Effect of Transplanting Practices on Growth and Water Relations of 'Colt' Cherry Trees During Reestablishment[1]

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Abstract

Dormant pruning, a film antitranspirant, and soil-applied paclobutrazol were evaluated as transplanting treatments in newly transplanted 'Colt' cherry trees under irrigated and water-stressed conditions. Under irrigated conditions all three treatments were effective in reducing plant water loss. However, all three treatments resulted in large reductions in mean growth rate, mean relative growth rate, root dry weight, and root surface area. The pruning treatment had no effect on the leaf area:root area ratio, whereas the antitranspirant treatment resulted in an increased leaf area:root area ratio, a response considered undesirable. Paclobutrazol decreased the leaf area:root area ratio but also induced abnormal radial enlargement of plant roots. Under water-stressed conditions, all three treatments were effective in reducing plant water loss and were successful in delaying plant water stress. Both pruned and antitranspirant treated plants had improved relative growth rates as compared to the controls.

Index words: Antitranspirant (Folicote), paclobutrazol (PP333), pruning, *Prunus avium* × *pseudocerasus* 'Colt', root, water stress

Introduction

Transplanting practices often result in a considerable reduction in a plant's root system (40). This disruption of the natural balance between root absorptive area and transpiring leaf area may predispose transplanted trees and shrubs to water stress (19) and can lead to poor performance or death.

A variety of transplanting treatments have been utilized in order to reduce plant water loss and minimize water stress during transplanting and reestablishment. Dormant pruning is often recommended during transplanting (14) in order to reduce transpiring leaf area, conserve water, and reestablish a balance between roots and leaves. The use of antitranspirants is an alternative method for reducing transpiration (6, 22) and improving plant water status during reestablishment (5). In addition to these conventional practices, plant growth regulators may be used to regulate leaf expansion, improve root regeneration, and stimulate increased partitioning of growth to the root system; all being common objectives of transplanting treatments. Paclobutrazol [(2RS, 3RS)-1-(4-chlorophenyl)-4, 4-dimethyl-2-(1H-1,2,4 triazol-1-yl) pentan-3-ol], a gibberellic acid biosynthesis inhibitor, has been found to increase root initiation (8, 9, 33, 35), to effectively control shoot and leaf expansion in a wide variety of woody plants (1, 29, 30), to increase assimilate partitioning to the root system (2, 36), and to reduce plant water stress (32, 41).

The purpose of this study was to evaluate and compare the effects of three transplanting treatments: dormant pruning (PR), a film antitranspirant (AT), and soil applied paclobutrazol (PB) on plant growth, partitioning patterns, and water relations of 'Colt' cherry trees under both irrigated and water-stressed conditions.

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Materials and Methods

Bare-root trees of *Prunus avium* × *pseudocerasus* 'Colt', 1.3 cm (0.5 in) in caliper, were acquired from Oregon Rootstocks Inc. (Woodburn, OR) on April 15, 1986 and stored at 5°C (41°F) with roots packed in moist peat moss. Prior to planting, root systems of all plants were pruned to a uniform overall dimension of 15 cm (6 in) in diameter and 20 cm (8 in) in length. Stems were pruned to a single leader 40 cm (16 in) in length. Plants were potted on May 15, 1986 in 38 l (#10) plastic containers filled with a peat moss : vermiculite : soil (1:1:1 by vol) mixture which was pasteurized and screened through 1.6 cm^2 (0.25 $inch^2$) mesh hardware cloth. Each plant received one of four treatments: 1) control, 2) pruning of dormant shoots to 20 cm (8 in) in length (50% reductions) at planting, 3) a foliar spray of 3% Folicote (manufacturers' recommended rate), a wax emulsion film antitranspirant, with 0.25% Triton B-1956 surfactant applied at 1300 hr EDT on July 1, 1986, or 4) 150 mg active ingredient paclobutrazol (50% WP, ICI Americas Inc., Wilmington, DE) per container applied as a soil drench in 1 l of water (14.34 kg/ha or 12.75 lbs/acre) at planting. Rates of paclobutrazol were based on previous experience and other reports (1). Each treatment was applied to 20 plants.

Plants were grown under natural conditions in Ithaca, NY. Containers were spaced on 2 m (6.6 ft) centers and were sunken in the ground such that the surface of the potting media was even with the surrounding grade. Empty containers were used as sleeves to line the holes so that the plant-holding containers could be removed and replaced more easily. The top of the containers were covered with white polyethylene film to minimize evaporation and prevent infiltration of rainwater.

