Australian Journal of Basic and Applied Sciences, 3(4): 3900-3905, 2009
1991-8178

The Effect of Undercutting on Growth and Morphology of 1+0 Bareroot Sessile Oak Seedlings in Relation to Acorn Size

[1]F. Tilki, [2]F.T. Yuksek and [1]S. Guner

[1]Artvin Coruh University, Faculty of Forestry, 08000-Artvin, Turkey.
[2]Sindirgi State Forest Enterprises, 10330-Sindirgi, Balikesir, Turkey.

Abstract: Effects of root undercutting in the seedbed and seed size grading on a variety of seedling morphological traits of sessile oak (seedling height, seedling diameter, root dry weight, shoot dry weight, number of large lateral roots > 1 mm and number of fine lateral roots < 1 mm) were studied at Ardanuc Forest Nursery, Artvin, Turkey. The growth and dry weight of 1+0 bareroot sessile oak seedlings were observed higher for the seedlings raised from acorns of medium and large sizes. Time of undercutting affected seedling morphological attributes, and undercutting in July produced greater seedlings from acorns of medium and large size class (for both height and diameter) that had greater numbers of large lateral roots compared to the other undercutting treatments. When averaged over three acorn sizes, undercutting increased shoot dry weight, number of large lateral roots and fine lateral roots. This study suggests that undercutting treatment and acorn sizing appear to be tools to the nursery manager to produce larger sessile oak seedlings in the nursery.

Key words: Lateral roots, seedling attributes, seedling growth, seeds grading

INTRODUCTION

The success of reforestation or afforestation is dependent on the availability of suitable planting stock. Generally, suitable planting stock includes only those seedlings that can survive under environmental stress and produce vigorous growth after outplanting (Puttonen, 1994). Often seedling assessment has emphasized shoot characteristics (height, diameter, sturdiness) rather than complete seedling or root system characteristics, and these alone have not been adequate predictors of field performance (Schultz and Thompson, 1996). Work with some hardwood species has indicated that root system morphology can be a major determinant of seedling field performance (Kormanik, 1986; Schultz and Thompson, 1990). Survival and shoot growth after transplanting depend to a great extent on the seedling root system form and the ability of the seedling to rapidly produce new roots (Sutton, 1980; Burdett *et al*., 1983).

Oak regeneration is a specific problem on poor sites. Bare-rooted 1- or 2-year old seedlings are used which have been undercut or not undercut in the nursery in the seedbed. Undercutting is one of the important cultural treatments that have potential to influence hardwood seedling morphology. The undercutting operation is done in order to facilitate transplanting operation in the forest of taproot species by reducing the taproot length and increasing the number of lateral roots above the undercut point. A large number of lateral roots are known to increase shoot growth compared to seedlings with fewer lateral roots (Kormanik, 1986; Harmer and Walder, 1994; Schultz and Thompson, 1996). The timing of undercutting can have an effect on number of lateral roots, though the results in the literature are not consistent. Early undercutting has been found to increase resource allocation to the roots, contrary to late undercutting which decreases resource allocation (Schultz and Thompson, 1996). Shoot growth and leaf area can be reduced, whereas root dry weight can be improved compared with uncut acer seedlings (Hipps *et al*., 1996).

McKay *et al*. (1999) found that survival was increased in undercut beech seedlings compared with uncut seedlings. Bare-rooted seedlings are exposed to desiccation and rough handling after lifting and during the transplanting process, which might affect the growth after transplanting. Afterwards the newly transplanted forest seedlings have to complete with weeds (Gemmel *et al*., 1996). The turnover of production is important and thus high survival and growth after transplanting are necessary.

A large variability in seed size is common in oak species and could affect seedling quality. Large seeds have traditionally been viewed as advantageous in closed communities, such as forests, whereas small seeds would be more suitable for open successional communities (Gross, 1984). Environmental influences during the

Corresponding Author: Dr. F. Tilki, Artvin Coruh University, Faculty of Forestry, Artvin-08000, Turkey.
E-mail: fahrettintilki@yahoo.com

development of seeds combined with genetic variability can result in variations in seed dimensions (Willan, 1985). In some deciduous and conifer tree species larger seeds were regarded to produce greater seedlings Large seeds have usually resulted in increases germination and seedling growth of some tree species (Negi and Todaria, 1997; Ke and Werger, 1999; Navarro *et al*., 2006; Cicek and Tilki, 2007).

