Influence of Rootstock, Scion, and Water Deficits on Growth of 'Colt' and 'Meteor' Cherry Trees

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Additional index words. Prunus avium × pseudocerasus, Prunus cerasus, drought, growth analysis, net assimilation rate, relative growth rate, water stress

Abstract. Growth and physiological characteristics were evaluated in autografted and reciprocally grafted plants of Prunus avium L. × pseudocerasus Lindl. 'Colt' and Prunus cerasus L. 'Meteor'. Containerized plants were grown for 150 days in a greenhouse under either well-watered or water-stressed conditions. Both the scion and rootstock influenced growth (relative growth rate, R), morphological (leaf area: root surface area (LAR-SA)) and physiological (mean net assimilation rate, É) characteristics of grafted plants. Regardless of the watering regime, plants with 'Meteor' scions and 'Colt' rootstocks maintained higher R than plants with 'Colt' scions and 'Meteor' rootstocks. This enhanced growth occurred as a result of higher É. Measurements on water-stressed plants also showed that the graft combination of 'Meteor' on 'Colt' had the lowest LAR-SA, while the reciprocal combination of 'Colt' on 'Meteor' had the highest. Differences in LAR-SA among water-stressed plants primarily reflected changes in SLA, as influenced by both rootstock and scion, and not in partitioning of dry weight between these organs.

A wide range of morphological and physiological characteristics has been found to be affected by rootstock, scions, and their resulting interactions (Lockard and Schneider, 1981; Syversten, 1985; Tubbs, 1973). Many of these characteristics have the potential for improving plant water relations and growth during water stress. For example, rootstocks have been found to influence transpiration rate and crop water-use efficiency in peach (Prunus spp.) (Natali et al., 1985), leaf conductance in apple (Malus spp.) (Girillo et al., 1985), leaf osmotic potential at full turgor and calculated hydraulic conductivity in apple (Olien and Lakso, 1986), root distribution in citrus (Citrus spp.) (Castle and Krezdorn, 1975, 1977), and midday leaf water potentials in citrus (Castle and Krezdorn, 1977), peach (Natali et al., 1983), and apple (Girillo et al., 1985; Olien and Lakso, 1986).

Few of these experiments, however, have examined how the influence of different rootstocks and scions can contribute to whole-plant growth and maintenance of growth under water stress.

Classical plant growth analysis provides a comprehensive method for evaluating plant growth that integrates growth over time and permits the partitioning of growth into morphological and physiological components (Hunt, 1982). Plant growth analysis has been used extensively as a method for evaluating and comparing growth of various species and progenies (Cain and Ormrod, 1984; Grime and Hunt, 1975; Ledig and Perry, 1969; Pollard and Wareing, 1968; Sweet and Wareing, 1968), the effects of water stress on growth processes (Ashtend et al., 1975; Jarvis and Jarvis, 1963), and the influence of rootstocks on plant growth and structure (Dudney, 1974; Vyvyan, 1955).

In this study, we combined the reciprocal grafting protocol of Vyvyan (1955) and plant growth analysis to examine the relationships between scion, rootstock, and water stress in two cherry cultivars with varying growth habits: Prunus cerasus 'Meteor', a strongly determinate grower, and P. avium × pseudocerasus 'Colt', a strongly indeterminate grower. The objective of this study was to evaluate the relative influence of rootstock and scion on plant growth and partitioning patterns in graft combinations of 'Meteor' and 'Colt' cherry trees under well-watered and water-stressed conditions.

All plant material was cloned and ranged in stem caliper from 1 to 2 cm. Stems were pruned to a uniform length of 20 cm from the stem–root junction. Root systems were pruned to a uniform overall diameter of 21 cm in diameter and 30 cm in length to conform to container dimensions. Cleft grafts, consisting of two scions with three buds each, were made between 2 and 23 Feb. 1985. Plants were then placed in the dark at 5C with roots packed in moist peat before being planted.

