Red Oak Transplanted to Different Bulk Density Soils Have Similar Water Use Characteristics

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Abstract. Container-grown red oak (*Quercus rubra* L.) produced in two bulk density growing media (0.4 or 0.9 g cm^{-3}) were transplanted into larger containers filled with Wooster silt loam soil compacted to 1.25, 1.50 and 1.75 g cm^{-3} densities. Growing media bulk density affected only the number of shoots elongating; there was no significant difference in stem diameter, shoot length and dry weight, leaf area and dry weight and regenerated root dry weight between plants grown in the low or high bulk density production media. Transplant media bulk density affected stem diameter in shoot length; both were significantly less when plants were transplanted to 1.75 g cm^{-3} than to the 1.50 g cm^{-3} bulk density soil. Water use, expressed either as whole plant or per unit leaf area, was greater for plants transplanted to 1.50 g cm^{-3} bulk density soil than those transplanted to 1.25 or 1.75 g cm^{-3} soil at only three times during the 80 day water use study period: 39, 55 and 69 days after leaf emergence. Transplanting container-grown red oak to high bulk density soils did not greatly affect regrowth potential under non-limiting soil moisture conditions.

A concern with transplanted container-grown plants is restricted root growth from low bulk density growing media into higher bulk density soil (13). Pine bark-sand combinations are commonly used as container growing media; a typical bulk density is 0.7 g cm^{-3}. Recent studies showed that root growth of transplanted container-grown plants into higher bulk density soil was sufficient for establishment (1, 2, 10).

Recently, low bulk density rice hull-based media (bulk densities between 0.36 and 0.62 g cm^{-3}) have been developed (17). It is unknown if plants produced in these lower bulk density media will also rapidly regenerate roots into the surrounding soil. Of special interest is the degree of root regeneration into compacted soils typically found in urban planting sites. This research was conducted to determine if growing media or transplant media bulk density affected regrowth potential or water use of transplanted container-grown red oak.

Materials and Methods

Three-year old red oak seedlings were produced in #3 round plastic containers (9" top dia and 8.5" bottom dia x 9" high, 23 cm by 22 cm by 23 cm, Lerio Corp., Mobile, AL) treated with Spinout (Griffin Corp., Valdosta, GA). Seedlings ranged from 5 to 6 ft. (1.5 to 1.8 m) tall and ° in. (10 mm) stem caliper. The seedlings were produced in a previous experiment (17) that explored the effect of sand- and rice hull-based media on red oak growth. For this study, 30 uniform seedlings were selected, 15 from the rice hull-based media and 15 from the sand-based media. The sand-based media average bulk density was 0.9 g cm^{-3}; the rice hull based media average bulk density was 0.4 g cm^{-3} (14).

On March 27, 1996 dormant plants were transplanted into #10 round nursery containers 15 in. top dia. and 13 in. bottom dia. by 14 in. high (38 cm by 33 cm by 36 cm, Lerio Corp, Mobile, AL). The containers were filled with Wooster silt loam compacted to one of three bulk densities, 1.25, 1.5 and 1.75 g cm^{-3}. For the 1.75 g cm^{-3} bulk density transplanting treatment, 42.3 Kg of oven dried Wooster silt loam was weighed into each of 10 containers. The weight of soil added to each container was determined by first subtracting the filled volume of the smaller container (8,888 cm^{-3})from the filled volume of the larger container (33,050 cm^{-3}) and then multiplying soil volume by the respective transplanting treatment bulk density to give the weight of soil to add to each container.

After weighing, each container was emptied, the soil pulverized by hand and layered in three 1 in. (2.5 cm) deep lifts. Each lift was compacted by hand tamping with the blunt end of a steel bar. After the third lift, a red oak was placed in the center of the #10 container and nine additional 1 in. deep lifts compacted as before. The root ball was covered with a 1 in. compacted layer of soil, leaving the #10 container filled to 1 in. of the rim. The root ball was covered with the 1 in. layer of soil to prevent evaporation from the 3 gallon root ball surface.

Table 1. Growth of container-grown red oak after transplanting to three bulk density media.

