the July 26 date reflected the lower rooting percentage. The average root quality across all treatments for the cutting dates were May 24—2.3, June 15—2.6, and July 26—1.2.

The above data agree with those presented by Harris (6) who recommended a rate of 3,000 to 8,000 ppm IBA in talc preparation to enhance rooting of *Amelanchier*. Dirr (3) has also shown good success with 5,000 ppm IBA. Bishop and Nelson (1) did not find that rooting hormone increased the rooting percentage or rooting quality. Perhaps higher IBA rates in their study would have affected root quality. In their study, the average root quality rating of June cuttings receiving no IBA was 2.2. In transplanting studies performed by Bishop and Nelson, a minimum rating of 3 was suggested to insure success. In their root quality index rating, which included 5 levels, a 3 was described as medium root development. In comparison a medium root developed in the present study would fall between 3 and 4. In this study, the average root qualities of May and June cuttings receiving 10,000, 15,000, or 25,000 ppm were 3.7, 3.8, respectively (Fig. 1 and 2). Although rooting percentage is a valid criterion it may not be as important as the quality of rooting, especially in the nursery industry.

Literature Cited

1. Bishop, B.H. and S.H. Nelson. 1980. Propagation and transplanting of saskatoon (*Amelanchier alnifolia* Nutt.) softwood cuttings. Can. J. Plant Sci. 60:883–890.

2. Cumming, W.A. 1976. Evaluation and propagation of saskatoons. Proc. West. Can. Soc. Hort. 25:76–80.

3. Dirr, M.A. 1987. Native amelanchiers: A sampler of northeastern species. American Nurseryman, Vol. 166(5):66–83.

4. Dirr, M.A. 1990. Manual of Woody Landscape Plants. Stipes Publishing, Champaign, IL.

5. Dirr, M.A. and C.W. Heuser, Jr. 1987. The Reference Manual of Woody Plant Propagation. Varsity Press, Inc., Athens, GA.

6. Doran, W.L. 1957. Propagation of woody plants by cuttings. Mass. Expt. Sta. Bul. 491, p. 20.

7. Fung, M.Y.P. 1984. Vegetative propagation of native shrubs in the Fort McMurray area, Alberta, Canada. Plant Propagator 30(4):7–9.

8. Harris, R.E. 1961. The vegetative propagation of *Amelanchier alnifolia*. Can. J. Plant Sci. 41:728–731.

9. Harris, R.E. 1980. The saskatoon. Canadian Dept. of Agr. Pub. 1246, pp. 3, 4, 5.

10. Hartmann, H.T., D.E. Kester and F.T. Davies, Jr. 1990. Plant Propagation—Principles and Practices. Prentice-Hall Inc., Englewood Cliffs, NJ.

11. Lamb, J.G.D., J.C. Kelly, and P. Bowbrick. 1975. Nursery Stock Manual. Grower Books, London, England.

12. Lineberger, R.D. 1981. Shoot tip culture of *Amelanchier laevis*. Ohio Agric. Res. Dev. Center Res. Circ. 263:17–19.

13. Wallace, J.A. and T.O. Graham. 1976. Outlook in Western Canada towards improvement of the genus *Amelanchier*. Proc. West. Can. Soc. Hort. 25:81–107.

Effect of the Amount of Dormant Pruning on Growth and Water Use of Containerized Crape Myrtle (*Lagerstroemia* × *Fauriei* 'Tuscarora')

Jayne M. Zajicek,[1] Susan L. Steinberg,[2] and M.J. McFarland[2]
Departments of Horticultural Sciences and Agricultural Engineering
Texas A&M University
College Station, TX 77843

Abstract

A study was conducted to determine the effects of different dormant pruning treatments on subsequent plant development and water use of crape myrtle (*Lagerstroemia* × *Fauriei* Koehne 'Tuscarora') transplanted into containers. Dormant, bare-root plants were pruned to the normal practice of a 30% reduction of existing shoot length by heading back and thinning of weak branches. Plants were randomly assigned to 3 pruning treatments including: 1) control—no further pruning, 2) shoot pruned—an additional 50% reduction of remaining shoot length for a total of 65% reduction in shoot length, or 3) a 50% reduction of root area in addition to the 30% reduction in shoot length. Fifty percent (50%) root pruning severely reduced earliness of bud-break and plant survival when compared to either the control or the 65% shoot pruning treatments. Earliest bud-break and highest plant survival were rated for plants in the 65% shoot pruned treatment. Plants in the 50% root pruned treatment had a significantly higher number of terminal shoots, but average shoot lengths were significantly shorter when compared to plants in the 65% shoot pruned treatment. At final harvest there were no significant differences in mean dry weights and leaf area, total shoot length, or average water use between treatments. However, a large plant to plant variation in growth and water use due to the pruning treatments was observed. Plants in the 50% root pruned treatment were less uniform in size and water use as compared to control plants or 65% shoot pruned plants which exhibited the greatest uniformity.