Plants were potted on 14 Mar. 1985 in 11.4-liter black plastic containers with 8 liters of medium consisting of 2 sand: 1


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Table 1. Mean relative growth rate (R), mean net assimilation rate (E), and leaf area ratio (LAR) for graft combinations of 'Meteor' and 'Colt' cherry after 150 days of well-watered or water-stressed conditions.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>( R ) (mg·g(^{-1})·wk(^{-1}))</th>
<th>( E ) (mg·cm(^{-2})·wk(^{-1}))</th>
<th>LAR (cm(^2)·g(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-watered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meteor/Colt</td>
<td>85.4</td>
<td>4.1</td>
<td>19.5</td>
</tr>
<tr>
<td>Meteor/Meteor</td>
<td>79.2</td>
<td>3.5</td>
<td>21.8</td>
</tr>
<tr>
<td>Colt/Colt</td>
<td>71.8</td>
<td>2.1</td>
<td>34.9</td>
</tr>
<tr>
<td>Colt/Meteor</td>
<td>64.0</td>
<td>1.8</td>
<td>38.3</td>
</tr>
<tr>
<td>Water-stressed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meteor/Colt</td>
<td>31.2</td>
<td>3.0</td>
<td>15.4</td>
</tr>
<tr>
<td>Meteor/Meteor</td>
<td>22.4</td>
<td>2.0</td>
<td>14.8</td>
</tr>
<tr>
<td>Colt/Colt</td>
<td>21.9</td>
<td>2.1</td>
<td>16.4</td>
</tr>
<tr>
<td>Colt/Meteor</td>
<td>14.4</td>
<td>1.4</td>
<td>16.4</td>
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</table>

Single degree-of-freedom contrasts

<table>
<thead>
<tr>
<th>Irrigation (Irr.)</th>
<th>**</th>
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<tbody>
<tr>
<td>Scion</td>
<td>**</td>
<td>**</td>
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</tr>
<tr>
<td>Stock</td>
<td>**</td>
<td>**</td>
<td>NS</td>
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<tr>
<td>Scion × stock</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Irr. × scion</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
</tr>
<tr>
<td>Irr. × stock × stock</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>16.1</td>
<td>0.6</td>
<td>5.2</td>
</tr>
</tbody>
</table>

**NS**, **NS** nonsignificant or significant at \( P = 0.05 \) or 0.01, respectively, \( n = 5 \).

sphagnum peat : 1 soil (by volume) that had been pasteurized and screened through a 1.3-cm mesh hardware cloth. Pea-sized gravel (1.1 liters) was placed in the bottom of each container to prevent loss of medium. Plants were grown in a glasshouse in Ithaca, N.Y., under natural light with the air maintained between 16 and 24°C. Once plants broke dormancy and success of the graft union was assured, plants were pruned to one scion containing two growing buds. Water-soluble fertilizer (10N–10P₂O₅–10K₂O) was applied at 10-day intervals at 200 mg N/liter. All plants were well-watered before the initiation of treatments.

The experiment was arranged as a three-way factorial (2 scions × 2 rootstocks × 2 watering regimes) in a completely randomized design. The graft combinations consisted of 'Meteor' and 'Colt' grafted onto rootstocks of the same cultivar ('Meteor'/'Meteor' and 'Colt'/'Colt') and plants reciprocally grafted onto the rootstock of the alternate cultivar ('Meteor'/'Colt' and 'Colt'/'Meteor').

The two watering regimes consisted of a well-watered and water-stressed treatment initiated on 18 Apr. 1985. Water-stressed plants were watered to container flow-through at 10-day intervals to provide repeated periods of water stress over the duration of the experiment. Well-watered plants were irrigated daily.

Five plants from each treatment combination were harvested 150 days after planting. Leaf areas (Lₘ) were measured with a leaf area meter (Model 3100; LI-COR, Lincoln, Neb.). Roots were washed free of soil, and root lengths were determined on roots <5 mm in diameter using a video image analysis system as described by Barnett et al. (1987). Root volumes were determined for the same root samples by volume displacement (Johnson, 1983). Root surface area was then calculated based on length and volume, assuming roots were round in cross section with uniform diameter. Because of the extensive time and labor required for measuring root length and surface area, these measurements were taken on the water-stressed plants only. Dry weights were determined for leaves, roots, and stems after 96 h at 70°C. A sample of 10 plants (five of each species) was harvested at planting to estimate initial plant dry weights for use in growth analysis. These dry weights were estimated for each plant based on individual fresh weights and a dry : fresh weight regression equation (\( R² = 0.988 \)). Regression analysis showed no species × fresh weight interaction (\( P = 0.22 \)). Thus, data were pooled and one regression equation was used to predict dry weight regardless of rootstock or scion.

