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Restoration of Oak Forests in Soils Compacted by Human and Livestock

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Abstract: Soil in the oak forests of northern Iran is compacted by human and livestock whereas this problem is resulted to a defect in natural regeneration of tree species. This investigation aims to determine the suitable rehabilitation of these forests using seed sowing of oak in canopy densities of 25-30% (open canopy), 45-55% (semi-closed canopy) and 65-75% (relatively closed canopy). For this purpose, each canopy density specified within the plots of 1000 m^2 was chosen in three replicates to plant oak acorn. The experiment was conducted as completely randomized design. The results in the first growing season indicted that seed germination rate as well as root length was greater in open canopy but no significant difference could be detected in terms of collar diameter, shoot growth, flush number and root/shoot ratio. The investigation reveals that for restoration of the soil-compacted oak stands, open canopies are better suited for seed sowing of oak.

Key words: Crown canopy, oak forest, restoration, seedling growth, seed sowing

INTRODUCTION

Caucasian oak (*Quercus castaneifolia* C.A. Mey.) is one of the main broadleaved species growing throughout the south of Caspian Sea, in length of about 1000 km, from coasts to elevations of 2300 m in Elborz mountains (Ersali, 1999). In recent decades, a large area from *Q. castaneifolia* forests has been devastated by human manipulation and grazing. In these forests soil has been degraded by compaction and crown canopy reduced by tree cutting whereas the necessity of restoration as seedling plantation and seed sowing is inevitable.

Plantation and seed sowing of some broadleaves as well as direct seeding of oak has a long background in Europe (Savill, 1991; Joyce, 1998) and United State (Twedt and Wilson, 2002). In Denmark and southern Sweden, transplanting of 2-3-year-old bare-rooted seedlings at a stock density of about 2500-5000 ha^{-1} is the most common practice used for afforestation with broadleaves and particularly with oak of former farm land (Henriksen, 1988). It is an expensive method. The cost per transplanted seedling is about 0.4-0.7 Euro including the seedling and the transplanting only. Thus, the development of alternatives is needed. Sowing of oak is an old regeneration technique (Thirgood, 1971) that has lately been revived (Willoughby *et al*., 1996; Kussner and Wickel, 1998. The regeneration cost is one-third to one-half of the cost of transplanting seedlings (Bullard *et al*., 1992). For 1 Euro it is possible to get about 20-100 pretreated acorns or 100-200 beechnuts. The periodical large crops may result in even lower prices. Consequently, sowing has potential for reaching high stock densities at low costs, resulting in high stand quality.

Although in Iran seedling plantation and seed sowing of oak have being implemented in the north forests for three decades (Rasouli, 1995) however there is few investigations with seed sowing (Mohadjer, 1998) and hence further investigations on this case are needed. To this reason, this research with acorn planting of Caucasian oak on the compacted soils of the oak stands under different canopy densities (open, semi-closed and relatively closed canopies) follows to find the condition of these non-regenerated stands. This experiment is also aimed to determine how germination, survival and growth are influenced by canopy density. It is hypothesized that these characteristics in seedlings of *Q. castaneifolia* are increased in open canopy density. The results are discussed with the aim of providing guidance to practical forestry in low costs afforestation.

MATERIALS AND METHODS

The study was conducted in an experimental temperate forest dependent on Tarbiat Modares University, located in 20 km from south of Noor city, north of Iran (latitude = 36°28′ N, longitude = 52°03′ E, altitude = 260-280 m a.s.l.) (Fig. 1). Mean annual rainfall is 803.4 mm and a distinct rainy season occurs between August and May. Mean annual temperature is 17°C and the dry season comes about between May and August (Fig. 2).