Index words: transpiration, root:shoot ratio, bare root, root pruning

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[1]Assistant Professor, Department of Horticultural Sciences.

[2]Post Doctoral Research Associate and Professor, resp., Department of Agricultural Engineering.

Significance to the Nursery Industry

Heavy heading back (65%) of shoot length on bare-root crape myrtle plants, transplanted into containers, produced more uniform branching patterns and a larger number of plants breaking bud earlier compared to light heading back (30%). Plant uniformity is essential in containerized production aiding in scheduling, crop turnover, and management of resources such as chemicals and water. Nurserymen initiating this pruning technique on bare-rooted crape myrtles could have an earlier maturing crop with less plant mortality. These benefits, in addition to better plant uniformity, would help in reducing labor costs, allow for faster turnover, and aid in incorporation of crape myrtle into modern mechanical systems. The benefits of this practice may not apply to all woody species due to the fact that some species can withstand heavy pruning better than others (14, 22) and research on additional species is needed.

Introduction

A trend toward container nursery production has been evident for a number of years, especially in warmer climates where it is estimated that 80–90% of the woody landscape plants produced are grown in containers (2). Some containerized shrubs and small trees are field-grown plants that are dug and transplanted while dormant into containers for later forcing and sale. This method produces more uniform plants that can be forced to break-bud earlier under controlled environments and are easier to transplant into the landscape. A popular small flowering tree or shrub in the southern United States, crape myrtle (*Lagerstroemia* sp. L.) lends itself to this type of production system due to its late spring bud-break. When crape myrtles are dug from the field, most of the absorbing roots are either removed or desiccate during handling and winter storage. The majority of roots left after digging are old and suberized, still capable of absorbing appreciable quantities of water, but only from a limited soil volume (12, 13). Therefore, establishment and survival of transplanted bare-root trees depends on rapid regeneration of a new root system (15, 21).

Thinning to remove weak branches and heading-back of 30% of existing shoot length is often recommended at planting time for dormant, bare-root trees and shrubs to compensate for the loss of roots and establish a more favorable root to shoot ratio (4, 11). This, in turn, reduces the probability of injurious water stress during establishment (5, 10).

Conflicting results have been reported on the effects of pruning as it relates to the establishment and subsequent growth of bare-root stock under field conditions. Several researchers have reported that pruning improved performance of transplanted landscape plants and fruit trees, with increased rate of growth, and number and length of new shoots (3, 9, 19, 23). In contrast, Maggs (16) reported decreased shoot growth of apple seedlings due to pruning, with a reduction in leaf area proportionate to the severity of pruning.

There is little or no data on pruning requirements for the establishment of bare-root plants transplanted into containers. With the trend towards more containerized stock, information is essential for successful establishment and subsequent growth of these plants. This study was conducted to determine the effects of shoot and root pruning on plant development and water use of bare-root crape myrtle plants subsequently transplanted into containers.

Materials and Methods

One-year old, dormant, bare-root crape myrtle (*Lagerstroemia* × *Fauriei* 'Tuscarora'), with an average shoot length of 45 cm (17.7 in) and an average root length of 23 cm (9.0 in), were received from a commercial nursery on January 5, 1988. Plants were held at 5°C (41°F) and moistened daily until planted on January 10, 1989 in 3.8 liter (1 gal) pots containing fritted clay. Plants were grown in a glasshouse [26 ± 4°C (79 ± 4°F), 80 ± 11% relative humidity, 400–1000 μmol m^{-2} s^{-1} PAR, 14 hr photoperiod] on the campus of Texas A&M University (30.4°N, 96.2°W). The shrubs were irrigated to maintain well watered conditions throughout the study and fertilized weekly with Peters Peat-Lite Special (15N-6.8P-14.3K) at 250 ppm N.

At the time of planting all plants were thinned to remove weak branches and 30% of existing shoot length was headed back. The plants were randomly assigned to 3 pruning treatments in a completely randomized design with 10 crape myrtles per treatment. The treatments were: 1) control—no further pruning, 2) shoot pruned—additional 50% of remaining shoot length headed back for a total of 65% shoot length removed and 3) root pruned—50% of root area removed in addition to the 30% shoot length headed back.