Mean relative growth rate (R), the mean change in dry weight per unit time per unit dry weight, was calculated according to (Radford, 1967):

\[
R = \frac{\ln W₂ - \ln W₁}{t₂ - t₁},
\]

where \( W₁ \) and \( W₂ \) = total dry weight at times \( (t₁, t₂) \) (planting) and 2 (harvest), respectively.

Mean net assimilation rate (E), also known as mean unit leaf rate, is defined as the mean rate of increase in total dry weight per unit of leaf area per unit of time (Ledig, 1974) and was calculated according to Radford (1967) as:

\[
E = \frac{2(W₂ - W₁)}{(Lₘ₂ + Lₘ₁)(t₂ - t₁)}
\]

where \( Lₘ₁ \) and \( Lₘ₂ \) = leaf area at times 1 and 2, respectively.

Table 2. Influence of scion, rootstock, and irrigation treatment on leaf area (Lₘ), leaf weight : root weight, specific leaf area (SLA), specific root area (SRA), leaf area : root length (LARL), and leaf area : root surface area (LARSA) for 'Meteor' and 'Colt' cherry after 150 days of irrigation treatments.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Lₘ (cm²·1000s)</th>
<th>Leaf wt : root wt (g·g⁻¹)</th>
<th>SLA (cm²·g⁻¹)</th>
<th>SRA (cm²·g⁻¹)</th>
<th>LARL (cm²·cm⁻¹)</th>
<th>LARSA (cm²·cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-watered</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Meteor/Colt</td>
<td>5.28</td>
<td>0.40</td>
<td>102</td>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>Meteor/Meteor</td>
<td>5.32</td>
<td>0.33</td>
<td>124</td>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>Colt/Colt</td>
<td>10.3</td>
<td>0.74</td>
<td>124</td>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>Colt/Meteor</td>
<td>10.6</td>
<td>0.69</td>
<td>136</td>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>Water-stressed</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Meteor/Colt</td>
<td>1.32</td>
<td>0.23</td>
<td>97</td>
<td>44</td>
<td>0.12</td>
<td>0.51</td>
</tr>
<tr>
<td>Meteor/Meteor</td>
<td>1.47</td>
<td>0.18</td>
<td>115</td>
<td>36</td>
<td>0.23</td>
<td>0.89</td>
</tr>
<tr>
<td>Colt/Colt</td>
<td>1.55</td>
<td>0.18</td>
<td>129</td>
<td>30</td>
<td>0.23</td>
<td>0.84</td>
</tr>
<tr>
<td>Colt/Meteor</td>
<td>1.77</td>
<td>0.17</td>
<td>137</td>
<td>23</td>
<td>0.29</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Single degree-of-freedom contrasts

Irrigation (Irr.): ** NS NS --- --- --- ---
Scion: ** NS NS NS ** **
Stock: NS NS ** NS NS NS **
Scion × stock: NS NS NS NS NS NS NS
Irr. × scion: NS NS NS NS NS NS NS
Irr. × stock: NS NS NS NS NS NS NS
Irr. × scion × stock: NS NS NS NS NS NS NS
LSD\(_{0.05}\): 0.76 0.12 7.2 21 0.65 0.29

**NS**, **NS** nonsignificant or significant at \( P = 0.05 \) or 0.01, respectively. Values are means; \( n = 5 \) for Lₘ, leaf weight : root weight, and SLA; \( n = 3 \) for SRA, LARL, and LARSA.
and 2, respectively. Both R and E were calculated as mean rates averaged over the per-
diode from planting to harvest. Leaf area ratio (LAR) was calculated as the ratio of LA to
plant dry weight. To avoid assumptions regard-
ing the integration of LAR over time (Radford, 1967), LAR is presented as an in-
nstantaneous value as measured at the terminal
harvest.

