, Turkey. But it is primarily found on calcareous (karstic) formations of the Mesozoic, Eocene, Miocene, Upper Cretaceous, Permian, etc. The parent rocks of these formations consist of crystalline, massive, black, soft, ordinary calcareous and marble [20,1,10,21,9,4].

The soils are generally shallow, medium, or medium-deep [22]. However, the soil's fertility is not attributable to the 20-30 cm depth of surface soils on karstic lands; many cracks between limestone blocks contain fine soil create physiologically deep soil [23]. The genetic soil types on the karstic areas where Lebanon cedar occur are rendzina [24], terra fusca [25], and terra rossa [21]. The soil texture is sandy loam, clayey loam, and loam; and the structure is granular at the top soil and block and coarse block at the subsoil. The soils have good drainage; but water holding capacity of the fine soil between the cracks is high [10]. The organic content varies between 1-4%. Content of CaCO_3 varies greatly. For example, the calcium carbonate content of reddish Mediterranean soils ranges between 1-3% and is over 50% on the phillites and soft limestone's and Neocene lake deposits, while the quartzite contain no calcium carbonate. The soil pH is slightly acid, neutral, or slightly alkaline, depending on condition of the leaching. There is a high base exchange capacity [10,4].

The absence of deep soils on the rugged terrain of this calcareous areas is not related to soil erosion [26,27,28,29]. Surface soil formation is very slow, because rainwater and snow melt penetrate immediately into the rock crack system and into deep rock layers. In this terrain soil is formed along the cracks and stratification surfaces of limestone [26,27,28,4].

The largest and most important karst region in Turkey is the Taurus Mountains, between the Mediterranean coast and Central Anatolia. This carbonate formation is nearly 200 km wide, and in some sections, the total thickness of the carbonate sequence is more than 1000 m. The high mountain ranges, sharp peaks, deep valleys, and narrow gorges give the region a very rough appearance. This region has one of the most complex karst circulation systems of all Mediterranean countries [30,4].

Climate

Lebanon cedar occurs at Supra-Mediterranean, Mountain-Mediterranean and Oro-Mediterranean zones on the Taurus Mountains facing seaside, where per humid, humid, sub-humid and semi-arid climatic conditions prevail [31,32,4]. At this general aspects of Taurus mountains its general distribution in semi-arid bioclimate is rather restricted as it can be seen on Table III of Quézel [31] study. Within the occurrences of Lebanon cedar at backwards of the Taurus Mountains and inner Anatolia sub-humid and semi-arid climatic conditions prevail, respectively. At inner Anatolia its populations are rather restricted and mostly in degraded conditions. The mean annual temperatures of the area ranges from 6 to 12°C. Mean July temperature is about 18 to 25°C, with an absolute maximum more than 30°C. Mean January temperature is between 0 to 5°C., with an absolute minimum 35°C. Mean yearly precipitation varies between 600 and 1200 mm. Summers are rainless. Duration of snow cover period ranges 1 to 5 months. Relative humidity during the growing season varies from about 40 to 60 % [10,33,4].

The east-west orientation of Taurus Mountain range forms a barrier between the Central Asia minor and Mediterranean regions. This barrier and the Mediterranean Sea account for the subtropical character of the southern side [34,9]. At the same time, the orientations of the mountains also influence the amount of precipitation occurring at different exposures.

Vegetation

Lebanon cedar vegetation in the Taurus Mountains occurs in two main vegetation types, the *Abieti-Cedrion* forests in the middle and east Taurus Mountains, and the *Lonicero-Cedrion* forests in the west Taurus Mountains [35,36,37]. Differential species of these community are tabulated in "Table 1". *Thlaspi catonicum-Cedrus libani* forest (eastern Taurus), *Quercus petraea* ssp. *pinnatiloba-Cedrus libani* forest (Amanos Mountains) and *Sesleria anatolica-Cedrus libani* forest (middle Taurus) are the associations of *Abieti-Cedrion* vegetation type.[36,37,4]. *Lonicera-Cedrion* type has two associations, which are *Allaria officinalis-Cedrus libani* forest and *Vicia cracca* sp. *Stenophylla-Cedrus libani* forest. [36,37,4].

