Effects of Topsoil-subsoil Fertilizer and Lime Amendments on Top and Root Growth of ‘Stuart’ Pecan Seedlings in a Simulated Norfolk Soil Profile

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Abstract. Fertilizer and lime topsoil treatments increased top and root growth of open-pollinated seedlings of ‘Stuart’ pecan [Carya illinoensis (Wang.) K. Koch] under simulated Norfolk profile conditions in the greenhouse. Positive response was greatest on root growth when lime was added to the subsoil. Rate of tap root growth in the subsoil was increased 64% by increasing subsoil pH from 5.1 to 6.5. Lime additions to the subsoil reduced weights of lateral roots in the topsoil and increased yields in the subsoil. Subsoil lime at 2 and 3 meq Ca/100 g soil (pH 6.0 and 6.5) increased yields of the small feeder roots 3 and 6 fold over the untreated check (subsoil pH 5.1). Acid subsoils can be an important factor limiting growth of pecan roots under soil conditions prevalent in much of the Southeast.

The highly weathered soils of the southeast commonly have infertile and acid subsoils (8). These soil conditions contribute to shallow rooting of some plants (3, 10). Under favorable soil conditions, the pecan tree tends to have a deep and extensive root system (13). The pecan responds to fertilizer (1) and has been described as pH sensitive with an optimum pH range from about 6.5 to 7.0 (12). Pecan seedlings are reported to grow well over a pH range of 6.4 to 7.5 and that best growth occurred at pH 6.1 and above. Hunter (5) showed that pecan production is improved by liming and suggested that acidity in the lower layers of the soil profile could be important to pecan growth. Sparks (12) observed that growth of nursery seedlings was associated better with subsoil pH than with topsoil pH and recommended subsoiling to help improve pH in the rooting zone. Nursery seedlings were observed to have a better distribution of lateral roots following deep placement of lime in the row at planting (11).

Lime is conventionally surface-applied in pecan orchards. Since Ca moves very slowly, its effect on soil pH is primarily in the vicinity of application and subsoils are often unaffected (9). Factual information concerning chemical requirements for growth and deep rooting of pecans under acid subsoil conditions is incomplete. This experiment determined, under simulated soil profile conditions in the greenhouse, the effects of topsoil and subsoil fertilizer and lime treatments on growth of ‘Stuart’ pecan seedlings, with emphasis on evaluating conditions affecting subsoil root growth.

Glass-fronted boxes similarly described by others (7, 9) were divided into 4 compartments with each containing a topsoil over a subsoil treatment combination (Fig. 1). Boxes were constructed with 1.25 cm marine plywood and were painted with waterproof epoxy paint. Inside dimensions of each compartment were 10 × 17.5 cm with a depth of 70 cm. Glass panels were held in place with silicone caulk and were inset 6.25 cm at the bottom providing a sloping front to induce roots to grow against the glass. During the growing period the glass fronts were covered with black plastic which could be readily removed to observe root growth. Topsoil (15 cm deep) and subsoil (46 cm deep) used in the boxes was obtained from a woodland site of Norfolk soil (fine-loamy, siliceous, thermic family of Typic Paleudults). The topsoil was a loamy sand (81% sand, 14% silt, 5% clay) with an exchange capacity of 2.3 meq/100 g soil, 0.4 meq Ca/100 g, and 22% base saturation. The sandy clay subsoil (48% sand, 13% silt, 39% clay) had an exchange capacity of 6.2 meq/100 g soil with 1.2 meq Ca and a 26% base saturation. Norfolk soil is found throughout the Coastal Plain of the Southeast (4) and pecans are often grown on it. Bulk topsoil and sub-soil samples were collected in the field from the A and B horizons. Soils were air-dried and pulverized to pass a 6-mm screen. Treatments shown in Table I were mixed with the topsoils and subsoils by batches in a concrete mixer. Commercial grade fertilizer 10-4.4-8.3 (N-P-K) was used and the lime source was reagent grade CaO. After treatments were mixed, soils were placed in metal tubs (coated with asphalt paint) and carried through three wetting and drying cycles to equilibrate lime and fertilizer treatments. The air-dried soil was pulverized again and remixed. Subsoils from each treatment were weighed (10.9 kg), placed with gentle vibration in the glass-fronted boxes, and watered with 2500 ml distilled water. After 2 days topsoils (3.6 kg) were added and wet with 500 ml water.