From January 16, 1989, until termination of the experiment (April 6, 1989), whole plant transpiration was determined gravimetrically by weighing all plants daily at 1600 hr with a Mettler PM16 balance accurate to 0.1 g (0.004 oz) on a 16 kg (35.2 lb) range. The pots were covered with white polyethylene plastic which was secured around the plant crown to prevent evaporation; thus, water loss was equivalent to transpiration.

Weekly growth measurements included day of bud break (detectable bud swell of the first bud), shoot length, and terminal shoot number. At the termination of the experiment, total terminal shoot number, shoot length, and leaf area were measured. The shrubs were partitioned into shoot, root, and leaves, and the respective dry weights were obtained.

An analysis of variance procedure was performed and separation of means was determined by Duncan's multiple range test. A log transformation of the data was performed on water use variation within treatments (18).

Results and Discussion

A major difference observed between pruning treatments was in the earliness of bud-break and total number of plants breaking bud in each treatment (Fig. 1). Thirteen days after

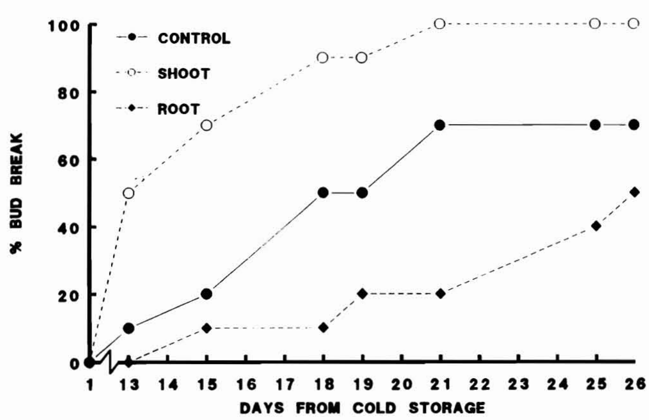

Fig. 1. Effect of pruning on bud break of bare-root crape myrtle plants transplanted into containers. Control = 30% shoot length headed back, Shoot = 65% shoot length headed back, Root = 50% root area removed and 30% shoot length headed back.

Table 1. **Effect of pruning on terminal shoot number and average shoot length of bare-root crape myrtle plants transplanted into containers.**

	Terminal Shoot Number		Avg Shoot Length (cm)	
	Removal from Cold Storage (Days)			
Treatment	**34**	**80**	**34**	**80**
Control[z]	26.70 ab[y] (±3.33)[x]	25.43 a (±3.60)	9.12 a (±0.92)	12.55 b (±1.25)
Shoot Pruned	18.10 b (±1.80)	18.89 a (±1.96)	9.32 a (±0.51)	17.07 a (±1.18)
Root Pruned	33.00 a (±8.54)	28.75 a (±7.49)	6.81 b (±0.89)	9.80 b (±1.17)

[z]Control = 30% shoot length headed back, Shoot Pruned = 65% shoot length headed back, and Root Pruned = 50% root area removed in addition to 30% shoot length headed back.

[y]Means are the average of 10 replications. Mean separation within columns by Duncan's multiple range test, P = 0.05.

[x] ±SE in parentheses to demonstrate variability within each treatment.

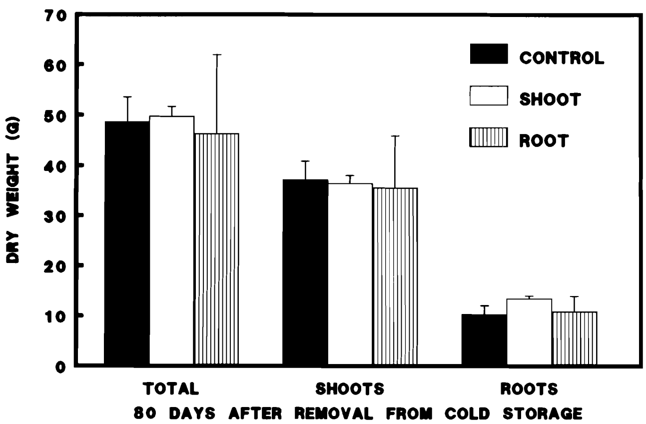

Fig. 2. **Effect of pruning on dry weights of bare-root crape myrtle plants transplanted into containers. Control = 30% shoot length headed back, Shoot = 65% shoot length headed back, Root = 50% root area removed and 30% shoot length headed back. Vertical bars represent SE of the mean (n = 10). Treatment means are nonsignificant P = 0.05.**

planting, 50% of the 65% shoot pruned plants had buds that were swelling, compared to 10% of the control plants and 0% of the root pruned plants. By day 21, 100% of the 65% shoot pruned plants had broken bud compared to 70% of the control plants and 20% of the root pruned plants. At the termination of the study, only 50% of the root pruned plants and 70% of the control plants had broken bud.