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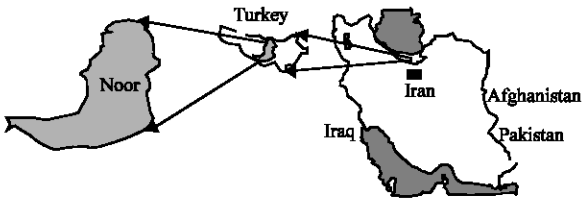

Fig. 1: Position of the study area in north of Iran

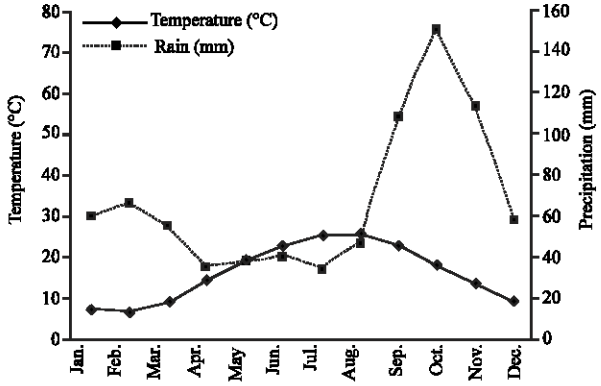

Fig. 2: Embrotermic curve of the study area, based on meteorolgical data

The site was an oak-Siberian elm stand, where *Quercus castaneifolia*, *Zelkova carpinifolia* and *Carpinus betulus*, respectively with 68.5, 20.2 and 10.0% of tree basal area were dominated on the north-facing slope ranging between 5 and 25%. Since some decades ago soil has being compacted and the tree stands devastated by the impact of anthropological and animal factors whereas crown canopy and consequently tree abundance reduced.

For doing the research, three macro-plots of 1000 m^2 with different canopy densities consisting of 25-30% (open canopy), 45-55% (semi-closed canopy) and 65-75% (relatively closed canopy) in three replicates (in total 9 macro-plot) were randomly chosen among the identified plots of the study site and then fenced. After removal of ground vegetation and shrubs, two micro-plots of 2×4 m were set up in center of the main-plots to sow oak acorns. In December 2002, acorns were collected from a mature tree in the neighboring stands. Seed germination determined in laboratory showing a rate of 85-95%. In each micro-plot, 40 healthy same-sized acorns were planted in 5 cm depth on two rows. The experimental set up was as a completely randomized design.

In the early spring of 2003 germination rate was monitored within the plots. Survival rate was calculated after measuring the surviving seedlings at the end of the growing season (November). From each micro-plot some 6-7 same-sized seedlings were selected to inventory collar diameter, shoot length and growth flush number. Three seedlings in each micro-plot were randomly excavated from the soil and rinsed free of soil to determine root length and root/shoot ratio. No weeding or irrigation was executed during the study period after acorn sowing.

Data were examined by one-way analysis of variance (ANOVA) and tested for significance with Multiple Range test. Only growth flush number was analyzed by Chi-square test. The significance level used was $p<0.05$, unless otherwise mentioned. All data analyses were performed using the statistical package of SPSS, version 11.5.

RESULTS

Results revealed that at the end of the first growing season difference of means in germination rate as well as root length was significant (Table 1). Data exhibited a negative correlation in all characteristics measured and significant correlations were observed between germination rate with canopy density and root length with canopy density (Table 1).

Germination rate was greater in open stand (25-35% canopy density) but there was no statistically significantly difference of germination rate in semi-closed stand (45-55% canopy density) and relatively closed stand (65-75% canopy density) (Table 2). As a whole, germination rate was poor because about 1/3 of acorns

Table 1: Analyses of variance (One-Way-ANOVA) and Pearson regression for characteristics measured of Caucasian oak raised under different canopy densities