Plants were watered every evening for 60 days after planting. At that time, 10 plants were harvested from each treatment. The remaining 10 plants in each treatment were then water-stressed by discontinuing watering for 24 days in order to observe how the treatments affected plant morphology, water use, and tolerance to water-stress.

Water use was measured gravimetrically using an electronic balance (Mettler EB60, Hightstown, NJ). Daily water use (0800 to 1700 hr EDT) for irrigated plants was measured on seven occasions between July 4 and July 11, 1986. Mean unit leaf transpiration rates were calculated from mean plant transpiration rates divided by total leaf area which was measured with a leaf area meter (LI-COR model 3100, Lincoln, NE) when plants were harvested July 15, 1986. Pre-dawn water potentials were measured with a pressure chamber (Plant Moisture Status Console, Soil Moisture Corp., Santa Barbara, CA) between 0300 and 0430 hr EDT. Vapor pressure deficit (defined as the difference between saturated vapor pressure at ambient temperature and actual vapor pressure) was measured with a Campbell 201 relative humidity probe in conjunction with a Campbell CR21 data logger (Campbell Scientific, Logan, UT). Accumulated vapor pressure deficit (AVPD) was calculated as the sum of hourly averages of vapor pressure deficit and was used as a standardized measure of evaporative demand.

Once harvested, roots were washed free of soil and root surface areas were determined on roots less than 5 mm (.2 in) in diameter. Root length and surface area was measured using a video image analysis system as described by Barnett *et al.* (3). The 2-dimensional area measured by the image analyzer was used to estimate root surface area, assuming roots were round in cross section, by multiplying the measured area by 3.1416. Mean root diameter was calculated from length and surface area measurements. Plant dry weights were determined after drying at 70°C (158°F) for 96 hrs. Leaves which abscised during the water-stress treatment were not included in final dry weights.

A sample of ten (additional) plants from each of the pruned and un-pruned treatments were harvested at the beginning of the experiment (May 15, 1986) to determine mean initial dry weights for use in growth analysis. Because the PR treatment reduced initial plant weight, and because absolute growth is typically relative to initial weight (16), mean relative growth rate was one measure used for comparing treatment. Mean relative growth rate was calculated according to Radford (25):

$$\text{Mean relative growth rate} = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

where ln is the natural log and W_1 and W_2 are total dry wt at times (t) 1 and 2 respectively.

The experiment was arranged as a completely randomized design and was analyzed by an analysis of variance. Transpiration data was analyzed using a repeated measures (nested) protocol with treatment representing the whole unit and time representing the sub unit (27).

Results and Discussion

Irrigated conditions. Analysis of transpiration data, measured on seven days showed no treatment by day interaction ($P > 0.1$). Therefore, the data were averaged for all days and only treatment main effects were presented (Table 1).

The AT, PR, and PB treatments were equally effective in reducing mean plant transpiration rates (Table 1). Such a reduction could have occurred due to reduced transpiration per unit leaf area or a reduction in plant leaf area.

Mean plant transpiration rate for the AT treatment was reduced primarily as a result of lower mean unit leaf transpiration as there was no significant decrease in plant leaf area (Table 1, 2). This reduction in transpiration rate most likely resulted from the physical blockage of stomatal pores.

Table 1. Transpiration rates of transplanted bare-root plants of 'Colt' cherry grown under irrigated conditions, Ithaca, New York.

Treatment	Mean plant transpiration rate ($g \cdot plant^{-1} \cdot hr^{-1}$)	Mean unit leaf transpiration rate ($mg \cdot cm^{-2} \cdot hr^{-1}$)
Control	62.1 a[z]	10.8 b
Antitranspirant	35.3 b	6.8 c
Pruned	38.9 b	11.6 b
Paclobutrazol	28.0 b	16.9 a

[z]Values are main effect means of treatments, for 10 plants, averaged over seven different days. Means followed by the same letter or letters, within a column, are not significantly different using LSD comparisons, $P < 0.05$. Average vapor pressure deficit, over all measurement periods, was 1.663 KPa.

In contrast, the decrease in mean plant transpiration rate in the PR treated plants resulted primarily from lower leaf areas as there was no significant decrease in mean unit leaf transpiration rate (Table 1, 2). The influence of dormant pruning on leaf area may be influenced by the method and severity of pruning and the species involved. Evans and Klett (11) found that for *Malus sargentii*, thinning reduced total leaf weight, but heading shoots back did not. However, thinning shoots of dormant *Prunus cerasifera* 'Newportii' resulted in only a small decrease in final leaf weight even when as much as 78% of the total branch length was removed (12).

