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Effect of the Extent of Root Pruning on Growth, Biomass and Nutrient Content of Oak (*Quercus castaneifolia C. A. Mey.*) Seedlings

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Abstract

The aim of this study was to determine the influence of the extent of root pruning on nutrient content, biomass, vitality and nursery growth of oak seedlings (*Quercus castaneifolia C. A. Mey.*). At the end of the first year of nursery growth the main root of oak seedlings was pruned by scissors at distances of 15, 30 and 45 centimeters from collar. Then, oak seedlings were planted in the field and vegetative characteristics were recorded after four growing seasons. Results showed that collar diameter growth, height growth and length of terminal inter node were significantly affected by root pruning treatments ($p<0.05$). However, no significant differences in seedlings survival, seedlings vitality and specific leaf area were evident at the different root pruning treatments ($p>0.05$). The lowest total biomass of oak seedlings was observed at 45 cm treatment. The pruned roots at distance of 15 cm from collar had lowest nitrogen content. Highest level of the Phosphorous content of leaves was observed at treatment of 30 and 45 cm. This study suggested that for access to better growth of oak seedlings, the 30 and 45 cm pruning treatments should be selected. The pruning treatment of 15 cm is only suitable for total biomass increasing.

Key words:*Oak (Quercus castaneifolia C. A. Mey.), Root pruning, Growth, Nutrient, Biomass*

INTRODUCTION

Caspian forests (in the region it is called-Hyrcanian Forests) with an area of about 1.9 million hectare are located in north of Iran, in southern coast of Caspian Sea. This area is rich in relict species that some of them came back to the Tertiary period of geological time [13]. Majority of these species such as Quercus castaneifolia, Parrotia persica, Zelkova carpinifolia, Pterocarya fraxinifolia, Tilia begonifolia and many others are concentrated in the Hyrcanian forest. Among these species, Q. castaneifolia C.A.Mey (Fagaceae) is the most commercial species after beech (Fagus orientalis Lipsky), which includes 6.6% of the area and 8.01% of the standing volume of these forests and it can measure 50 m in height and 2 m in dbh [10].

Root Pruning is the practice of removing a portion of a tree's root system [8]. Several methods of root pruning have been used to avoid root malformation, such as chemical and air pruning [17 and 18]. The goals of this suitable nursery cultural practices are to manage tree-crop competition for resources, reduce the vegetative and reproductive growth of fruit trees growing under an ultra high density planting system [15], produce planting stock capable of tolerating stresses, affects the plantation performance by form of root development of seedlings [6] and Well-develops or well-structure root systems with numerous laterals roots, which are one of the most essential attributes of high quality seedlings [1 and 4]. The lateral root increases the seedling stability and the access of the plants to the nutrients nearer the field soil surface, resulting in high survival and growth [2 and 14]. Besides the number of laterals, the root pruning increases the biomass and root collar diameter of seedlings [12].

The continued existence of the oak (*Quercus castaneifolia C. A. Mey.*) is threatened by lack of natural regeneration which is limited by grazing of livestock, soil compaction, seed predation by many wildlife species specially boar, herbaceous competition, low light levels, and continued harvesting of plus oak trees. Thus, the potential for maintenance and expansion of the oak forests by natural regeneration appears to be limited [13]. In order to promote expansion and rehabilitation of the oak forests, a program of oak seedling planting may be required [7 and 16]. However, the techniques for a successful establishment of this species are not fully developed. In recent years, northern nurseries of Iran produced a lot of Q. castaneifolia seedlings for afforestation, but many of them were died berceuse of unsuitable root pruning. This study presents a best method of root pruning for economical production of Q. castaneifolia seedlings.

The objectives of this study were (i) to determine the influence of the extent of root pruning on survival, growth, Nutrient Concentrations, stem, root and leaf biomass of Q. castaneifolia seedlings and (ii) to assess the optimum root pruned length.