Predawn (0400-0500 HR) leaf water poten-
tials were measured using a pressure
chamber (Plant Moisture Status Console, Soil
Moisture Corp., Santa Barbara, Calif.) on replicate plants. Plants were selected for that
purpose. Measurements of predawn water
potential were taken starting 70 days after
planting and again at 20-day intervals thereafter. These dates coincided with the last
day of a given dry-down cycle. One measure-
ment was taken per plant on the third or
fourth fully expanded leaf.

Because of differences in evaporative de-
mand over the treatment period, the level of
stress for each 10-day dry-down period varied.
Mean predawn water potentials for water-
stressed plants were -2.6, -2.0, -0.8, -3.0, and -3.3 MPa at the end of individual
dry-down intervals measured on days 70, 90, 110, 130, and 150, respectively.

Growth analysis. R decreased for all graft
combinations in response to water stress (Ta-
ble 1). However, plants with 'Meteor' scions
maintained higher R than plants with 'Cotl'
scions, irrespective of the irrigation treat-
ment. The rootstock influenced R such that
plants with 'Cotl' rootstocks had higher R than plants with 'Meteor' rootstocks, ir-
respective of the irrigation treatment.

As was found for R, E typically decreased
in response to water stress and was signifi-
cantly affected by both the rootstock and
scion. Plants with 'Meteor' scions main-
tained higher E than plants with 'Cotl'
scions; however, this pattern was accentuated under well-watered conditions. Plants with 'Cotl'
rootstocks maintained higher E than plants with 'Meteor' rootstocks, regardless of the
irrigation treatment. Under well-watered
conditions, plants with 'Meteor' scions had
lower LAR than did plants with 'Cotl'
scions. However, values of LAR were similar under water-stressed conditions. There was no ef-
effect of the rootstock on LAR.

Plants with 'Cotl' scions had a larger LA
than plants with 'Meteor' scions, but only
under well-watered conditions (Table 2).
The LA of well-watered plants with 'Cotl'
scions most likely resulted due to the indefi-
tinate nature of 'Cotl'. There was no ef-
effect of the rootstock on LAR.

Partitioning of dry weight. The leaf weight:
root weight ratio decreased in response to
water stress for all plants; however, plants
with 'Cotl' scions showed a greater decrease
than did plants with 'Meteor' scions (Table 2). There were also significant changes in the partitioning of dry weight within the leaf and roots. The scion, rootstock, and ir-
rigation regime influenced specific leaf area (SLA) (leaf area : leaf dry weight) such that plants with 'Meteor' scions had lower SLA than did those with 'Cotl' scions; however, this effect

was greatest under water-stressed conditions
and for plants with 'Cotl' rootstocks. There
were no treatment effects on root surface
area : rootstock dry weight. Although there
were no significant differences in leaf : root
weights among water-stressed plants, differ-
ences in SLA resulted in significant differ-
ences in the ratio of leaf surface area : root
surface area (LARSA) as influenced by both root-
stock and scion. The LARSA : root length ratio showed similar trends.

R is a function of two components: 1) the
ratio of assimilatory surface area : plant dry
weight (LAR) and (2) the assimilation rate of
the leaf surface area (E) (Hunt, 1982). In this
study, 'Meteor'/Cotl' plants maintained higher R than did 'Cotl'/Meteor' plants while
maintaining similar or lower LAR, depending
on the watering regime. The higher R of 'Me-
teor'/Cotl' plants therefore was achieved as
a result of a higher E. This trend held under
both well-watered and water-stressed condi-
tions.

Under water-stressed conditions, a higher
E may contribute to improved drought resis-
tance. Ashenden et al. (1975) found that
under drought, populations of orchard grass
(Dactylis glomerata L.) from dry sites had
higher E than populations from moisture sites,
suggesting that maintenance of high E under
drought conditions may provide for im-
proved growth, adaptability, and tolerance to
water stress.