The PB treated plants maintained lower mean plant transpiration rates most likely as the result of a large (71%) reduction in plant leaf area (Table 2). This reduction in leaf area more than overcame a significant increase in mean unit leaf transpiration rate (Table 1). The effect of PB on unit leaf transpiration rate and stomatal conductance is often found to vary depending upon the method and rate of application and the species treated. A few studies have found paclobutrazol to reduce leaf conductance or unit leaf transpiration rate (1, 41) while other studies have shown paclobutrazol to increase leaf conductance or unit leaf transpiration rate (10, 32, 34, 41). An increase in leaf conductance may result due to indirect influences of paclobutrazol. Wang *et al.* (37) found that PB treatment reduced endogenous abscisic acid levels. A reduction in abscisic acid concentration might paritally be responsible for increased leaf conductance in PB treated plants, particularly under water stressed conditions, through decreased capacity for abscisic acid control of stomatal closure (7).

Although the AT, PR, and PB treatements were effective in reducing plant water use, the three treatments also reduced mean growth rate by 31%, 49% and 71% respectively (Table 3). Comparisons of mean relative growth rate showed similar trends. The reduction in mean relative growth rate of the PR plants demonstrates that the PR treatment inhibited growth independent of its effect on initial plant weight.

The overall reduction in growth exhibited by the treated plants was also evident in other measures of growth. Mean caliper growth rate was reduced by all three treatments and mean shoot growth rate was reduced by the PR and PB treatments (Table 3). The large reduction in growth of the PB treated plants suggests that the dosage may have been excessive for the desired objective.

Table 2. Morphological measurements of transplanted bare-root plants of 'Colt' cherry after 60 days under irrigated conditons.

Treatment	Leaf area (cm^2)	Shoot:root ratio ($g \cdot g^{-1}$)	Leaf area: root area ratio ($cm^2 \cdot cm^{-2}$)	Root dry weight (g)	Root surface area (cm^2)	Mean root diameter (mm)
Control	5806 a[z]	3.15 a	1.48 b	7.14 a	3970 a	1.38 a
Antitranspirant	5190 a	3.32 a	2.47 a	3.58 c	2166 b	1.26 a
Pruned	3418 b	2.16 b	1.55 b	5.30 b	2653 b	1.24 a
Paclobutrazol	1682 c	1.88 b	0.95 c	3.46 c	2111 b	1.94 b

[z]Values represent means of 10 plants for shoot:root ratios and leaf areas and means of 5 plants for leaf area:root area ratios, root dry weight, root surface area, and mean root diameters. Means followed by the same letter or letters, within a column, are not significantly different using LSD comparisons, $P < 0.05$.

Table 3. Growth measurements of transplanted bare-root plants of 'Colt' cherry after 60 days under irrigated conditions.

Treatment	Mean growth rate ($g \cdot day^{-1}$)	Mean relative growth rate ($mg \cdot g^{-1} \cdot day^{-1}$)	Mean shoot growth rate ($cm \cdot day^{-1}$)	Mean caliper growth rate ($mm \cdot day^{-1}$)
Control	1.11 a[z]	21.6 a	5.78 a	0.08 a
Antitranspirant	0.77 b	18.6 b	5.23 a	0.07 b
Pruned	0.58 b	17.3 b	2.75 b	0.05 c
Paclobutrazol	0.32 c	9.5 c	1.16 c	0.01 d

[z]Values represent means of 10 plants. Means followed by the same letter or letters, within a column, are not significantly different using LSD comparisons, $P < 0.05$.

The AT treatment caused a substantial (31%) reduction in mean growth rate even though the treatment was applied 45 days into the 60 day growth period. If it is assumed that these plants grew at the same rate as the controls (1.11 $g \cdot day^{-1}$) for the first 45 days, then the calculated mean growth rate for the last 15 days, when the AT was applied, would be -0.25 $g \cdot day^{-1}$. This severe reduction in growth most likely reflects an inhibition of photosynthesis below the photosynthetic compensation point, as there was no leaf abscision observed during the growth period. Antitranspirants have been shown to inhibit photosynthesis and growth in a variety of plant species (6, 22, 24). Davies and Kozlowski (6) found that antitranspirants were generally toxic to *Fraxinus americana* and that photosynthesis of treated plants decreased with time, even when the direct physical effects of the AT had worn off. Antitranspirants may inhibit growth by limiting net photosynthesis as a result of blocked stomata, inhibited metabolic function, reflected light, or toxic buildup of metabolic products (24). These restrictions on net photosynthesis and potential toxic side effects suggest that use of AT under irrigated conditions will generally reduce plant growth and reestablishment of transplanted plants.