MATERIALS AND METHODS

Study Area

The study was conducted from February 2000 to October 2004 in Darzicola nursery of Farim region (Hyrcanian forest), where the mean annual temperature is 11.3°C and the average annual precipitation is 658.7±250 mm. This area is located in 52°18′00″ east longitudes and 36°21′30″ north latitude at an elevation of 1350 m above sea level. The soil was well drained and with texture classes of clay loam at 0-25 cm, silts clay at 25-50 cm and clay at 50-75 cm depth of soil. The pH was 7.56, 7.32 and 7.06 at 0-25 cm, 25-50 cm and 50-75 cm depth, respectively. The total organic carbon and EC at 0-25 cm were 0.86% and 0.59, respectively.

Treatments and Experimental Design

At the end of the first year of nursery growth the oak seedlings were extracted from nursery treasure bed and their main root was pruned by scissors at distances of 15, 30 and 45 centimeters from collar (Figure 1). Then, seedlings transplanted in the field. Experimental plantations were established in three blocks and nine plots with a size of 2.5×2.5 m (Figure 2). Each plot had 25 seedlings. Three pruning treatments were arranged in a randomized complete block design with three replications. There were 75 seedlings per treatment per replication.

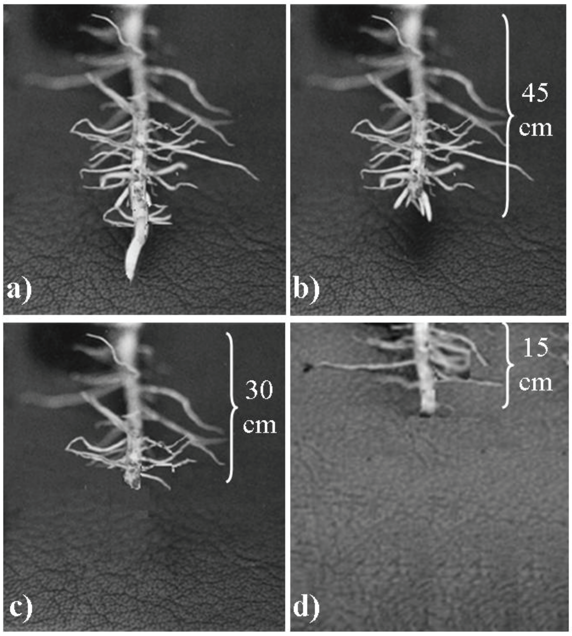

Figure 1. (a) Original extent of seedlings root (b) Pruning at the distances of 45 cm (c) 30 cm and (d) 15 cm from collar

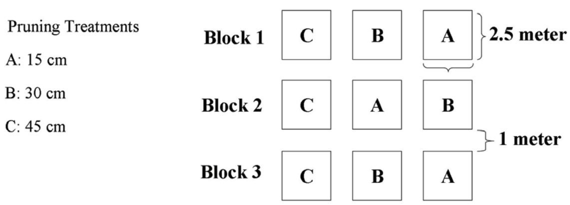

Figure 2. Transplanting design of pruned seedlings in Darzicola nursery

Seedlings Survival and Growth Measurement

At fourth year of oak (Q. castaneifolia C. A. Mey.) transplantation (4th growth season), survival rate were calculated from ratio of residual seedlings in year 2004 to number of transplanted seedlings in year 2000, multiply 100. At the end of the growth period in the nursery (in autumn) the terminal inter node length, height of seedlings from collar to terminal bud (with an accuracy of cm) and stem diameter at collar (with an accuracy of mm) of all seedlings were measured with Vernier Caliper and diameter tape. Leaf area was measured using a digital leaf area meter and DIAS software. In next stage, specific Leaf area (SLA) was calculated according to leaf area and its dry weight.

Vitality Measurement

Seedlings vitality was estimated according to Anonymous [3] classification using strength of green leaf colour as an indicator. Class 1 include of seedlings with very low vitality (more than 60% of leaves were pale), class 2 include of seedlings with low to medium vitality (25-60% of leaves were pale), class 3 include of seedlings with relatively high vitality (10-25% of leaves were pale), class 4 include of seedlings with high vitality (0-10% of leaves were pale).

