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Effect of Root Pinching on Growth Patterns of Blue Oak *(Quercus douglasii* H. & A.) Seedlings

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With 1 Figure

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Summary

KOUKOURA Z. & MENKE J. 1994. Effect of root pinching on growth patterns of blue oak (*Quercus douglasii* H. & A.) seedlings. – Phyton (Horn, Austria) 34 (1): 109–118, 1 figure. – English with German summary.

The influence of root pinching on growth patterns of seedlings of blue oak *(Quercus douglasii H. & A.)* was investigated. The immediate responses of the seedlings were: a) Increase of root branches in the upper 10 cm of the soil profile, and b) Increase of root dry mass in the upper 10 cm of the soil profile, and c) Faster root growth rate. The total root length and dry mass were not affected. Indirect effects were: a) Increase in the number of leaves, and b) Increase in the ratio between leaf area and root dry mass. The differentiation of root distribution in space and time are an important means of partitioning the soil resources.

Zusammenfassung

KOUKOURA Z. & MENKE J. 1994. Auswirkungen des Beschneidens von Wurzeln auf das Wachstumsmuster von *Quercus douglasii* H. & A. Sämlingen. – Phyton (Horn, Austria) 34 (1) 109–118, 1 Abbildung. – Englisch mit deutscher Zusammenfassung.

Der Einfluß des Beschneidens von Wurzeln auf das Wachstumsmuster von *Quercus douglasii* H. & A. Sämlingen wird untersucht. Als unmittelbare Reaktion der Sämlinge konnte festgestellt werden: a) Zunahme der Wurzelverzweigungen in den

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oberen 10 cm des Bodens, b) Anstieg der Wurzeltrockenmasse in den oberen 10 cm des Bodens, c) ein schnelleres Wurzelwachstum.

Die gesamte Wurzellänge und Trockenmasse wurden nicht beeinflußt. Als indirekte Effekte konnten mehr Blätter und ein Anstieg des Verhältnisses zwischen Blattfläche und Wurzeltrockenmasse beobachtet werden. Die Unterscheidung der Wurzelverteilung in Raum und Zeit ist ein wichtiges Mittel zur Nutzung der Bodenresourcen.

Introduction

Blue oak (*Quercus douglasii,* H. & A.) savanna communities in California's Mediterranean type ecosystems are composed of deciduous trees with an understory of herbaceous annual plants. They form a nearly continuous belt in the foothills surrounding the Great Valey of California. This type of vegetation covers over 3 million hectares with tree densities between 10 and 750 trees/ha (Holland 1979). Oak savannas today are usually dominated by older age classes of trees with a few or no individuals in the 2–3 yr-old seedling and sapling age classes (White 1966, Muick & Bartolome 1986).

Griffin (1971, 1973, 1976) discussed the distribution and regeneration of California oak trees in relation to moisture availability in habitats. Soil moisture availability and plant growth characteristics that are related to water stress (germination time, seedling root growth rate and material distribution) apparently have important effects on the success or failure of seedling establishment. Changes in species composition of California's grassland ecosystems may demonstrate the impact of temporal changes in water availability on species establishment. Non – native annuals potentially have altered the seasonal availability of soil moisture (Biswell 1956).

The root system of grass species with extensive production of adventitious roots have, more or less, similar parts which are joined to the stem base and lack the single dominant root that can be achieved by primary root systems (Fitter 1987). In contrast, blue oaks have single dominant roots by a primary root system Matsuda & McBride 1986. The statement that plants normally utilize the soil moisture at the soil surface first, can be interpreted as an indication of different levels of root effectiveness as well as of different root densities (Pearson 1974). However, recent data of Taylor & Klepper 1974 has shown clearly that absorption of water per unit length of roots is the same for deep and shallow roots.

Sen 1980 found that most of the fibrous root mass extends in the upper 20 cm of the soil profile and rarely penetrates below 80 cm when working on *Buchloe dactyloides,* while Matsuda & McBride 1986 state that *Q. douglasii* seedlings develop a long main root because of their early germination and the high rate of root elongation.

Both Griffin 1973 and Matsuda & McBride 1986 suggest that *Q. douglasii* has morphological and physiological attributes which allow occupation of dry sites. Blue oak is consistently placed at the dry end of the mesic – xeric scale when compared to other deciduous and evergreen oaks. WELKER & MENKE 1987 postulate that as the intensity of xerism increases blue oak is not able to effectively compete for limited water supplies. CALDWELL & RICHARDS 1986 state that even with fixed root biomass and soil volume, altering the root structure has a greater effect than physiological characteristics of the roots. Also COWAN 1965 states that rooting density is a particularly sensitive parameter in models of water uptake from drier soils. The effects of root pruning on plant growth and development have been observed in a number of plant species and especially on root regeneration, root and shoot growth and functional equilibrium of root to shoot ratio by GEISLER & FERREE 1984.