Differences were observed between terminal shoot number and average shoot length of the root pruned plants versus the shoot pruned plants throughout this study (Table 1). Sixty-five percent (65%) shoot pruned plants had fewer terminal shoots, but average shoot length of the terminal shoots present was significantly longer than those of the root pruned plants. This is in agreement with reports on several varieties of fruit trees that pruning of dormant branches increased the rate and length of new growth (3).

At the termination of the experiment there were no significant differences between treatments in mean dry weights (Fig. 2), total shoot length or leaf area (data not presented). We did not observe a negative effect due to the amount of shoot pruning on root growth (Fig. 2). However, reduced root growth after pruning has been observed by others (6, 8, 23).

The pruning treatments did not appear to have any effect on water use of the plants. There were no differences between treatments in mean daily water use measured over a six week period (Table 2). Daily water use on a leaf area basis was also non-significant (data not presented).

From Fig. 1 it is apparent that plants in the root pruned treatment broke bud sporadically over a longer period of time. This caused a large variability in plant size compared to the 65% shoot pruned or control plants. The variation in plant growth of root pruned plants was at least twice that

Table 2. **Effect of pruning on average daily water use per week and water use variation within treatments of bare-root crape myrtle plants transplanted into containers.**

	Water Use					
	Grams per Day			Water Use Variation		
Week	**C[z]**	**S**	**R**	**C**	**S**	**R**
1	3.98[y]	3.57	4.16	1.20 a[x]	0.99 a	1.23 a
2	17.77	16.98	14.47	5.31 a	3.87 b	5.82 a
3	37.69	37.08	32.66	6.23 b	5.01 c	7.12 a
4	53.92	57.12	46.52	6.54 a	5.53 b	7.28 a
5	103.33	110.52	90.71	7.66 b	6.49 c	8.73 a
6	227.28	246.46	196.99	7.47 b	6.67 c	8.46 a

[z]C = 30% shoot length headed back, S = 65% shoot length headed back, and R = 50% root area removed in addition to 30% shoot length headed back.

[y]Average daily water use means are nonsignificant, P = 0.05.

[x]A log transformation of the data was performed on water use variation within treatments. Mean separation across rows by Duncan's multiple range test, P = 0.01.

of the 65% shoot pruned plants as indicated by the standard error bars in Fig. 2. This variation of plant size within treatments caused significant differences in the variation of water use between plants of the different pruning treatments (Table 2). The variation in water use of the root pruned plants was significantly greater than the 65% shoot pruned plants after week 2 and for the control plants at week 3 and after week 5 (Table 2). For both growth and water use, the least amount of variation was recorded among 65% shoot pruned plants.

It has been reported by Hansen (7) and further documented by Young and Werner (24) and Young et al. (25), that carbohydrate reserves stored in the root system are mobilized in the xylem before bud-break and used rapidly during bud-break to support new shoot growth. In the present study, the shortage of these reserves, due to the lack of roots in the root pruned treatment, may have been partially responsible for the low percentage of plants that broke bud in this treatment. It has also been suggested that plant hormones synthesized in the root, such as cytokinins, may be involved in reinvigorated growth of pruned plants (20). Shoot pruning may contribute directly to the accumulation of cytokinins in the remaining shoots by removing competing shoot area which would metabolize cytokinins. The present study suggests that the larger root to shoot ratio of the additional shoot pruned plants may reduce competition between shoots for water, nutrients, hormones, and other growth-promoting factors. In addition, Carlson (1) reported that the presence of leaves may be necessary for new root initiation in some woody plants. Richardson (17) reported that root growth of *Acer saccharinum* is only possible when at least one bud is physiologically nondormant and able to export the necessary growth factors to the roots. Imposed dormancy, however, is no barrier to this process, and root growth is possible in the field, therefore when plants are leafless. If this is the case in crape myrtle, increasing the earliness of bud break and leaf development would be beneficial to new root development.