Biomass Measurement

In late of growth season, three Q. castaneifolia C. A. Mey seedlings per plot were randomly selected for biomass measurements. Root, stem and leaf of each seedling were completely separated, and transferred to the lab. In lab these organs washed and oven dried at 70°C for at least 48 h and then weighed with an accuracy of µgr.

Nutrient Measurement

The root, stem and five developed leaf of three selected seedlings from each plot were powdered. Then nitrogen was analyzed after digesting the sample in concentrated H_2SO_4 using a catalyst mixture with a quick digestion unit. The total nitrogen was estimated using the Kjeldhal method. The total phosphorous was determined by Vanado-Molybdate phosphoric yellow colorimetric procedure and spectrophotometer method. Potassium concentration, were determined using an AGS methods in Flame Emission Spectrometer.

Statistical Analysis

All statistics were calculated with SPSS and MINITAB softwares. Analysis of variance (ANOVA) was used to determine the effects of pruning treatments on independent parameters. Wherever treatment effects were significant the Duncan's multiple range tests at probability level of 5% was carried out to compare the means. The graphs drawing were done in EXCEL software.

MATERIALS AND METHODS

Effects of Root Pruning on Seedlings Survival and Growth Factors

Results of this study showed that the root pruning treatments had no significant effect on oak (Q. castaneifolia C. A. Mey) seedlings survival ($P=0.11$) and specific leaf areas ($p=0.288$). Collar diameter, height growth and length of terminal inter node were significantly ($p<0.05$) increased by decreasing the length of pruning (Table 1). Height growth of the pruned seedlings in treatment of 30 and 45 cm were more than the treatment of 15 cm. The collar diameter of the seedlings increased from

2.17 to 2.80 cm with increasing pruning distance from collar. Length of terminal inter node in treatment of 45 and 35 cm were more than treatment of 15 cm (Table 2). Other researchers confirmed that the maximum height growth of oak seedling (Q. castaneifolia) was occurred in 50% and 75% light intensities. Also, the pruned roots at the distances of more than 30 from seedling collar was the best treatment for obtaining the thicker and longer oak seedlings [9].

Table 1. Effect of root pruning treatments on oak seedlings

Characteristics	df M	ST M	SE F	
Survival (%) 2	2	8.44 7	.10	4 [ns]
Collar diameter (cm) 2	3	.06	0.42 7	.12*
Height growth (cm) 2		14490	2549	5.68*
Specific leaf area (cm2g-1)	2	195709	113506	1.72 [ns]
Length of terminal inter node (cm) 2		48757	926.2 5	.26*

*,**,***: Significant in probability level of 5, 1 and 0.1 %, respectively; ns: not significant.

Table 2. Comparison of oak seedlings survival and growth features in different treatments

Growth factors	Pruning treatments		
	15 cm	30 cm	45 cm
Survival (%)	96.47 [a] ± 2.30	95.96 [a] ± 1.90 9	6.11 [a] ± 2.40
Collar diameter (cm)	2.17 [a] ± 0.52	2.58 [a] ± 0.65 2	.80 [a] ± 0.76
Height growth (cm)	151.50 [b] ± 43.50	188.70 [a] ± 47.60	213.80 [a] ± 66.60
Specific leaf area (cm2g-1)	993.35 [a] ± 19.70	578.21 [a] ± 369.18	539.714 [a] ±393.78
terminal inter node Length (cm)	52.70 [b] ± 20.18	74.40 [a] ± 36.95 7	9.61 [a] ± 39.22

Means ± standard errors, according to Duncan's multiple range tests at probability level of 5 %.

Effects of Root Pruning on Seedlings Vitality

No significantly differences were found among seedlings vitality when comparing different pruning treatments (p=0.994). Seedlings with high vitality (class 4) had more frequency compared to other classes in each treatment. The other vitality classes (1, 2 and 3) frequency reduced by decreasing pruning distance to collar (increasing pruned root length), while this status was reverse for class 4 (Figure 3).