The following experiment using sessile oak (*Quercus petraea* (Mattuschka) Liebl.), which is an important forestry species widely distributed throughout Turkey and Europe, was carried out to investigate the growth of 1+0 bareroot seedlings in nursery following undercutting in relation to acorn size.

MATERIALS AND METHODS

The seeds of sessile oak were collected from its natural habitats in Ardanuc, Turkey (lat. 41° 08' N, long. 42°10' E, altitude 650 m a.s.l.) in mid-October 2005 and immediately after collection all seeds were washed, and those obviously defective were discarded and seeds were floated to remove debris and empty or weeviled seeds (any that floated) (Pichon and Guibert, 2001). Acorn size classes were determined by mixing and spreading acorns on a flat surface, and the seeds were visually separated into three seed size sizes, small, medium and large according to their sizes. Average acorn weight, length and diameter of each group were determined in four replicates of 100 acorns and three acorn size classes were determined as small (seed length 24.82 mm, seed diameter 13.14 mm, seed weight 3.37 g), medium (seed length 32.59 mm, seed diameter 16.76 mm, seed weight 5.96 g) and large (seed length 36.83 mm, seed diameter 19.65 mm, seed weight 8.38 g).

The nursery experiment was carried out on a clay loam soil at Ardanuc Forest Nursery, Turkey (alt. 700 m a.s.l.). The nursery soil was clay loam with a soil pH of 7.1. The seeds from each seed size were sown by hand in nursery bed which was standard 1.2 m wide with five rows, and each plot (experimental units) was 1 m long. Each bed represented a block which was divided into equal plots of 1.2 m^2, and in each plot 100 seeds were sown in March 2006. Before sowing, the seeds were soaked overnight in water. Acorns were also fumigated with Pomarsol Forte before sown in nursery bed. After sowing, the seeds were covered with 3-5 cm of the mixtures of sand, forest soil and mineral soil. During the vegetation period, following the sowing date, the only treatment given was irrigation and weed control-hoeing regularly. The seedbed was covered with net for protection against birds. The net was removed after the sign of acorn germination in early April. The experiment in nursery was a randomized block design with four replicates of 100 seeds for each seed size. Undercutting treatment was done with a lifting blade at a depth of 20 cm cutting the roots horizontally according to the time (June, July and June/July) and acorn size.

Only the seedlings in the three middle rows were used for morphological analysis in the experiment. The seedlings were measured for height (cm) and diameter at the root collar (mm) in December 2006. Samples of 10 seedlings per plot selected at random (40 seedlings in each seed size) were randomly hand-lifted without harming the roots from each acorn size class in December 2006 and a variety of morphological traits were measured. The media was carefully removed from the roots using both water and tweezers. The number of large lateral roots with diameters >1mm and fine lateral roots <1mm were measured and recorded (Harmer and Walder, 1994; Andersen, 2004). Seedlings were then cut at the cotyledon scars, and dry weight of roots in roots pruned to 25 cm and shoots was determined after drying for 48 h at 70 °C (Andersen, 2004).

An analysis of variance was used to compare the germination performance to the seed sizes, and to evaluate the effects of the undercutting treatments on seedling growth in relation to acorn sizes. When significant differences were found, Duncan' New Multiple Range Test was performed for comparison of the means. Count data (root number) were arcsine transformed to stabilize any heterogeneous variance (Zar, 1996). When significant differences were found, Duncan' New Multiple Range Test was performed for comparison of the means. Statistical analyses were performed with the help of the computer software package SPSS.

