Variation in Tree Size, Yield, Cropping Efficiency, and Alternate Bearing Among ‘Kerman’ Pistachio Trees

R.S. Johnson
Kearney Agricultural Center, University of California, Parlier, CA 93648

S.A. Weinbaum
Pomology Department, University of California, Davis, CA 95616

Abstract. The pistachio (Pistacia vera L.) industry in California is based largely on a single pistillate (i.e., nut-producing) cultivar (Kerman) supported by seedling rootstocks of P. atlantica Desf. Data were collected and analyzed for tree growth and productivity of 113 mature ‘Kerman’ trees/P. atlantica seedlings over two cycles of alternate bearing. Tree size as estimated by trunk cross-sectional area varied 4-fold among the trees analyzed; tree yields, averaged over four years, varied 8-fold within the plot, and cropping efficiency (yield/cm² of trunk cross-sectional area) varied 3-fold among the trees within the orchard. The severity of alternate bearing was also calculated. Eight superior trees were identified within the orchard that not only had higher average yields and cropping efficiencies, but also exhibited much more regular cropping patterns (i.e., reduced severity of alternate bearing) than adjacent trees and the orchard as a whole.

Cultivation of the pistachio in California has expanded rapidly since its commercial beginnings in the 1960s. Less than 200 ha were planted to pistachio in 1968; currently there are about 20,000 ha. Pistacia vera is dioecious, and the industry in California is based entirely on a single pistillate (i.e., nut-producing) cultivar (Kerman), and a single staminate cultivar (Peters) (6).

The pistachio tree of commerce, like many other deciduous fruit species, is a compound plant, i.e., the scaffold and bearing surface (scion) is grafted onto and supported by the root system of another genetic constitution (rootstock). Both ‘Peters’ and ‘Kerman’ are grown on P. atlantica Desf. or P. terebinthus L. seedling rootstocks, which are more resistant to root-knot nematodes and other soil organisms than P. vera (8). P. intergerina Steward has shown increased resistance to verticillium wilt and is being used extensively in affected areas (6). Where verticillium wilt is not a problem, ‘Kerman’ yields were highest on P. atlantica seedling rootstocks as compared with P. palastina, P. terebinthus, and P. vera (5). Use of P. atlantica seedlings as rootstocks accounts for >80% of the bearing acreage (J.C. Crane, personal communication).

Pistachio rootstocks are propagated exclusively by seed, because cuttings of Pistachia spp. are difficult to root, and commercially acceptable methods of vegetative propagation have not been developed.

This work was initiated because of the extreme and apparently random variation in size among equal-aged trees within commercial orchards. Heavy annual bearing has been noted in certain ‘Kerman’ trees (J.C. Crane and L.E. Joley, personal communication), in contrast to the severe alternate-year bearing characteristic of most ‘Kerman’ trees (6). As ‘Kerman’ is the only scion cultivar, the degree of alternate bearing and persistent tree-to-tree differences in percentage blanks (seedless fruit) may be attributed to variation among seedling rootstocks (3, 4). Although research is being conducted in California to develop methods for vegetative propagation of Pistacia spp., the potential that clonal propagation of rootstocks offers the pistachio industry will remain unfulfilled unless superior rootstocks worthy of propagation first can be identified.

The objectives were to quantify the variation in tree size, yield, cropping efficiency, and alternate bearing that exists among ‘Kerman’ trees grafted on P. atlantica seedling rootstocks, and to identify ‘superior’ trees if sufficient tree variation exists.

Materials and Methods

Two-hundred and twelve seedlings of P. atlantica were planted in a 6.1 × 4.9 m spacing near Lost Hills, Calif. in Spring 1970. The trees were budded to ‘Kerman’ 1 month later with 99% success. Standard practices of irrigation, fertilization, weed control, and light pruning were applied uniformly to the block.

Border, male, and replant trees were excluded from the analysis as were trees exhibiting any symptoms of verticillium wilt in Fall 1983. This left 113 trees for the analysis.

Trunk circumference was measured above the graft union and 51 cm above the soil surface in Oct. 1984, and trunk cross-sectional area (CSA) calculated. Total nut yields were obtained before processing on individual trees in 1981, 1982, 1983, and 1984, which represent two cycles of alternate bearing. The cropping efficiency of each tree was calculated according to the method of Westwood (11). Tree yields were averaged over the 4 years of record. The intensity of alternate bearing (“I”) as developed by Hobly (7) was determined for each tree. “I” is calculated by dividing the absolute difference in yields for consecutive years by their sum. Thus, I will vary from 0 to 1, where 0 denotes equal crops (no alternation) and 1 indicates no crop at all in the off year. Since two cycles of alternate bearing (4 years) were used in this analysis, the average of the two off years was compared with the average of the two on years.