The reduction in leaf area of the PR plants did not occur without a concomitant reduction in root growth, both in dry weight and surface area (Table 2). Others have found shoot pruning to reduce both root initiation and growth (13, 15, 18, 20, 21, 26, 43) with the exceptions of *Quercus coccinea* (23, 31) and *Liriodendron tulipifera* (17) where root initiation has been found to be stimulated in response to dormant shoot pruning. The general dependence of root growth on actively growing shoots might reflect a requirement for photosynthate or a shoot-produced growth regulator and further suggests that pruning at transplanting is generally counter productive to plant growth and reestablishment under irrigated conditions. The PR and PB treatments reduced the shoot:root dry weight ratio (Table 2) below that of the control. However, the leaf area:root area ratio (Table 2), a more specific measure of transpirational area in relation to root area, did not differ between the CO and PR treatment, indicating that both treatments had a similar functional balance between leaf area and root area, but that the pruned treatments were simply reduced in scale.

The AT treatment resulted in an unfavorable increase in the leaf area:root area ratio, a result counter to desired objectives. Because there was no significant difference in leaf area between the AT and CO treated plants, this adverse effect was primarily the result an inhibition of root growth, both in dry weight and area (Table 2). This result suggests that after the AT looses effectiveness, the AT treated plants may be more predisposed to water-stress than the untreated CO.

The PB treatment significantly reduced the leaf area:root area ratio; but not without causing peculiar abnormalities. Roots of the PB plants were found to be unusually short with significantly greater mean root diameter as compared to other treatments (Table 2). Similar changes in root morphology have been reported for PB treated *Prunus persica* and *Tagetes erecta* (42), *Malus* (28), *Citrus sinensis* (4), and were observed by the authors in seedlings of *Nyssa sylvatica* (unpublished data). The unusual enlargement of PB treated roots have been found to be the result of radial rather than longitudinal expansion of the inner most layer of cortical cells (42). Because PB is translocated primarily in the xylem (38) and yet foliar application of PB is also found to cause increases in root diameter (42) the effects of PB on root growth may represent, to some degree, indirect changes in endogenous plant growth regulators indirectly affected by PB.

Water-stressed conditions. When irrigation was withheld, the CO plants lost water at the greatest rate followed by the AT, PR, and PB treated plants (Fig. 1A). The reduced rate of water loss in treated plants resulted in the delay of plant water stress (Fig. 1B). The CO plants reached a mean pre-dawn water potential of −1.0 MPa (a stress sufficient to induce mid-day wilting) after 17 days (315 AVPD) and a mean pre-dawn water potential of −2.0 MPa (a stress sufficient to induce pre-dawn wilting) by 22 days (400 AVPD). In contrast, the AT and PR plants reached −1.0 MPa after approximately 20 days (350 AVPD) and 24 days (450 AVPD) respectively, both never reaching a mean of −2.0 MPa pre-dawn water potential. The PB plants never dropped below a mean of −0.6 MPa even after 24 days without irrigation. These data demonstrate that AT, PR, and PB treatments can effectively reduce plant water use and minimize water stress under drought-like conditions.