Table 1. Differential species of *Abieti-Cedrion* and *Lonicero-Cedrion* (in general, drier than *Abieti Cedrion*) vegetation types [35, after Quezel *et al.*]

	<i>Abieti-Cedrion</i>	<i>Lonicero-Cedrion</i>
Trees	<i>A. cilicica</i> <i>C. libani</i> <i>A. hyrcanum</i> subsp. <i>Tauricum</i> <i>Sorbus torminalis</i> subsp. <i>Orientalis</i>	<i>C. libani</i> (local) <i>hyrcanum</i> subsp. <i>Sphaerocaryum</i>
Shrub	<i>Coronilla varia</i> subsp. <i>Libanotica</i>	<i>Lonicera nummulariaefolia</i> subsp. <i>Glandulifera</i>
Forbs	<i>Corydalis solida</i> subsp. <i>Tauricola</i> <i>Cyclamen cilicium</i> <i>Campanula psilostachya</i> <i>Asyneuma amplexicaule</i> <i>Brunnera orientalis</i> <i>Tanacetum cilicicum</i> <i>Cephalorrhynchus tuberosus</i> <i>Cicerbita brevirostris</i> <i>Scilla cilicica</i>	<i>Digitalis cariensis</i>

SILVICULTURAL CHARACTERISTICS OF LEBANON CEDAR

Lebanon cedar is a light-demanding species; however, it survives well in the partial shade when young and sometimes at tree stages between 30-70 years [38]. Research results revealed that Lebanon cedar is a drought resistant tree species [39,40]. Lebanon cedar seedlings develop rapidly growing tap roots while the stems grow slowly during early years. Stem growth generally increases after 4 to 6 years on karstic lands [18,41]. On the other hand, planted seedlings exhibited early rapid growth in some intensive plantations on fertile soils, outside its natural range [7,42]. Moreover, root regeneration was earlier and more abundant in Lebanon cedar seedlings which were preconditioned with restricted watering [43,4].

Lebanon cedar generally bears cone at about 30 years old in natural stands. Male flowers appear in July and elongate 3-5 cm in August, while female flowers can be seen in September. Pollination takes place in September or early October, depending on the elevation. The following year between April or May to June, conelets develop to normal cone sizes. Anatomical ripeness is reached in May, 20-21 months after flowering [44]. Opening of the cone scales begins in October, about 25-26 months after flowering. Seed dispersal begins at the end of November or December and continues throughout the winter [45,46]. Seeds of cones collected in August (23-24 months after flowering) from different provenances had germination percentages of 44 to 67% [46]. Good seed years have been reported as generally every 3 years [8,9,4] or 3 to 5 years [46].

REFORESTATION BY BROADCAST SEEDING WITH LEBANON CEDAR IN BARE KARSTIC LANDS

Background and research results of broadcast seeding with Lebanon cedar in bare karstic lands

As mentioned earlier, broadcast seeding has many advantages to planting when reforesting or afforesting bare karstic lands with shallow or medium soil depth and with bedrock cracks. When many seeds are dispersed in an karstic area with shallow or medium soil depth with bedrock cracks at least one or a few are able to elongate into cracks. By contrast, it is less likely that a planting seedling will be able to find and penetrate the cracks when planted at the usual planting spacing (1.5m by 3m) for Lebanon Cedar in Turkey. In medium-deep or deep soil depth reforesting by planting can be preferable.

The idea of planting by broadcast seeding method by Lebanon cedar in bare karstic lands with shallow or medium soil depth and with bedrock creaks was recommended by Boydak, in the summer of 1983 in Armutkırı, Anamur, Turkey, after his two years observations on Lebanon cedar ecosystems (Figure 2) [18]. He prepared a report which included details of the application of broadcast seeding method [8,18]. Mersin Forest Regional Directorate of Turkish Forest Service prepared a reforestation



Figure 2. The bare karstic land after the destruction of Lebanon cedar forest since many thousand years, where the broadcast seeding was applied, in Armutkırı, Anamur, Turkey (Photo: M.Boydak).

project about broadcast seeding of Lebanon cedar based on this report. This first comprehensive reforestation project was applied in the fall of 1984 in Armutkırı, Anamur, Turkey [18,19]. In following years, the area seeded was increased to about 1.000 hectares. Results showed the broadcast seeding method to be very successful, and this application was considered a breakthrough for reforestation of bare karstic lands with Lebanon cedar. (Figure 3 and 4).