Results and Discussion

Trunk CSA varied from 121 to 436 cm² among the 113 test trees, and 4-year average yields varied from 65 to 482 kg/tree (Table 1 and Fig. 1). Plotting tree yield against tree size indi-
Table 1. Growth, crop productivity, and alternate bearing of 113 ‘Kerman’ pistachio trees grafted on P. atlantica seedling rootstocks. Yield values are before processing.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield (kg/tree)</th>
<th>Trunk cross-sectional area (cm²)</th>
<th>Avg. yield efficiency (kg·cm⁻²)</th>
<th>Alternate bearing intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>11.3</td>
<td>268</td>
<td>0.103</td>
<td>0.76</td>
</tr>
<tr>
<td>1982</td>
<td>35.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>9.4</td>
<td>135</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>54.5</td>
<td>15.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave.</td>
<td>27.6</td>
<td>53</td>
<td>0.026</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Table 2. Growth, crop productivity, and alternate bearing of 113 ‘Kerman’ pistachio trees grafted on P. atlantica seedling rootstocks. Yield values are before processing.

Fig. 1. Relationship of tree size (as estimated by trunk cross-sectional area in 1984) with average yield before processing (A) and cropping efficiency (B) of ‘Kerman’ pistachio trees, 1981-84. Data in A were fit to a linear function \[ y = 2.66 + 0.93x; R^2 = 0.86 (P < 0.01) \]. Data in B showed no significant correlation \( R^2 = 0.0002 \).

Fig. 2. Alternate bearing intensities (I) vs. tree yields (A) and yield efficiencies (B) of 113 ‘Kerman’ pistachio trees averaged over 4 years. An I value of 1 indicates extreme alternate bearing, while a value of 0 represents regular bearing. The solid triangle designates the eight superior trees.

The data indicate pronounced alternate bearing over the 4 years of record with the mean yield/tree during off years (1981 and 1983) being one-third to one-sixth the yield during the on years (1982 and 1984; Table 1) and an alternate bearing intensity of almost one for most of the trees (Fig. 2). Eight of the 113 experimental trees were conspicuous in having low indices of alternate bearing coupled with above-average yields and yield efficiencies (Fig. 2). These superior trees differed significantly from the 27 trees immediately adjacent to them in having higher (44%) average yields, greater (31%) cropping efficiency, and more regular cropping [reduced alternate bearing intensity (Table 2 and Fig. 2)]. A comparison of these eight trees with adjacent ones indicates little difference in on-year yields, but almost 4-fold higher yields during off years (Table 2). The trees adjacent to the superior trees were similar to the rest of the block in all parameters measured. These adjacent trees were used in the statistical analysis to minimize site-specific variability.

Not only tree yields but also tree yield distributions differed greatly between on and off years. During off years (Fig. 3A) the tree population was positively skewed. During on years, however, the population represented a much more normal distribution of yield, although slightly negatively skewed (Fig. 3B).

Although the yield capacity of ‘Kerman’ trees varies among Pistacia spp. used as rootstocks (5), the variation in tree productivity, as influenced by individual seedling rootstocks (i.e.,
The data indicate pronounced variation in tree growth, yield, and cropping among individual deciduous fruit trees. Larsen and Fritts (9) reported lower cropping efficiencies on seedling rootstocks as compared with clonal rootstocks. It appears that the 3-fold variation in yield efficiency among mature 'Cox's Orange Pippin' apple trees varied between 20% and 30% (10). The CV in yield during individual years for 'Navel' orange, 'Valencia' orange, 'Eureka' lemon, and 'Jonathan' apple trees all ranged from 29.7% to 41.2% (2). Such variability among trees is much lower than the 135% measured among pistachio trees in their off years (Table 1). This variability in the off year presumably is due to a) a percentage of superior trees that crop fairly regularly while most trees carry a minimal or no crop at all (Fig. 3A); and, b) trees that are out of cycle with the rest of the orchard.

The objective was to quantify the variability in tree size and productivity among 'Kerman' pistachio trees budded on P. atlantica seedling rootstocks. Two potential sources of variation must be considered: a) genetic and b) edaphic. An overwhelming influence of genetic factors would mean that the cropping potential of pistachio tree reflects the variability inherent among the P. atlantica seedlings used as rootstocks. Variation in tree performance also may be associated with soil heterogeneity and associated influences on water and/or nutrient availability. Inadequate soil moisture reduces tree growth and yield in apple, but favors the partitioning of assimilate to the crop at the expense of vegetative growth (1). Of the eight superior trees, six were located in two of the nine rows within the experimental block. Therefore, the influence of environment on the variation in tree performance cannot be discounted, even though adjacent trees were used in the analysis. Confirmation of seedling rootstock-dependent variation on yield efficiency and alternate bearing in pistachio must await clonal propagation and establishment of test plots to compare variation in tree performance of 'Kerman' on seedling vs. clonally propagated rootstocks. Only then can the tree variation be partitioned definitively between genetic (rootstock) and edaphic (site) sources.