The aim of this study is to examine the influence of root – pinching on growth patterns of blue oak seedlings. It is hypothesized that root pinching stimulates the number of root branches, root dry mass in the upper soil layers and root growth rate. This differentiation of root distribution in space and time of blue oak seedlings is an important means of partitioning the soil resources.

Material and Methods

Acorns from four blue oak trees were collected at Hopland Field Station, Mendocino county, California in September 1987. The acorns were placed in a cold room (4° C) to germinate. In February 1988, when the radical of the acorns had an average length of 21 mm, they were planted into a wooden, 1.0 m deep growth box separated into eight sections (slots).

In each slot, 16 acorns (4 from each tree) were planted on soil obtained from an oak – woodland site at Hopland. Before planting the tip of the acorn radical was cut off by 3 mm (pinching – unpinching acorn treatment) in half of the acorns that derived from each individual tree. These treated acorns were planted alternatively with the uncut individuals. The acorns were watered twice a week. Every 15th day seedlings were pulled out and washed thoroughly. The following features were determined:

1. Total root length (TRL)
2. Number of root branches (NRBR)
3. Number of leaves (NLV)
4. Leaf area (LA)
5. Leaf dry mass (LDM)
6. Shoot dry mass (SHDM)
7. Root dry mass (RDM)

The root system was divided into 10 cm long sections and the dry mass of each section was measured up to 110 cm (RDM 0–10, RDM 10–20...). Eight bunches of seedlings were determined at 15-day intervals.

A split plot statistical design was used and all data was analysed for 2-way analysis of variance through MSTAT VERSION 3.00/M (NISSEN 1982). Differences in growth at different collection dates were examined using the least significant difference tests (STEEL & TORRIE 1960).

The total root dry mass (TRDM) was calculated by adding the weights of root sections. The ratio leaf area/total root dry mass was calculated from the corresponding dependent variables LA and TRDM and similarly the ratio root total dry mass/shoot dry mass was calculated from the TRDM and SHDM. The root growth rate was calculated by dividing the root length of each sampling date by the number of days (15).

Parent tree identity and acorn fresh weight at planting were determined and used as covariates. The influence on the dependent variables TRL, NRBR, NLV, RDM-10 to RDM100–110 and on the ratios LA/TRDM and root/shoot (R/S) was determined using the MSTAT statistical program and the F-tests at the $P < 0.05$ level.

Results

Root pinching affected significantly:

1. The number of root branches and leaves.
2. The dry weight of roots extending in 0–10 cm soil
3. The growth rate of roots, and
4. The ratio between leaf area and total root dry mass (Table 1).

The above parameters were time dependent with significant effect (Table 2). The number of root branches increased significantly (LSD = 1.07) in the pinching treatment after 60 days from planting in comparison with the unpinching (Table 1). The root dry mass in the 0–10 cm layer of soil had higher values in the pinching treatment than that in the unpinching during the growing season. Significant differences (LSD = 0.06) were observed only after 45 and 60 days from planting (Table 1). The root growth rate increased significantly (LDS = 0.11) in the pinching treatment at the beginning of the growing season and became equal to the unpinching treatment towards the end of the growing season (Table 1). The number of leaves in the pinching treatment increased significantly (LSD = 2.0) after 60 days from planting,and only at the end of the growing season reached the same level with the unpinching treatment. The ratio between leaf area to total root dry mass increased significantly (LSD = 12.07) in both treatments after 75 days from planting with higher values in the pinching treatment. For the rest of the growing season this ratio was nearly stable in both treatments without significant differences between them. The total root length didn't differ significantly during the growing season between treatments although in the pinching treatment it increased from 45 to 75 days after planting (Table 1). The root/shoot ratio had significantly lower values in the pinching treatment in comparison with the unpinching only 15 days after planting (LSD = 3.18), while for the rest of the growing season no significant differences were observed between the treatments.

Also, no significant difference was detected between treatments in sectional root dry mass other than that at 0–10 cm depth of soil (Fig. 1).

Table 1

Means of growth parameters of pinching (p) and unpinching (unp) seedlings of *Quercus douglasii.* at several days after planting.