E is a measure of photosynthetic effi-
ciency per unit leaf minus losses of CO2 due
to respiration (Ledig, 1974). The effect of the
scion on E was anticipated because spe-
cies often vary in photosynthetic rate and
canopy architecture. Because well-watered
'Cotl' scions typically had larger LA than
'Meteor' scions, the higher E of well-watered
plants with 'Meteor' rootstocks may have re-
sulted from lower LA with higher light in-
terception per unit LA.

The significant effect of the rootstock on
E was less expected and may be the result of
several rootstock influences. Lack of a
significant rootstock effect on E indicates
the influence of the rootstock on E was not
one of variation in total light interception.
One potential influence of the rootstock on
E could result from the indirect effect of the
rootstock on leaf morphology. In our study,
plants with 'Cotl' rootstocks had lower SLA and higher E than did plants with 'Meteor'
rootstocks. SLA has been found to be neg-
atively correlated with rates of photosyn-
thesis within a wide variety of woody plants
(Jurik, 1986; Nelson and Michael, 1982; Oren
et al., 1986). Association of high rates of
photosynthesis with low SLA may be due to
increased mesophyll cell surface area per unit
LA (Nobel et al., 1975). E in this study was
negatively correlated (P < 0.05) with SLA in
both well-watered (r = -0.82) and
water-stressed plants (r = -0.66) and may rep-
resent a significant mechanism by which
rootstocks can influence E.

LARSA is a measure of transpirational surface area to root area and may be an im-
portant factor in the ability of a plant to
function and grow under water stress. Dif-
ferences in LARSA among plants under water
stress primarily reflected changes in par-
titioning patterns within leaves (SLA). A lower
LARSA may improve water uptake per unit
of leaf area and the ability to maintain turgor
and stomatal conductance, resulting in an
improved E.

The low LARSA and SLA and high R and E
associated with the 'Meteor' scion is con-
sistent with drought-adapted ideotypes
(Brown, 1980). Observations made in the
field also indicate that plants with 'Meteor'
scions typically show less evidence of stress
under drought conditions than do other cherry
variety (C. Cummins, personal communi-
cation). Conversely, both the LARSA and SLA
and high R and E associated with the 'Cotl'
rootstock suggest that scions on 'Cotl' root-
stocks would be better adapted to drought
than scions on 'Meteor' rootstocks.

Success of any plant under drought con-
ditions depends on its ability to acquire and
use water such that photosynthesis and growth
can be maintained under increasingly dry
conditions. Selection of more drought-resis-
tant rootstocks with extensive and deep root
systems has been pursued with citrus (Castle
and Krezdorn, 1977). However, little atten-
tion has been given to the influence of both
the rootstock and scion on physiological and
morphological traits and their potential in-
fuence on growth under water stress. The
results of this study indicate that both root-
stock and scion can affect a variety of char-
acteristics that influence growth under both
well-watered and water-stressed conditions.

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Transpiration by Crape Myrtle Cultivars Surrounded by Mulch, Soil, and Turfgrass Surfaces

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Additional index words. stem flow gauge, stomatal conductance, sap mass flow rate, surface temperatures, Lagerstroemia indica

Abstract. A study was conducted to explore how surface materials, including pines bark mulch, bare soil, and turfgrass, affect water use of diverse cultivars (dwarf weeping, dwarf upright, standard weeping, and standard upright) of crape myrtle (Lagerstroemia indica L.). Daily water use was measured gravimetrically, and instantaneous rates of sap flow were measured using heat balance stem flow gauges. Plants of all cultivars surrounded by the mulched surface lost 0.63 to 1.25 kg m⁻² day⁻¹ more water than plants on the soil surface and 0.83 to 1.09 kg m⁻² day⁻¹ more than plants surrounded by turf. The surface temperature of the mulch was higher than that of the other surfaces, resulting in greater fluxes of longwave radiation from the surface. Because of the greater energy load, plants on the mulched surface had higher leaf temperatures and higher leaf-air vapor pressure deficits (VPD) throughout the day. Plants on the mulched area also had higher stomatal conductances during most of the day compared with those on bare soil and turfgrass surfaces.

The role of vegetation in the urban environment, not only from an aesthetic standard...