The 4-fold range in yield efficiency among the 113 'Kerman' pistachio trees tested suggests that small trees selected on the basis of high cropping efficiency could greatly enhance yields per acre if planted at high densities. Whatever criteria for superior trees are used, the potential for increased production appears to be substantial and continued research to identify, propagate, and test superior pistachio rootstocks is justified.

**Literature Cited**

Photon Flux and Leaf Temperature Effects on Flower Initiation and Early Development of 'Red Elite' Geraniums

J.W. White¹ and S.M. Polys²

Department of Horticulture, Pennsylvania State University, University Park, PA 16802

Additional index words. photosynthetic photon flux, Pelargonium × hortorum, infrared thermometry

Abstract. Geranium (Pelargonium × hortorum Bailey 'Red Elite') seedlings were grown with five daily mean temperature (DMT) and daily light integral (DLI) treatment combinations: DMT of 23°C/day at DLI of 8.64 mol day⁻¹ m⁻² (T1), DMT of 25°C at 8.64 mol (T2), DMT of 23°C at DLI of 17.28 mol (T3), DMT of 25°C at DLI of 17.28 mol (T4), and DMT of 21°C at 17.28 mol (C1). Using infrared thermometry to control leaf temperature, DMT had a greater influence on flower initiation at the transition stage and on flower bud development to macrobud stage than DLI. Seedlings in T4 reached transition stage 24 days after sowing with a cumulative irradiance of 415 mol. Transition occurred in T1 at 27 days from sowing, with a cumulative irradiance of only 233 mol. Some time after 27 days from sowing, transition occurred in T2, T3, and C1. With a DLI of 17.28 mol, a DMT reduction from 25°C to 23°C to 21°C effected macrobuds in 54 or 51 days.

Researchers over the past 20 years have conducted numerous studies in an attempt to understand the factors affecting the juvenile phase in seed propagated geraniums (3–5, 10, 13, 15, 19). Past reports concerning the importance of high irradiance levels in reducing the juvenility phase in seed-propagated geraniums have not examined the thermal effects of light sources on the leaf surface (1, 7, 11, 17). In prior studies, temperatures were based solely on air temperature. Our study considered thermal effects by basing daily mean temperature (DMT) on temperature readings at the leaf surface using infrared thermometry.

The purpose of our study was to test the hypothesis that early flower initiation and subsequent macrobud (first visible flower bud) development occurs as a result of high leaf temperature caused by increased thermal radiation associated with increased irradiance levels.

Materials and Methods

Seeds of hybrid geranium 'Red Elite' were sown into 2.5-cm-diameter, 8-unit cell packs containing 1 peat : 1 perlite : 1 redi-earth (by volume) amended with gypsum at 2.97 kg m⁻². Germination environment was intermittent mist under natural light with 21°C ± 2°C night air temperatures. Once cotyledons were fully expanded, cell packs were placed in a completely random design into one of five growth chambers (Conviron, Models E15 and EY15).

Growth chambers were lighted by a combination of nine cool-white (F72T12/CW/VHO) and nine warm-white (F72T12/WW/VHO) fluorescent lamps aged 336 hr to assure uniform irradiance. Photosynthetic photon flux (PPF) (400–700 nm) was measured at plant height in each chamber using a quantum sensor (Model LI-COR LI-190SB). Instantaneous irradiance readings were averaged over a 24-hr photoperiod and height of lamps above plants adjusted to create daily light integrals (DLI) of either 8.64 or 17.28 mol day⁻¹ m⁻².

A capillary mat system was used for sub-irrigation. Plants received 0.21 g liter⁻¹ N (15N–6.5P–12.4K) at each irrigation. At 20 days, the N was increased to 0.42 g liter⁻¹. Every fourth day thereafter, plants were irrigated overhead with 0.42 g liter⁻¹ N (15N–0.5P–12.4K).

Carbon dioxide was added starting on the seventh day of the experiment. Carbon dioxide levels, determined by monitoring weekly with a portable CO₂ monitor (Horiba Model APBA-210), were maintained at 350 ± 50 μl liter⁻¹ in each growth chamber.

Temperature within each chamber was measured and controlled using an infrared thermometer at an emissivity of 0.98 (Everest Interscience Model 210). Daily temperature readings...