RESULTS AND DISCUSSION

Results:

Analysis of variance indicated significantly differences in seedling height, diameter, dry weight and numbers of roots due to undercutting, acorn size, and undercutting treatment by acorn size interaction ($p<0.05$). For uncut control treatment, seedlings from acorns of small size class exhibited significantly poor growth, and seedling height, root collar diameter, shoot dry weight and root dry weight were the lowest (13.2 cm, 5.7 mm, 1.6 g and 4.0 g, respectively) (Tables 1-4). The growth and dry weight were observed higher for the seedlings raised from acorns of medium and large size classes. Seedlings from acorns of large size class had the highest number of lateral roots (Tables 5 and 6).

Table 1: Seedling height (cm) of sessile oak after undercutting treatments in the seedbed in relation to seed size.

Undercutting treatment	Acorn size			
	Small	Medium	Large	Mean
Uncut control	13.2bA	20.5aA	22.9aB	18.9AB
June	10.4cB	18.6bA	26.4aAB	18.5AB
July	11.7cB	20.7bA	28.5aA	20.4A
June/July	11.3cB	15.8bB	24.3aB	17.1B
Mean	11.6c	18.9b	25.5a	

Values in the row followed by the same lowercase letter are not significantly different at p<0.05.
Values in the same column followed by the same capital letter are not significantly different at p<0.05.

Table 2: Seedling diameter (mm) of sessile oak after undercutting treatments in the seedbed in relation to seed size.

Undercutting treatment	Acorn size			
	Small	Medium	Large	Mean
Uncut control	5.7bA	6.8aB	7.3aB	6.6AB
June	5.3cA	6.5bB	7.5aB	6.5AB
July	5.5bA	8.4aA	8.8aA	7.6A
June/July	4.6aB	4.7bC	7.0aB	5.4B
Mean	5.3c	6.6b	7.6a	

Values in the row followed by the same lowercase letter are not significantly different at p<0.05.
Values in the same column followed by the same capital letter are not significantly different at p<0.05.

Table 3: Root dry weight (g) of sessile oak after undercutting treatments in the seedbed in relation to seed size.

Undercutting treatment	Acorn size			Mean
	Small	Medium	Large	
Uncut control	4.0Ab	8.2Aa	7.7Aa	6.7A
June	2.9Bb	5.9Ba	6.6Ba	5.2B
July	2.8Bb	9.5Aa	8.6Aa	6.9A
June/July	2.2Bc	4.1Cb	6.1Ba	4.2C
Mean	3.0b	6.9a	7.3a	

Values in the row followed by the same lowercase letter are not significantly different at p<0.05.
Values in the same column followed by the same capital letter are not significantly different at p<0.05.

Table 4: Shoot dry weight (g) of sessile oak after undercutting treatments in the seedbed in relation to seed size.

Undercutting treatment	Acorn size			Mean
	Small	Medium	Large	
Uncut control	1.6Ab	3.3Ba	3.7Ba	2.8B
June	1.0Bb	2.2Ca	3.8Ba	2.4B
July	1.2ABb	4.2Aa	4.9Aa	3.4A
June/July	0.9Bc	1.7Cb	3.2Ba	1.7C
Mean	1.1c	2.9b	3.9a	

Values in the row followed by the same lowercase letter are not significantly different at p<0.05.
Values in the same column followed by the same capital letter are not significantly different at p<0.05.

Table 5: Number of fine lateral roots of sessile oak after undercutting treatments in the seedbed in relation to seed size.

Undercutting treatment	Acorn size			Mean
	Small	Medium	Large	
Uncut control	6.5Bc	9.2Bb	13.6Aa	9.8B
June	10.1Ab	14.0Aa	10.2Bb	11.4A
July	9.2Ab	12.5Aa	11.8Ba	11.2A
June/July	7.1Bb	9.1Ba	5.3Cc	7.2C
Mean	8.2b	11.2a	10.2a	

Values in the row followed by the same lowercase letter are not significantly different at p<0.05.
Values in the same column followed by the same capital letter are not significantly different at p<0.05.

Table 6: Number of large lateral roots of sessile oak after undercutting treatments in the seedbed in relation to seed size.