Transplant media bulk density (g cm^{-3})	Growing media bulk density (g cm^{-3})	Stem dia. (mm) Initial	Stem dia. (mm) Final	Shoot no.	Shoot length (cm)	Shoot dry wt (g)	Leaf no.	Leaf area (cm^{-2})	Leaf dry wt. (g)	Regenerated root dry wt (g)
1.25	0.3	10.4	13.8	15.4	281.4	22.0	117	7134	53.5	27.7
	0.9	10.4	14.6	21.8	338.2	19.6	138	7503	52.9	35.9
	Average	10.4	14.2	18.6	309.8	20.8	127	7318	53.2	31.8
1.50	0.3	10.6	15.4	12.2	291.0	24.8	115	6989	52.8	37.2
	0.9	10.6	14.6	15.8	335.0	28.1	129	7438	56.6	39.0
	Average	10.6	15.0	14.0	313	26.5	122	7214	54.7	38.1
1.75	0.3	10.4	13.4	16.6	237.2	19.5	141	7687	56.4	36.0
	0.9	10.0	12.8	18.6	277.0	17.2	138	6995	53.6	32.5
	Average	10.2	13.1	17.6	257.1	18.4	140	7341	55.0	34.3
ANOVA										
Growing media		NS[y]	NS	0.08	NS	NS	NS	NS	NS	NS
Transplant media		NS	0.05	NS	0.11	NS	NS	NS	NS	NS
Growing media x transplant media		NS	NS	NS	NS	NS	NS	NS	NS	NS

[z] Each value is the mean of five individual plant replications.
[y] NS, not significant at P = 0.15 level.

For the 1.25 and 1.5 g cm^{-3} transplant bulk density treatments, the appropriate weight of pulverized Wooster silt loam was added to each container and the remaining container volume filled with rice hulls (bulk density of 0.32 g cm^{-3}). The containers were emptied, the pulverized Wooster silt loam uniformly mixed with the rice hulls and the containers filled as before. Thus, red oak from two bulk density production media, 0.4 and 0.9 g cm^{-3} were transplanted to three bulk density transplanting media, 1.25, 1.50 and 1.75 g cm^{-3}.

After transplanting, an 18 in. (45 cm) diameter black plastic disk with a 2 in. (5 cm) center hole was placed over each container to reduce evaporation from the transplanting media surface. The containers were moved to a greenhouse where they remained for the duration of the study.

The containers were watered to soil capacity, allowed to drain for one hour and weighed. At approximately one week intervals for the next 80 days, the containers were re-weighed, re-watered to field capacity, allowed to drain and weighed again. The difference between consecutive wet and dry weights was used as an estimate of whole plant transpiration between the weighing periods. The plants were watered as needed after the 80 day transpiration study period.

On Nov. 27, 1996 the leaves of each plant were removed, counted and leaf area determined with a Model Li-3100 (LiCor, Inc., Lincoln, NB) leaf area meter. The leaves were oven dried and the dry weights recorded. Current season's shoot growth was removed, its length measured, oven dried and the dry weights recorded.

Each plant was then removed from its container and the transplanting media removed from the regenerated roots, those roots outside of the original container root ball. The regenerated roots were removed, oven dried and dry weights recorded. Each plant stem was severed 1 in. (2.5 cm) above the root collar and the initial and final 1996 growth ring diameters were measured.

Whole plant average daily transpiration was estimated by dividing the individual plant weight differences for each weighing period by the number of days between weighings. Average daily transpiration on a per unit leaf area basis was estimated by dividing the average daily whole plant transpiration by each plant's leaf area.

Transpiration data was subject to ANOVA for a time series using SPSS (Version 7.5, SPSS for a personal computer). Growth and dry weight data were subject to ANOVA using SPSS. Means were separated using the Student-Newman-Kuels test.

Results

Initial average plant calipers averaged 0.5 in (10.6 to 10.2 mm), but the differences were not statistically significant (Table 1). After one growing season, red oak transplanted to 1.5 cm^{-3} bulk density soil had significantly greater stem diameter than those transplanted to 1.75 cm^{-3} soil (Table 1). There was no statistical difference in final trunk caliper between plants transplanted to the 1.5 and 1.25 cm^{-3} bulk density soil treatments. Production media bulk density did not affect final trunk caliper (Table 1). Similar results were found if trunk caliper increase is expressed relative to the initial trunk caliper (data not presented).

Plants transplanted from the lower bulk density medium had significantly fewer shoots elongating than those transplanted from higher bulk density media (14.7 vs 18.7, respectively when shoot number is averaged over transplant media bulk densities). Plants transplanted to the lowest bulk density medium had greater shoot length (P=0.11)than plants transplanted to the higher bulk density media (Table 1). There were no other statistically significant effects, including total plant dry weight (sum of leaf, shoot and root dry weights), data not presented.