Figure 3. At upper: 2 years old seedlings of Lebanon cedar after broadcast seeding in the same bare karstic land which is seen at Figure 2 in Armutkırı, Anamur, Turkey. Below: 4 years old seedlings of Lebanon cedar which successfully covered the bare karstic land at the same area in Armutkırı, Anamur, Turkey (Photo: M. Boydak).



Figure 4. 16 years old trees of Lebanon cedar which successfully covered the bare karstic land in the same area, in Armutkırı, Anamur, Turkey (Photo: M. Boydak).

The locality became an excursion point for the foresters. The method was then successfully applied on a large scale to other areas throughout the bare karstic lands on the Taurus Mountains which occurred after destruction of Lebanon cedar since 5000 years. Turkish Forest Service successfully planted 40.457 ha Lebanon cedar by broadcast seeding method between the years 1984-2005.

At Armutkiri, Anamur, Turkey, 133 kg of seeds with cone scales (about 13 kg pure seeds) per hectare were used (about 21 seeds per sqm) [8]. At the end of the fifth growing season, according to the measurements which were made at 274 sample plots (3x3 m) and were systematically distributed all over the area (174 sample plots at sunny slopes and 100 sample plots at shady slopes), an average of one seedling per square meter (9.000 seedlings per hectare) was obtained (Table 2). An average of 0.6 seedlings per square meter was obtained on sunny slopes (6.000/ha); and 1.4 seedlings per square meter on shady slopes (14,000/ha) [18,9,4]

Table 2. Average number of seedlings and average seedling height at the end of fifth growing seasons at sample plots of Armutkiri, Anamur, Turkey [18].

Exposure	Number of sample plots	Average number of seedlings		Average height of seedlings cm
		3x3m	m ²	
Sunny	174	5,6	0,6	23,1
Shady	100	12,8	1,4	22,4
Average	274	8,2	0,9	22,7

At the end of the fifth growing season the average seedlings height were nearly equal at sunny (23.1 cm) and shady (22.4 cm) slopes. The maximum height in ample plots was 98 cm; in the seeded area, in some places with deep soil 150-200 cm seedling height were also measured [18].

In karstic areas rapid shoot growth and height differentiation begin when the seedlings are 4-6 years old. The relatively slow growth of seedlings in bare karstic lands in Armutkiri, Anamur, Turkey, was caused by compact soil conditions and/or configuration of bedrock crack systems. The height of the trees achieved up to 8 meters, at the end of the 16 th growing season (Figure 4). But depending on the soil conditions and bedrock crack systems the height of trees were rather small in some places in the field.

According to his observation, Boydak (1996) suggested between 25 kg / ha and 50 kg / ha Lebanon cedar seeds (about 250 kg/ ha and 500 kg/ha seeds with cone scales) in broadcast seeding in bare karstic lands, depending on the locality, environmental conditions, seed weight (depending on seed origin), and predation potential of insects and birds [9,4]. Moreover, studies suggest that about twice as many seeds are needed on sunny exposures compared to shady ones[18].

Special research works are necessary to find out the amount of seeds to be dispersed in bare karstic lands considering ecological sites, exposures ect., and loosening of compact soils with suitable equipments when needed. Recently valuable results were obtained from a comprehensive research project which conducted at backward of Taurus Mountains range (Ermenek Forest Enterprise, Konya, Turkey) at three different ecological sites on karstic lands, which different percentages of stones and boulders; such as less stony site (abandoned marginal agricultural lands), medium stony site (surface stoniness between 30-50%) and densely stony site (Surface stoniness between 70-90) [47]. In each ecological site two exposures (sunny and shady), two soil treatments (surface soil tillage; 10-20 cm depth) and untreated parcels, and three different levels of seed weight with cone scales (200 kg/ha, 400 kg/ha and 600kg/ha) were considered. Surface soil tillage couldn't be applied in densely stony ecological site.