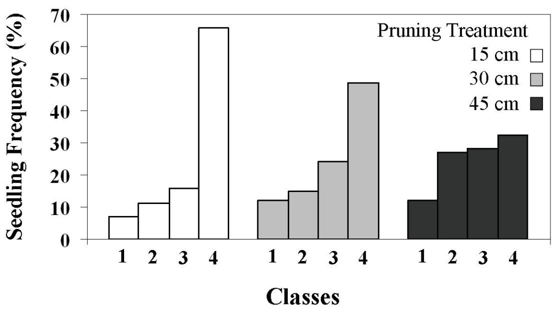

Figure 3. Seedlings vitality classes frequency in different pruning treatments

Effects of Root Pruning on Seedlings Biomass

ANOVA results showed a significant effect (p<0.05) of root pruning treatments on total biomass of seedlings, whereas the pruning treatments hadn't significant effect (p>0.05) on root, stem and leaf biomass ratio (Table 3). Stems biomass (294.68 gr) in treatment of 30 cm and leaves biomass (243.82 gr) in treatment of 15 cm were more than other organs biomass. The lowest total biomass (454.23 gr) was observed in pruning treatment of 45 cm (Table 4). Generally, the total biomass of oak seedling organs in treatment of 15 cm was significantly more than other pruning treatments (Figure 4). The results of root pruning treatments on stem growth, root morphology and field performance of the Mediterranean pine (Pinus halepensis Mill.) revealed that the chemical pruning had significant effect on seedling morphology. Copper concentration increased the seedlings height, diameter, shoot and root biomass. However, there were no differences among treatments for survival, 2 years after planting [18].

Table 3. Effect of root pruning treatments on oak organs biomass

Biomass (gr) d f	MST	MSE	F
2Root biomass	364.4	836.5	0.41 [ns]
2Stem biomass	11159	17365	0.64 [ns]
Leaf biomass	229045	36640	0.79 [ns]
2Total biomass	2357	99408	5.02*
2Root b. (Total b)-1	0.0023	0.0062	0.37 [ns]
2Stem b. (Total b)-1	0.025 0	.0075	3.33 [ns]
Leaf b. (Total b) -1	20.0325 0	.0293	1.11 [ns]
Root b. (Stem b)-1	20.0487 0	.0686	0.71 [ns]

Table 4. Comparison of oak or gans biomass in dif ferent pruning treatments

Biomass (gr)	Pruning treatments		
	15 cm	30 cm	45 cm
Root biomass	150.04 [a] ± 37.78	170.49 [a] ± 59.69	150.75 [a] ± 35.77
Stem biomass	194.01 [a] ± 28.11	294.68 [b] ± 47.12	234.68 [a] ± 122.79
Leaf biomass	243.82 [b] ± 39.55	78.30 [a] ± 9.59	68.80 [a] ± 40.19
Total biomass	587.87 [a] ± 310.07	543.47 [a] ± 105.50	454.23 [b] ± 98.53
Root b. (Total b)-1	0.30 [a] ± 0.16	0.31 [a] ± 0.03	0.25 [a] ± 0.03
Stem b. (Total b)-1	0.38 [a] ± 0.15	0.54 [a] ± 0.03	0.54 [a] ± 0.09
Leaf b. (Total b) -1	0.32 [a] ± 0.27	0.30 [a] ± 0.28	0.13 [a] ± 0.40
Root b. (Stem b)-1	0.80 [a] ± 0.32	0.57 [a] ± 0.10	0.59 [a] ± 0.34

Effects of Root Pruning on Organs Nutrient Contents

Nitrogen is one of the most important nutrients for plants and its availability is a major limiting factor for plant growth. Because of its importance various mechanisms have evolved in plants for efficient capture of Nitrogen nutrients [5]. Indeed, current study had revealed complex effects of root pruning on increase of root Nitrogen content in 30 and 45 cm treatments.