Literature Cited

1. Carlson, W.C. 1972. Indoleacetic acid content of roots of northern red oak seedlings during root regeneration. M.S. Thesis, Ohio State University, Columbus.

2. Davidson, H., R. Mecklenburg and C. Peterson. 1988. Nursery Management Administration and Culture. 2nd Edition. Prentice Hall, Englewood Cliffs, New Jersey.

3. Elfving, D.C. 1976. Growth and fruiting responses of vigorous apple branches to pruning and branch orientation treatments. J. Amer. Soc. Hort Sci. 101:290–293.

4. Evans, S.P. and J.E. Klett. 1984. The effects of dormant pruning treatments on leaf, shoot and root production from bare-root *Malus sargentii*. J. Arboric. 10:298–302.

5. Flemer III, W. 1982. Successful transplanting is easy. J. Arboriculture 8:234–240.

6. Fordham, R. 1972. Observations on the growth of roots and shoots of tea (*Camellia sinensis* L.) in southern Malawi. J. Hort. Sci. 47:221–229.

7. Hansen, P. 1971. ^{14}C-studies on apple trees: VII. The early seasonal growth in leaves, flowers and shoots as dependent upon current photosynthates and existing reserves. Physiol. Plant. 25:469–473.

8. Head, G.C. 1967. Effects of seasonal changes in shoot growth on the amount of unsuberized root on apple and plum trees. J. Hort. Sci. 42:169–180.

9. Kelly, R.J. and B.C. Moser. 1983. Root regeneration of *Liriodendron tulipifera* in response to auxin, stem pruning, and environmental conditions. J. Amer. Soc. Hort. Sci. 108:1085–1090.

10. Kozlowski, T.T. 1976. Drought and transplantability of trees. pp. 77–90. *In*: Better trees for metropolitan landscapes: symposium proceedings. USDA For. Serv. Gen. Tech. Rept. NE-22.

11. Kozlowski, T.T. and W.J. Davies. 1975. Control of water balance in transplanted trees. J. Arboriculture 1:1–10.

12. Kramer, P.J. and H.C. Bullock. 1966. Seasonal variation in proportions of suberized and unsuberized roots of trees in relation to the absorption of water. Amer. J. Bot. 53:200–204.

13. Kramer, P.J. and T.T. Kozlowski. 1979. Physiology of Woody Plants. Academic Press, New York, N.Y.

14. Larson, M.M. 1975. Pruning northern red oak nursery seedlings: effects on root regeneration and early growth. Can. J. For. Res. 5:382–386.

15. Lathrop, J.K. and R.A. Mecklenburg. 1971. Root regeneration and root dormancy in *Taxus* spp. J. Amer. Soc. Hort. Sci. 96:111–114.

16. Maggs, S.B. 1960. The effect of number of shoots on the quantity and distribution of increment in young apple trees. Ann. Bot. 24:345–355.

17. Richardson, S.D. 1958. Bud dormancy and root development in *Acer saccharinum*. pp. 409–425. *In*: K.V. Thimann, W.B. Critchfield and M.H. Zimmerman (eds.). The Physiology of Forest Trees. Ronald Press, New York, N.Y.

18. Steele, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGraw Hill. New York, N.Y.

19. Sterling, K.A. and C.L. Lane. 1975. Growth and development of shoot and root pruned yellow poplar seedlings on two sites. Tree Planters' Notes. 26:1–2, 25.

20. Taylor, J.S., T.J. Blake and R.P. Pharis. 1982. The role of plant hormones and carbohydrates in the growth of and survival of coppiced *Eucalyptus* seedlings. Physiol. Plant. 55:421–430.

21. Watson, G.W. and E.B. Himelick. 1982. Root distribution of nursery trees and its relationship to transplanting success. J. Arboriculture 8:225–229.

22. Woessner, R.A. 1972. Four hardwood species differ in tolerance to pruning. Tree Plant. Notes. 23:28–29.

23. Young, E. and D.J. Werner. 1982. Early season root and shoot growth of 'golden delicious' apple on four rootstocks as affected by pruning at planting. J. Amer. Soc. Hort. Sci. 107:822–826.

24. Young, E. and D.J. Werner. 1985. Effects of shoot, root, and shank chilling during rest in apple and peach on growth resumption and carbohydrates. J. Amer. Soc. Hort. Sci. 110:769–774.

25. Young, E., Y. Motomura and C.R. Unrath. 1987. Influence of root temperature during dormancy on respiration, carbohydrates, and growth resumption in apple and peach. J. Amer. Soc. Hort. Sci. 112:514–519.