Undercutting treatment	Acorn size			Mean
	Small	Medium	Large	
Uncut control	3.5Bb	3.7Bb	4.3Ba	3.8C
June	6.1Aa	6.2Aa	6.5Aa	6.3A
July	3.3Bb	6.1Aa	5.7Aa	5.0B
June/July	3.2Bb	3.5Bab	3.7Ba	3.5C
Mean	4.0b	4.9a	5.0a	

Values in the row followed by the same lowercase letter are not significantly different at p<0.05.
Values in the same column followed by the same capital letter are not significantly different at p<0.05.

Seedling height ranged from 10.4 cm for small sized undercut seedlings in June to 28.5 cm for large sized undercut seedlings in July (Table 1). Seedling height was the highest in large sized seeds when averaged for the undercutting treatments. Time of undercutting had an effect on height growth. A negative effect of undercutting in June/July was found compared with all the other treatments (Table 1).

Seedling diameter was the highest in seedlings produced from medium and large sized seeds when undercut in July (8.4 and 8.8 mm, respectively) (Table 2). Root dry weight was the highest in seedlings produced from medium and large sized seeds when undercut in July or uncut control. Undercutting in June-July decreased root dry weight significantly (Table 3). Shoot dry weight was the highest in seedlings produced from medium and large sized seeds (>4 g) when undercut in July (Table 4).

Numbers of fine lateral roots < 1 mm ranged from 6.5 for small sized uncut control seedlings to 14.0 for medium size undercut seedlings in June (Table 5). Mean numbers of lateral fine roots < 1 mm were the highest in seedlings undercut in June and July when averaged over three acorn sizes. Time of undercutting had an effect on number of fine lateral roots < 1 mm and a negative effect of undercutting was found in large sized seeds.

Numbers of large lateral roots > 1 mm ranged from 3.2 for small sized undercut seedlings in June-July to 6.5 for large sized undercut seedlings in June (Table 6). Mean numbers of large lateral roots > 1 mm were the highest in seedlings undercut in June when averaged over three acorn sizes. The large lateral roots were the highest in seedlings produced from medium and large sized seeds when undercut in June or July.

Discussion:

The better performance of larger seeds may simply be a reflection of the greater amount of nutrients available to the embryo (Abideen *et al*., 1993). Brookes and Wingston (1979) found that large acorns of *Q. petraea* and *Q. robur* had greater amounts of nutrients. In this study small sized seeds produced less seedling growth. In some deciduous tree species larger seeds were regarded to produce greater seedlings and seedlings from larger seeds grew stronger including some oaks as found in the present study (Long and Jones, 1996; Singh, 1998; Karrfalt, 2004; Upadhaya *et al*., 2007). Large size in *Quercus ilex* enhanced seedling growth (Gomez, 2004), and the effect of seed size was also significant for *Quercus rugosa* and *Q. laurina*, with a positive correlation between seed mass and growth (Bonfil, 1998). However, in some species large seed did not produce the highest seedling growth (Indira *et al*., 2000; Khera *et al*., 2004; Tilki and Alptekin, 2005; Moles and Westoby, 2006).

Cicek and Tilki (2007) found that seed size of sweet chestnut did not significantly affect the average numbers of seedling roots. But in the present study it was found that undercutting and acorn size affected number of roots and large sized seeds produced highest number of lateral fine roots and lateral large roots for uncut control. Lateral roots are important for initial seedling survival and shoot development, and according to Harmer and Walder (1994) nursery management should maximize fine lateral root production. In the present study large seed size produced the highest fine and large lateral roots. Seedlings from small seed size class also produced small growth features and low dry weight in this study. This phenomenon may confer a competitive disadvantage in the small sized seeds. The production of seedlings that are both large and vigorous is important to the forester who will outplant at the end of the first growing season. Seedling size is critical from the standpoint of survival and the ability to withstand competition from other seedlings, grasses, and weeds. Thus, seedlings from smaller seeds would grow and compete less successfully than the seedlings from large or medium seeds, hence plants from large or medium seeds would likely to establish more successfully. Andersen (2004) found that undercutting reduced height, root and shoot dry weight compared with uncut control although not significantly in the treatments. It was also found that undercutting reduced root dry weight, although only significantly in September of year 1. Shoot dry weight was significantly reduced in all undercutting treatments in year 1 (July, September, November, July/November) compared with controls. Undercutting in September and July in two consecutive years increased the number of first-order lateral roots and undercutting in two consecutive years had a more negative effect, than undercutting in 1 year (Andersen, 2004). Harmer and Nalder (1994) found similar effects of undercutting on morphological characteristics in *Q. robur*, whereas other have found no morphological effects (Hipps *et al*., 1996; McKay *et al*., 1999). However differences in time of sowing, undercutting and lifting etc. can make it difficult to compare the results, as age of the seedling at the time of undercutting can alter the results as found in the present experiment. In the present study when averaged over three acorn size classes undercutting did not reduce seedling height and diameter, and increased shoot dry weight, number of large lateral roots and fine lateral roots. But time of undercutting affected seedling morphological attributes and a negative effect of undercutting in June/July was found compared with all the other treatments. Undercutting in July produced greater seedlings from acorns of medium and large size class (for both height and diameter) that had greater numbers of large lateral roots compared to the other undercutting treatments.