	One-Way-ANOVA		Pearson regression	
Variables	F	p-value	R	p-value
Germination rate	10.312	0.026 *	-0.685	0.000*
Survival rate	0.946	0.439 ns	-0.254	0.192 ns
Shoot length	1.487	0.226 ns	-0.228	0.054 ns
Root length	6.380	0.001*	-0.443	0.000*
Root/shoot ratio	0.562	0.642 ns	-0.131	0.274 ns
Collar diameter	1.384	0.255 ns	-0.207	0.081 ns
Growth flush No.	2.384	0.365 ns	-0.103	0.387

ns non significant; * = Significant

Table 2: Average values of Caucasian oak seedling characteristics at the end of the first growing season

	Canopy density		
Variables	Open	Semi-closed	Relatively closed
Germination (%)	34.50a	16.70b	19.10b
Survival (%)	76.10	66.30	70.80
Shoot length (cm)	25.00	22.10	22.30
Root length (cm)	24.20a	19.70b	18.90b
Root/shoot ratio	0.97	0.89	0.85
Collar diameter (mm)	4.40	4.60	4.10
Growth flush No.	1.50	1.30	1.30

Within rows, values followed by different letters are significantly different at $p \leq 0.05$

were germinated in open stand and <20% in the semi-closed and relatively closed stands. In all stands survival rate was satisfactory whereas about 2/3 and 3/4 of the emerged seedlings were remained at the end of period. The open stands with higher survival rate (76.1%) apparently indicated better circumference compared to the other stands but no statistically significantly difference of this character could be found in the different stands. Shoot length was 25 cm in the open stand and about 22 cm in the other stands, however there was clear difference of this term among the stands. Contrary to shoot length, root length varied among the different stands; it responded better in the open stand (24.2 cm). Root/shoot ratio ranged from 0.85 to 0.97; this represented that in the different stands seedlings never obtained the roots longer than the shoots. Collar diameter was not distinctly different in the stands; however it was <5 mm in all environments examined. Growth flush number was not affected by canopy density; it was weak and never reached 2 units/seedling at the end of the first period (Table 2).

DISCUSSION

In the present investigation germination rate of Caucasian oak was very weak; however it was greater in open stands where the canopy density was 25-35%. Similarly, Li and Ma (2003) report that seed germination of *Quercus liaotungensis* decreases when a closed canopy occurs. This is while the research made by Colpi *et al.* (1997) reveals that germination is not influenced by canopy density. It seemed that in this study in spite of protection of stands by fence, a great number seed were likely eaten by rodents and insects. It implies that for restoration of the deforested oak stands sufficient seeds should be planted whereas a satisfactory portion of seedlings is emerged.

In this investigation survival was not affected by canopy density. This is in agreement with Li and Ma (2003), who declare survival does not differ significantly with increasing light intensity. This confirms that Caucasian oak in early years can tolerate shading and obtain a good survivorship in shade just like in higher radiation. The mean survival rate was about 70%; this rate can be satisfactory for such stands since no highly protection was organized in the stands despite of the presence of rodents, insects and fungus. Shoot length of Caucasian oak was not raised with decreasing canopy density, a finding in the line with Tabari *et al.* (2002) on this species. In this relation, the different views are observed in reports of some authors. Some people claim shoot length is promoted in low light (Lupke *et al.*, 1998; Vera, 2000), others declare that the highest shoot length is perceived in intermediate light levels (Gardiner and Hodges, 1998) and high light levels (Kozlowski, 1949; Holmes, 1995). In our research the same as Li and Ma (2003, on *Q. petraea*) report root length increased in more opening environment. Opposite result was observed in work of Callaway (1992), who show that generally heavy shade is suited for raising oaks. Present results with Caucasian oak also demonstrated that root/shoot ratio did not differ among the stands studied. This is while that Vera (2000) reveals that oak seedlings are different in this attribute and obtain lower ratio in shade than in full light.

As a whole, by the current investigation it can be deduced that better condition of the germination rate and root length is yielded in the open canopies but survival rate as well as shoot length do not significantly differ in different crown canopies. Hence, it may be suggested that in the Caspian oak forests, where the soil has been compacted by man and livestock, open canopy to be more proper for restoration when implemented acorn sowing of Caucasian oak.

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