After evaluation of survived seedlings, at the end of forth growing period, the research results reveal that the amount of seeds with cone scale to be dispersed varied between 200 kg/ ha and 600 kg/ha depending on the ecological sites, exposures (sunny or shady) and surface soil tillage (Table 3).

According to the findings valuable recommendations have been made by authors, about amount of seeds to be dispersed when applying broadcast seeding, considering above mentioned criteria. Moreover, at abandoned marginal agricultural lands, deep soil cultivation together with broadcast seeding or planting by containerized seedlings was suggested as better alternatives, instead of surface

soil tillage. Because in abandoned agricultural lands, due to soil compactation seedlings have not developed a desirable root and shoot growth both treated (surface soil tillage; 10 - 20 cm depth) and untreated soil conditions, However, it was also recommended that the last decision should be made after observing the seedlings a few more years [47].

Moreover seedling mortality was higher at sunny exposures than shady exposures. Seedling growth was also better at shady exposures. The results of the research revealed that, in general, the amount of seeds with cone scales to be dispersed at sunny exposures must be 1.5-2 times of the shady exposures of the same ecological site [47].

Table 3. After evaluation of seedling survival at the end of fourth growing period, the recommended amount of seeds with cone scales while applying broadcast seeding in bare karstic lands of different ecological sites, exposures, with and without surface soil treatment (10-20 cm depth), at sample plots of Ermenek, Konya, Turkey [47] (Tabulated from the data of the article).

Ecological sites	At sunny exposures		At shady exposures	
	Treated soil	Untreated soil	Treated soil	Untreated soil
	Amount of seeds with cone scales to be dispersed per ha			
	kg/ha	kg/ha	kg/ha	kg/ha
Less stony site (marginal abandoned agricultural land)	200 or 200-400	200 or 200-400	200 or 300	200 or 300
Medium stony site	200-400	400-600	200	400
Densely stony site	-	400 or 400-600	-	200-300 or 400

Recommendations while applying the broadcast seeding with Lebanon cedar in bare karstic lands

The area to be reforested must be fenced before seeding to protect it from grazing by goats.

Surface soil treatment (or deep soil treatment in abandoned agricultural lands) must be applied by a ripper, mounted an agricultural tractor or crawler tractor in compact soil conditions and/or densely weed covered areas.

Broadcast seeding should be applied just before snowfall to reduce seed predation by insects and birds. If necessary, seeds can also be dispersed on snow. As the seed dispersal of Lebanon cedar begins at the end of November or December and continues throughout the Winter, application of broadcast seeding just before snowfall is close to nature which greatly effect more seed germinations that means more seedling survival [9].

Even distribution of seeds can be attained by dividing the area to be sown into divisions conforming to the topography and then dispersing suitable amounts of seeds to each division [9].

The stones and boulders, which cover the surface of soils, reduce the evapotranspiration and so increase seedling survival. Observations suggest seedlings are most healthy where 70-75% of the soil surface or more is covered with stones [8,9]. Therefore the position of stones and boulders on the surface of soils must not be changed as much as possible during the soil treatment. Especially at medium stony sites, shallow soil tillage (10-20cm depth; maximum 30 cm) should be preferred to deep soil cultivation.

The seeds to be used for seeding should be extracted from the cones collected from surrounding Lebanon cedar forests or from stands on the same exposure and similar elevations (± 150 -200m) in the same locality. [9,4]

Within the Lebanon cedar region, of Taurus Mountains, Turkey, uncontrolled goat grazing is one of the foremost problems. Every effort should be given to reduce the goat populations, to develop a balanced solution between forestry and grazing, and other alternative approaches considering socio-economic conditions of the rural inhabitants.

In occasional years, extremely hot and dry weather during the growing season may cause seedling failure. Such failures should be accepted. The following years seedlings (or necessary additional seedlings) must be repeated.

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