There were few differences in estimated daily whole plant water use. It was significantly less for plants transplanted to the 1.5 and 1.75 g cm^{-3} bulk density media than for those transplanted to the 1.25 g cm^{-3} bulk density medium 10 days after leaf emergence (Figure 1). Thereafter, whole plant water use tended to be greatest for plants transplanted to the 1.5 cm^{-3} bulk density treatment; however, the differences were statistically significant at only three times: 39, 55 and 63 days after leaf emergence. The maximum difference in whole plant water use was 244 ml $plant^{-1}$ day^{-1}. Similar differences were seen when water use was expressed on a per unit leaf

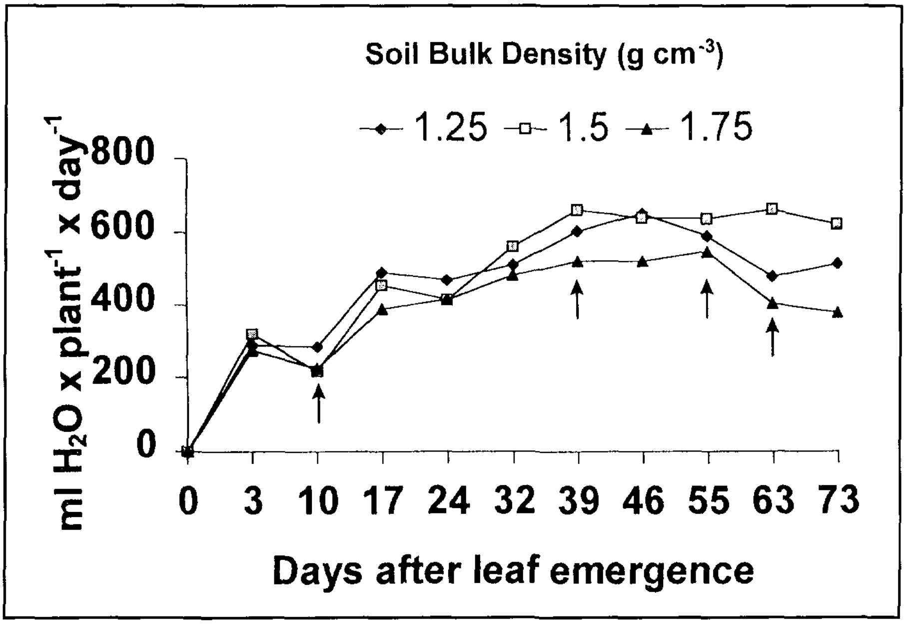

Figure 1. Water use in liters of water per plant per day, for red oak after transplanting to three different bulk density media, 1.25, 1.50 or 1.75 g cm-3. The arrows indicate differences in water use significant at the alpha=0.05 level.

surface area basis (data not presented). This finding is not unexpected as there were no differences in leaf area among the treatments or treatment combinations. Water use, expressed either on a whole plant or per leaf area basis, was not affected by the production media bulk density.

After weekly watering, the re-saturated container weights were within 3% of initial weights. The extreme difference, 7%, occurred twice.

Discussion

In this study, bulk density of the transplanting media did not greatly affect regrowth of red oak including regenerated root dry weight, although 1.75 g cm^{-3} soil bulk density typically inhibits root growth (9, 13). In other studies where plants were transplanted into amended or non-amended compacted soils, the effects of soil bulk density on first year growth were minimal (1, 3, 6, 7, 11, 13, 20, 21, 22), including root growth into the surrounding soil. Potential container stock establishment problems attributed to low bulk density growing media are caused by low moisture holding capacity (excessive drainage characteristics) of the media (4,12). Although the two types of growing media used in this study differed in bulk density by a factor of two, both were well drained. Thus, the advantage (reduced weight) of growing nursery stock in low bulk density media need not be sacrificed for the putative transplant advantages of using heavy, but well drained, bulk density growing media.

Also, growing media bulk density did not greatly effect whole plant or unit leaf area water use. Similar water use would be expected given that root regeneration into the different bulk density soils and leaf areas were similar. In this study and the studies cited above, available soil water was not a limiting factor as supplemental irrigation was applied during the study period. Unknown are the combined effects of soil compaction and limited available soil moisture on survival and regrowth potential of transplanted container-grown plant material. Under non-limiting soil moisture conditions, bulk density does not appear to inhibit establishment.