Days after planting	Root growth rate cm/day		Total root length cm		Number of root branches		Number of leaves		Root dry mass in 0–10 cm soil depth g		Leaf area/ Total root dry mass		Root/Shoot dry mass	
	P	UNP	P	UNP	P	UNP	P	UNP	P	UNP	P	UNP	P	UNP
15	0.65	1.04	9.77	15.61	1.0	1.0	0.0	0.0	0.06	0.6	0.0	0.0	4.6	7.9
	±0.10	±0.14	± 1.50	± 1.61	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00	± 0.00	± 0.00	±2.56	± 3.13
30	0.61	0.89	18.56	26.90	1.0	1.0	0.0	0.0	0.13	0.11	0.0	0.1	10.10	10.6
	±0.07	±0.15	± 2.30	± 0.00	±0.00	±0.00	±0.00	±0.00	±0.03	±0.02	± 0.00	± 0.01	± 2.14	± 2.40
45	0.76	1.07	34.56	48.25	1.0	1.6	0.0	0.0	0.22	0.15	0.1	0.1	8.54	6.26
	±0.13	±0.09	± 2.83	± 3.20	±0.00	±0.49	±0.00	±0.00	±0.04	±0.02	± 0.01	± 0.01	± 0.25	± 0.81
60	0.91	1.03	55.12	62.25	2.29	1.14	3.10	1.71	0.29	0.18	3.9	3.2	7.85	6.93
	±0.10	±0.06	± 3.40	± 3.51	±0.97	±0.12	±0.02	±1.20	±0.05	±0.04	± 0.27	± 1.20	± 1.38	± 1.30
75	1.02	1.01	76.75	75.81	1.28	0.75	5.85	4.22	0.26	0.21	46.2	32.9	5.9	3.77
	±0.05	±0.08	± 3.7	± 3.67	±0.41	±0.16	±0.97	±1.29	±0.03	±0.04	± 7.35	± 6.12	± 0.53	± 0.89
90	0.85	0.90	76.62	81.31	1.70	1.37	6.76	6.05	0.28	0.28	45.1	46.7	5.13	5.62
	±0.04	±0.12	± 3.69	± 3.94	±0.49	±0.37	±1.29	±0.37	±0.06	±0.06	± 7.25	± 7.36	± 0.68	± 0.95
105	0.81	0.73	85.15	77.0	2.39	1.30	8.02	5.04	0.34	0.28	39.3	31.2	4.64	3.78
	±0.02	±0.05	± 3.87	± 3.72	±0.56	±0.37	±1.06	±1.52	±0.08	±0.07	± 6.35	± 6.08	± 0.42	± 0.84
120	0.75	0.70	90.06	84.56	2.09	1.01	6.23	6.71	0.28	0.23	49.3	43.7	3.51	4.89
	±0.01	±0.03	± 4.10	± 3.95	±0.46	±0.00	±1.17	±1.16	±0.08	±0.01	± 7.43	± 7.16	± 0.59	± 1.01
L.S.D.	0.11		15.93		1.07		2.0		0.06		12.07		3.18	

Table 2

Analysis of variance of growth parameters as affected by root pinching and acorn fresh mass of *Quercus douglasii* at several days after planting.

Growth parameters	Root pinching F ratio	Days from planting F ratio	Acorn fresh mass F ratio
NRBR	4.29*	2.67*	10.40**
NLV	4.98*	18.42***	13.62***
GRRL	7.13**	2.52*	ns
LA/TRDM	5.23*	32.00***	ns
TRL	ns	79.23***	ns
RDM 0–10	8.40**	3.64*	154.47***
RDM 10–20	ns	4.28**	83.02***
RDM 20–30	ns	5.27**	83.39***
RDM 30–40	ns	5.93***	66.54***
RDM 40–50	ns	4.81**	6.84*
RDM 50–60	ns	6.41***	40.62***

NRBR = Number of root branches, NLV = Number of leaves, LA/TRDM = Leaf area/ Total root mass, TRL = Total root length, RDM = Root dry mass. Level of significance: * p = 0.05, ** p = 0.01, *** p = 0.001, ns = not significant.

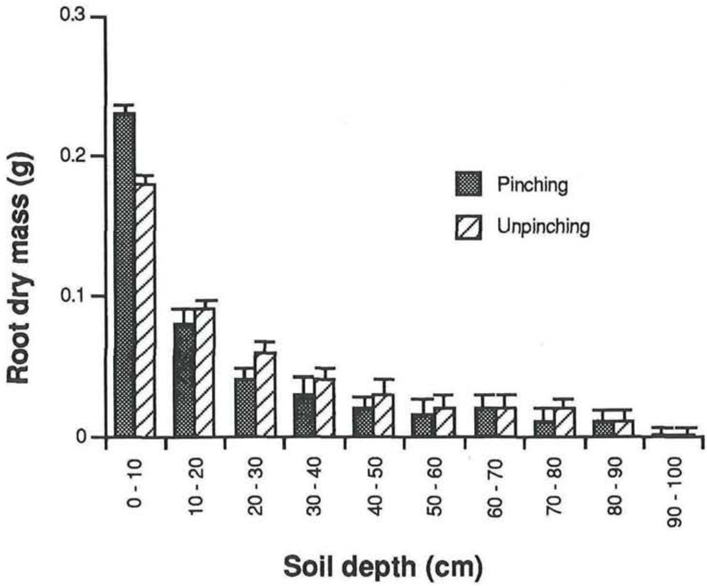

Fig 1. Effect of root pinching on mean root dry mass at different soil depths. (Arrows show Standard Error).