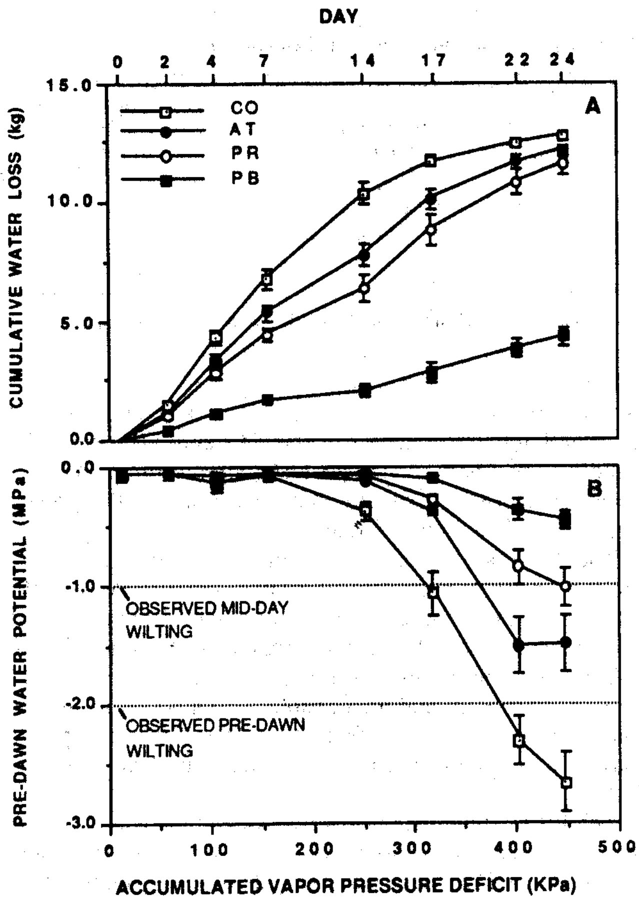

Fig. 1. Water use (A) and corresponding pre-dawn water potentials (B) of control (CO), antitranspirant (AT), pruned (PR) and paclobutrazol (PB) treated plants during a 24 day period with no irrigation, Ithaca, New York. Symbols represent means of 10 plants ± SEM. Accumulated vapor pressure deficit is the sum of hourly means over the treatment period.

Although the AT and PR treatments had lower growth rates than controls under irrigated conditions, there was no significant difference in mean growth rate, mean shoot growth rate, or mean caliper growth rate among these plants under water-stressed conditions (Table 4). Furthermore, comparisons of mean relative growth rate show that the AT and PR treated plants had higher growth rates as compared to the controls. The enhanced growth of the AT and PR plants most likely resulted from improved water status during the growth period. Paclobutrazol treated plants had lower growth rates than the AT, PR, and CO plants (Table 4), as was the case under irrigated conditions.

Significance to the Nursery Industry

There is little justification for dormant pruning, use of antitranspirants, or application of paclobutrazol when transplanting dormant stock if the plants are to be well irrigated. All three treatments severely reduced overall plant growth of 'Colt' cherry under irrigated conditions. Furthermore, the application of an antitranspirant after a spring flush of leaves can limit growth and photosynthesis at a time when growth and regeneration of the root system are most critical. Pruning was successful in reducing leaf area but also impaired root growth. Paclobutrazol also had adverse effects on root morphology.

Consideration of these treatments is more justified if adequate irrigation is not possible and plant survival is of primary concern. All three treatments effectively reduced plant water loss and postponed the onset of water-stress. Furthermore, both the pruned and antitranspirant treated plants had improved relative growth rates in the absence of irrigation. Paclobutrazol treated plants maintained the most positive water potentials; however, the reduction in growth and potential effects on root morphology should be considered prior to application.

The conservation of water during drought periods is particularly important in determining the short term survival of newly transplanted trees as the regeneration of a proportionally sized root system may take a number of years, especially for larger trees (39). The effectiveness of an antitranspirant, dormant pruning, or paclobutrazol in regulating water loss would most likely depend on: 1) the species of plant being treated and 2) the rate or extent, the timing, and method of treatment. The selection of any one of these options would have to be based on and compatible with management objectives.

Table 4. Growth measurements of transplanted bare-root plants of 'Colt' cherry after 24 days under water-stressed conditions.

Treatment	Mean growth rate ($g \cdot day^{-1}$)	Mean relative growth rate ($mg \cdot g^{-1} \cdot day^{-1}$)	Mean shoot growth rate ($cm \cdot day^{-1}$)	Mean caliper growth rate ($mm \cdot day^{-1}$)
Control	3.48 a[z]	25.2 b	4.99 a	0.11 a
Antitranspirant	3.68 a	31.5 a	6.61 a	0.12 a
Pruned	3.06 a	32.6 a	4.78 a	0.14 a
Paclobutrazol	1.02 b	16.7 c	0.25 b	0.05 b

[z]Values represent means of 10 plants. Means followed by the same letter or letters, within a column, are not significantly different using LSD comparisons, $P < 0.05$.

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Soybean plants treated with 5 minutes of EOD FR light had greater shoot dry weights than plants treated with 5 minutes of EOD R light (8). Lack of differences in the present study may be attributed to the fact that a large percentage of total shoot dry weight was produced before light treatments started.

On the day of removal from simulated storage, plants treated with EOD incandescent light had more etiolated shoots than plants treated with EOD fluorescent light or controls (Table 3). This suggests that during storage, plants treated with EOD incandescent light continue to exhibit shoot elongation responses similar to those displayed during production. After 5 days in the IE, there were no differences in percent leaf chlorosis among treatments (Table 3). When compared to differences observed in experiment 1, it can be concluded that altering the R:FR is not enough to affect postharvest leaf chlorosis. Exclusion of either FR or R light must be attained to give an effect, thus making applications of this practice impractical when trying to reduce postharvest leaf chlorosis in the greenhouse. A possible alternative could be found with using a red light source after darkness.

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