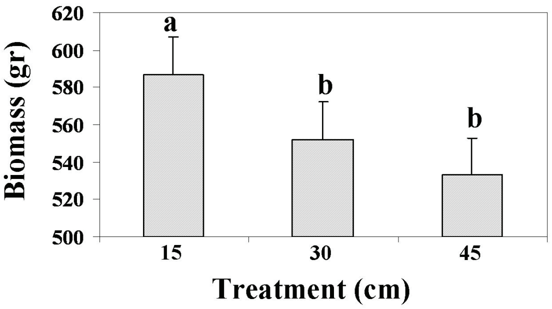

Figure 4. Comparison of total biomass in different pruning treatments

Treatments had significant effects on root Nitrogen ($p<0.01$) and leaf Phosphorous ($p<0.05$) content. The root treatments effect on potassium content of organs was not significant (Table 5). The pruned roots at distance of 15 cm from collar had the lowest Nitrogen content (0.42±0.05). Highest level of leaves Phosphorous content (approximately 0.20%) was observed in treatments of 30 and 45 cm (Table 6). The effects of wrenching treatments on leaves potassium, manganese and calcium content of Prunus avium L. and Castanea sativa Mill species were generally negligible. The reduction in concentrations and total foliar content of nitrogen and phosphorus caused by the wrenching treatments in leaves of these species did not have a negative effect on growth following outplanting [11].

Table 5. Effects of root pruning on nutrient contents of oak seedling organs

Nutrient (%)	df	M	STM	SE	F
R	2 oot	0	.0121	0.0006	19.68**
Nitrogen	2 Stem	0	.0176	0.0180	0.98^{ns}
L	2 eaf	0	.0014	0.0250	0.06^{ns}
R	2 oot	0	.0000	0.0020	0.00^{ns}
Phosphorous	2 Stem	0	.0001	0.0001	0.55^{ns}
L	2 eaf	0	.0006	0.0001	5.09*
R	2 oot	0	.0002	0.0017	0.13^{ns}
Potassium	2 Stem	0	.0021	0.0021	1.03^{ns}
L	2 eaf	0	.0002	0.0073	0.03^{ns}

Table 6. Comparison of nutrient contents of seedling organs in different root treatments

Nutrient (%)	Pruning treatments			
	Organs	15 cm	30 cm	45 cm
	Root	0.42 ^{b} ± 0.05	0.53 ^{a} ± 0.05	0.54 ^{a} ± 0.51
Nitrogen	Stem	0.76 ^{a} ± 0.03	0.91 ^{a} ± 0.26	0.84 ^{a} ± 0.10
	Leaf	2.25 ^{a} ± 0.25	2.26 ^{a} ± 0.20	2.29 ^{a} ± 0.18
	Root	1.40 ^{a} ± 0.01	1.40 ^{a} ± 0.02	1.40 ^{a} ± 0.03
Phosphorous	Stem	8.67 ^{a} ± 0.02	0.09 ^{a} ± 0.02	0.01 ^{a} ± 0.01
	Leaf	0.18 ^{b} ± 0.01	0.20 ^{a} ± 0.01	0.21 ^{a} ± 0.01
	Root	0.41 ^{a} ± 0.03	0.39 ^{a} ± 0.01	0.43 ^{a} ± 0.01
Potassium	Stem	0.43 ^{a} ± 0.40	0.49 ^{a} ± 0.05	0.47 ^{a} ± 0.02
	Leaf	0.83 ^{a} ± 0.12	0.85 ^{a} ± 0.07	0.85 ^{a} ± 0.05

CONCLUSION

Root systems of terrestrial plants serve many important tasks among which anchorage of the plant and uptake of water plus nutrients are the most important ones. Root growth potential is a physiological attribute that can be easily measured and used to assess seedling quality. It is defined as a gauge of the ability of a seedling to produce new roots when growing in an ideal environment. Root pruning is used routinely on seedlings and young plants growing in soil beds in amenity and forest tree nurseries. The aim is to control shoot vigor and produce planting stock with compact fibrous root systems well suited to transplanting. Root pruning can also affect the nutrient content of the young trees. Root pruning is likely to stimulate the production of plant hormones such as ABA and ethylene in response to tissue wounding. It is also plausible that root pruning stimulated new root growth directly. Results of this study indicated that collar diameter, height growth and length of terminal inter node were increased by decreasing the length of pruning. This study also suggested that for access to better growth of oak seedlings, the 30 and 45 cm pruning treatments should be selected, whereas 15 cm treatments was suitable for total biomass increasing.

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