Undercutting produced smaller seedlings in red oak and black walnut (for both height and diameter) that had greater numbers of first-order lateral roots (Schultz and Thompson, 1996). Cutting the tap root of *Q. robur* seedlings had little effect on shoot growth but markedly chanced the structure of the root system (Harmer and Walder, 1994). Red oak seedlings with five or more large first-order lateral roots have a greater probability of success both in terms of survival and early growth than do those with four or fever first-order lateral roots (Thompson and Schultz, 1995). For red oak and black walnut, seedlings that were undercut had greater numbers of first-order lateral roots (Schultz and Thompson, 1996).

According to the present study acorn sizing and undercutting treatment in the nursery appear to be a tool to the nursery manager to produce larger seedlings. Seedlings from acorns of small size class exhibited significantly poor growth and undercutting in July produced greater seedlings from acorns of medium and large size class (for both height and diameter) that had greater numbers of large lateral roots. Thus, it is desirable to remove the seeds of small size class from the bulk sample to ensure more seedling growth. However, as stated by Karrfalt (2004), discarding small seeds should not be practiced unless there is good genetic evidence to demonstrate the practice is not discarding whole families with possible good growth potential.

REFERENCES

Abideen, M.Z., K. Gopikumar and V. Jamaludheen, 1993. Effect of seed character and its nutrient content on vigour of seedlings in *Pongamia pinnata* and *Tamarindas indica*. My Forest, 29: 225-230.

Andersen, L., 2004. Field performance of *Quercus petraea* seedlings grown under competetive conditions: influence of prior undercutting in the seedbed. New For., 28: 37-47.

Bonfil, C., 1998. The effects of seed size, cotyledon reserves, and herbivory on seedling survival and growth in *Quercus rugosa* and *Q. laurina* (Fagaceae). Amer. J. Bot., 85: 79-87.

Brookes, P.C. and D.L. Wingston, 1979. Variation of morphological and chemical characteristics of acorns from populations of *Quercus petraea* (Matt.) Liebl., *Q. robur* L. and their hybrids. Watsonia, 12: 315-324.

Burdett, A.N., D.G. Simpson and C.F. Thompson, 1983. Root development and plant establishment success. Plant and Soil, 71: 103-110.

Cicek, E. and F. Tilki, 2007. Seed size effects on germination, survival and seedling growth of *Castanea sativa* Mill. J. Biol. Sci., 7: 438-441.

Czabator, F.J., 1962. Germination value: An index combining speed and completeness of pine seed germination. For. Sci., 8: 386-396.

Gemmel, P., U. Nilsson and T. Welander, 1996. Development of oak and beech seedlings planted under varying shelterwood densities and with different site preparation methods in southern Sweden. New For., 12: 141-161.

Gomez, J.M., 2004. Bigger is not always better: Conflicting selective pressures on seed size in *Quercus ilex*. Evolution, 58: 71-80.

Gross, K.L., 1984. Effects of seed size and growth form on seedling establishment of six monocarpic perennial plants. J. Ecol., 72: 369-387.