Acorn wet fresh mass as a covariate had a significant effect on sectional dry root mass at 10– 20 cm through 50–60 cm depth of soil. It also significantly affected the number of root branches and the number of leaves.

Discussion

From the above work it was found that the immediate responses to root pinching were: a) A profound increase in the number of root branches, b) Increase of root dry mass in the upper 10 cm of the soil, and c) Faster root growth rate. GEISLER & FERREE 1984 reported that root regeneration consists of elongation of existing roots and initiation of new laterals with subsequent elongation. According to WILCOX 1955 and CARLSON 1974 lateral roots, which formation is stimulated by pruning, originate close to the cut surface and not in other nondisturbed areas of the root system. In our study root branching occurred at an average depth of 4.2 cm from the base of the acorn where the average radical length was 1.7 cm at the time of pinching and planting. HACKETT & STEWART 1969, MCLEAD & THOMPSON 1979 found that each root segment formed in a root system passes through a maturation sequence which includes initiation of lateral primordia 1–2 cm proximal to the tip. ROHRING 1977, BROWN 1969, EIS & LONG 1972, CARLSON 1974, STERLING & LANE 1975 also suggested that new root systems have higher densities because roots form new laterals near the point of cut. This is in agreement with the significant increase in the 0–10 cm soil depth of the root dry mass in the pinching treatment during the growing season. No differences were detected in the deeper root section between the treatments.

The increase of root growth rate that was observed in the beginning of the growing season in the pinching treatment appears as an effect of root pinching. This effect didn't influence the root length in the end of the growing season between the treatments because the root growth rate was equal from the middle to the end of the growing season in both treatments. Comparison of the root length of oak seedlings with data from MATSUDA & MCBRIDE 1986 for the same species, showed that it was about the same for the same growing period.

There is evidence that lateral root formation is stimulated by endogenous indolacetic acid (IAA) levels within the root which increased between pruning and the appearance of new lateral root (GEISLER & FERREE 1984). Also LARSON 1975 working with red oak suggested that these auxins promote the accumulation of carbohydrates and other factors needed for root formation and that especially short – lived peak in auxin production may be responsible for triggering root initiation primordia. So, growth behaviour (root growth rate, root branching, root mass in the upper 10 cm of soil) in oak seedlings after radical cutting may be attributed to disturbances in the auxin balance.

Another indirect response to root pinching was the increase in number of leaves of the seedlings. According to RICHARDS & ROWE 1977 who worked on peach seedlings and JAMES & HUTTO 1972, the number of leaves is related to the growth promoting substances produced by new root apices. Stability of the root/shoot ratio for most of the growing season in both treatments comes in agreement with GEISLER & FERREE 1984. They stated that during the time of increasing root growth a reduction in the growth rates of shoots can be observed with the development of root apices and the simultaneous production of growth promoting substances that are translocated to the shoots.

Balance between water absorption by roots and transpiration from leaves determines the water economy of plants. A small ratio of leaf area to root dry mass therefore can be regarded as a morphological adaptation developed by xerophytes and a large ratio by mesophytes (MATSUDA & MCBRIDE 1986). In our study this ratio showed that oak seedlings were adapted to the mesic experimental conditions.

Acorn fresh weight had an effect on growth parameters such as number of root branches and root dry mass in the upper 10 cm, of soil but not on root growth rate. MATSUDA & MCBRIDES 1986 work on root elongation of *Quercus agrifolia* and *Quercus lobata* is in agreement with our results which show that there is no effect of acorn fresh weight on root growth rate. In particular, they found that the dry weight of cotyledons was positively correlated with small seeds of *Q. agrifolia* but not with larger seeds of *Q. lobata*. GORDON & al. 1989 working on blue oak elongation found also no effect on root growth rate.

Pinching had no effect no root total length and root dry mass in soil layers deeper than 0–10 cm although it promoted the number of root branches and their growth rate. According to WEAVER 1919, PARRISH & BAZZAZ 1976, and SEN 1980, differentiation of root distribution in space and time is known to occur. Such differentiation can be used as an important means of partitioning the soil resources. Species coexistence in semiarid and arid habitats is in related to differentiation of rooting patterns in space and time (YEATON & al. 1977, CALDWELL & RICHARDS 1986, HUNT & NOBEL 1987). A competition experiment of soil water that involved two perennial plants, *Elymus glaucus* and *Q.douglasil* revealed that pinched treatment helped the blue oak seedlings to avoid desiccation for longer periods of time (KOUKOURA & MENKE, unpublished data).

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