Root regeneration and root growth into the surrounding soil are essential for plant establishment (5, 18). Thus, many studies have used root growth (either dry weight or surface area) outside of the original root ball as an indicator of plant establishment (1, 2, 3, 6, 7, 10, 15, 20, 21). The field studies (2, 10, 15, 22) required great effort to recover the regenerated roots. Regenerated roots are easier to recover from container experiments. The question is; do the results of container studies reflect field conditions? Because of the differences among species in root regeneration potential (10), comparisons should be made for similar species. Unfortunately, there are no other studies conducted with red oak. There are three studies conducted with oaks, one with containerized soil monoliths (1) and two with field soils (6,10) for comparison.

We used regenerated root (those roots outside of the original root ball) dry weight density, adjusted for length of the experiment as a comparison statistic: g regenerated root dry weight x cm^{-3} x soil day^{-1}. In this study, adjusted regenerated root dry weight density ranged from 4.68×10^{-6} to 6.59×10^{-6} g cm^3 day^{-1}. In Arnold and Welsh (1) regenerated root dry weight density ranged from 7.08×10^{-7} to 4.68×10^{-6} g cm^3 day^{-1}, suggesting that results from hand compacted soil profiles used in our study are similar to containerized soil monoliths. Under field conditions, adjusted regenerated root dry weight densities ranged from 9.66×10^{-7} to 2.96×10^{-6}, assuming a 30 cm deep excavation depth (10) and from 1.7×10^{-7} to 1.5×10^{-6} (6). Grabosky and Bassuk (9,10) have successfully used containers of compacted substrates to predict field performance. If recovery of regenerated roots is a research objective, then conducting those studies in containers will facilitate root recovery and give results similar to field studies.

The results suggest that container grown red oaks can be established in compacted soils if the plants are properly irrigated. Root growth was not inhibited by high bulk density soil if the soil moisture was properly managed. The results do not suggest that container grown red oak can be successfully established in compacted soils if post-transplant maintenance results in growth limiting soil moisture levels. Supplemental irrigation after transplanting would promote root growth into moist compacted soils, relative to dry soils as, moist soils, relative to dry soils, have lower root penetration resistance.

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Résumé. Des chênes rouges (*Quercus rubra* L.) cultivés en contenant dans deux substrats de densités différentes (0,4 et 0,9 g/cm≈) ont été transplantés dans des contenants plus gros remplis avec un loam limoneux qui a été compacté à des densités de 1,25, 1,50 ou 1,75 g/cm≈. La densité du milieu de culture a affecté seulement le nombre de pousse en élongation; il n'y avait pas de différence dans le diamètre de la tige, la longueur des pousses et leur masse sèche, la surface foliaire et sa masse sèche, ainsi que la masse sèche des racines qui se sont régénérées entre les plantes produites dans le substrat plus dense ou moins dense. La densité du substrat de transplantation a affecté le diamètre de la tige et la longueur des pousses; les deux étaient significativement moindres dans les deux sols les plus compactés. La quantité d'eau absorbée était supérieure pour les plantes transplantées dans le sol à 1,50 g/cm≈. La transplantation de chênes rouges produits en contenants dans des sols plus denses n'a pas affecté grandement le potentiel de reprise de croissance sous des conditions non restrictives d'humidité du sol.

Zussammenfassung. In Containern vorgezogene Roteichen aus einem Nährsubstrat von 0,4 bzw. 0,9 g cm^{-3} Körperdichte wurden in nächstgrößere Container mit einem lehmigen Nährsubstrat mit 1,25, 1,50 und 1,75 g cm^{-3} Dichte verpflanzt. Die Dichte des Nährmediums beinflußt nur die Anzahl der Triebe. Es gab keinen Unterschied in Stammdurchmesser, Trieblänge und Trockengewicht, Blattfläche und Trockengewicht und neugebildeter Wurzelmasse. In dem Nährmedium mittlerer Konzentration wurde der Stammdurchmesser und die Trieblänge beeinflußt - beide waren deutlich niedriger als in den beiden dichteren Böden. Der Wasserverbrauch war höher bei den Pflanzen in dem Boden mit 1,5 g cm^{-3} Dichte. Das Verpflanzen von Roteichen in Böden mit großer Körperdicht beeinflußt nicht die Regenerierungseigenschaften unter uneingeschränkten Bodenwasserbedingungen.