Harmer, R. and K.E. Walder, 1994. The growth of shoots and lateral roots of *Quercus robur* L. seedlings following simulated undercutting. New For., 8: 351-362.

Hipps, N.A., K.H. Higgs and L.G. Collard, 1996. The effect of irrigation and root pruning on the growth of sycamore (*Acer pseudoplatanus*) seedlings in nursery beds and after transplantation. J. Hort. Sci., 71: 819-828.

Indira, E.P., S.C. Basha and K.C. Chacko, 2000. Effect of seed size grading on the germination and growth of teak (*Tectona grandis*) seedlings. J. Tropic. For. Sci., 12: 21-27.

Karrfalt, R.P., 2004. How acorn size influences seedling size and possible seed management choices. In National Proceedings: Forest and Conservation Nursery Associations-2003, Eds., Riley, I.E. *et al.,* USDA For. Serv. RMRS-P-33. Fort Collins, CO, pp: 117-118.

Ke, G. and M.J.A. Werger, 1999. Different responses to shade of evergreen and deciduous oak seedlings and the effect of acorn size. Acta Oecol., 20: 579-586.

Khera, N., A.K. Saxena and R.P. Singh, 2004. Seed size variability and its influence on germination and seedling growth of five multipurpose tree species. Seed Sci. Technol., 32: 319-330.

Kormanik, P.P., 1986. Lateral root morphology as an expression of sweetgum seedling quality. For. Sci., 32: 595-604.

Long, T.J. and R.H. Jones, 1996. Seedling growth strategies and seed size effects in fourteen oak species native to different soil moisture habitats. Trees, 11: 1-8.

McKay, H.M., R.L. Jinks and C. McEvoy, 1999. The effect of desiccation and rough-handling on the survival and early growth of ash, beech, birch and oak seedlings. Ann. For. Sci., 56: 391-402.

Moles, A.T. and M. Westoby, 2006. Seed size and plant strategy across the whole life cycle. Oikos, 113(1): 91-105.

Navarro, F.B., M.M. Jimenez, M.A. Ripoll, E.F. Ondono, E. Gallego and E. De Simon. 2006. Direct sowing of holm oak acorns: effects of acorn size and soil treatment. Ann. For. Sci., 63: 961-967.

Negi, A.K. and N.P. Todaria, 1997. Effect of seed size and weight on germination pattern and seedling development of some multipurpose tree species of Garhwal Himalaya. Indian For., 123: 32-36.

Schultz, R.C. and J.R. Thompson, 1990. Nursery practices that improve hardwood seedling root morphology. Tree Planters' Notes, 41: 21-32.

Schultz, R.C. and J.R. Thompson, 1996. Effect of density control and undercutting on root morphology of 1+0 bareroot hardwood seedlings: five year field performance of root-graded stock in the central USA. New For., 13: 297-310.

Singh, O., 1998. Effect of seed weight on germination, survival and initial growth of *Quercus dilatata* in the nursery. Indian For., 124: 959-961.

Sutton, R.F., 1980. Planting stock quality, root growth capacity, and field performance of 3 boreal conifers. New Z. J. For. Sci., 10: 54-71.

Thomson, J.R. and R.C. Schultz, 1995. Root system morphology of *Quercus rubra* L. planting stock and 3-year field performance in lowa. New For., 9: 225-236.

Tilki, F. and C.U. Alptekin, 2005. Variation in acorn characteristics in provenances of *Quercus aucheri* Jaub. et Spach and provenance, temperature and storage effects on acorn germination. Seed Sci. Technol., 33: 441-447.

Upadhaya, K., H.N. Pandey and P. Law, 2007. The effect of seed mass on germination, seedling survival and growth in *Prunus jenkinsii* Hook.f. & Thoms. Turk. J. Bot., 31: 31-36.

Willan, R.L., 1985. A guide to forest seed handling with special reference to the Tropics. FAO Forestry Paper 20-2. FAO, Rome.

Zar, J.H., 1996. Biostatistical Analysis. 3rd edition. Prentice Hall Inc., Upper Saddle River, New Jersey.