Nuts harvested from open pollinated ‘Stuart’ pecan trees were stratified at 7°C for 9 months. After 12 days germination in peat moss, seed showing 3–6 cm radicle growth and beginning plumule growth were selected for planting. Seed (2/treatment) were planted on October 19 and plants were harvested after 147 days. Plants were grown in a heated greenhouse with supplemental lighting to provide a 14-hr day length. Temperatures during the growing period ranged from 20–35°C. Plants were watered with distilled water regularly and sprayed for insect control. Depth of taproot penetration, visible against the glass front, was measured daily for the first 34 days. At harvest, main stems were measured for height from soil surface to the growing tip, and for diameter at 2 cm above the soil surface. Soil was washed from the roots with a gentle spray followed by a detergent rinsing to remove fine soil particles. Leaves, stems, and roots were separated and oven-dried at 70°C for 1 week. Roots were further separated into taproot and lateral roots in both topsoil and subsoil. Lateral roots recovered from the subsoil were later redried, crushed gently by hand, then sieved through 0.5 and 0.25 mm sieves for 5 min on a vibrating shaker and reweighed. Treatments were replicated 5 times in a completely random design and data were statistically analyzed.

Application of both fertilizer and lime to the topsoil increased leaf dry weights (Table 1). The additional yield increase from liming the subsoil was not significant. Main stem weights were increased by topsoil fertilization, but no additional increase in stem weight from liming either topsoil or subsoil was measured. Stem diameter increased only

Fig. 1. Glass fronted boxes containing simulated Norfolk soil profiles used for studying growth of ‘Stuart’ pecan seedlings in the greenhouse.
When both fertilizer and lime were added to the topsoil and 2 meq Ca to the subsoil,

effects of liming were most noticeable on root growth (Table 2). Taproot growth rate in the subsoil was greatest when lime was added to the subsoil (Trit. 5 & 6). Where 3 meq Ca/100 g soil was added to the subsoil, taproot growth rate increased 64% over the topsoil-subsoil check treatment (Trit. 1), and 34% over treatment 3 where only the topsoil received fertilizer and lime. Subsoil taproot weights improved where lime was added to the topsoil (Trit. 2 vs. 3). Although highest subsoil taproot yields were measured where Ca was added to the subsoil (Trit. 5 & 6), these increases were not significantly higher than those where the topsoil alone received lime (Trit. 3).

Lateral root growth was influenced markedly in some cases by the various topsoil-subsoil treatments. Total weight yields were not significantly affected by treatments, however root distribution in the topsoil and subsoil was changed. Lateral root weights in the topsoil were highest with no subsoil treatment (Trit. 3). Where 3 meq Ca to the subsoil (Trit. 5 & 6), lateral root weights improved markedly in the subsoil (Trit. 2 vs. 3). Although highest subsoil lateral root yields were measured where Ca was added to the subsoil, these increases were not significantly higher than those where the topsoil alone received lime (Trit. 3).

Acid soils can be a limiting factor in root growth and yields of some crops (2, 3, 10). Data in the present study show that acid subsols also can limit deep rooting of 'Stuart' pecan seedlings. Taproot and lateral root growth increased markedly with reductions in subsoil acidity (higher pH). Deep lime placement in established orchards may not be practical; however, the importance of subsoil acidity should be recognized and management practices should be followed to enhance movement of Ca into the soil and attempt to prevent further increase in subsoil acidity. A good surface-soil liming program can aid in preventing further increases in soil profile acidity. It may be feasible to mix lime in planting holes at the time of orchard establishment. Further studies are underway at this location to evaluate the effects of lime additions in the planting hole on growth and production of pecans.

Literature Cited


Table 1. Soil treatments and pH levels in simulated Norfolk soil profiles and effects of treatments on top growth of pecan seedlings after 147 days in glass-fronted boxes.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Topsoil</th>
<th>Subsoil</th>
<th>Soil pH*</th>
<th>Leaf wt (g/plant)</th>
<th>Stem wt (g/plant)</th>
<th>Stem length (cm)</th>
<th>Stem diam (mm)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>5.2</td>
<td>5.1</td>
<td>2.4a*</td>
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<td>500</td>
<td>0</td>
<td>0</td>
<td>4.9</td>
<td>5.1</td>
<td>2.9ab</td>
<td>1.8b</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>2</td>
<td>0</td>
<td>6.1</td>
<td>5.2</td>
<td>3.6bc</td>
<td>1.8b</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>2</td>
<td>1</td>
<td>6.1</td>
<td>5.5</td>
<td>3.0abc</td>
<td>2.0b</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>2</td>
<td>2</td>
<td>6.2</td>
<td>6.0</td>
<td>4.1c</td>
<td>2.0b</td>
</tr>
<tr>
<td>6</td>
<td>500</td>
<td>2</td>
<td>3</td>
<td>6.1</td>
<td>6.5</td>
<td>3.8bc</td>
<td>1.8b</td>
</tr>
</tbody>
</table>

*Soil pH determined on 1:1 soil-water.
1 Fertilizer – 10-4.4-8.3 (N-P-K).
2 meq Ca/100 g soil. (Note: 1 meq Ca/100 g soil is equivalent to 500 ppm CaCO3).
3 Mean separation in columns by Duncan’s multiple range test, 5% level.

Table 2. Effects of fertilizer and lime treatments applied to a simulated Norfolk soil profile on taproot and lateral root growth of 'Stuart' pecan seedlings grown in glass-fronted boxes.

<table>
<thead>
<tr>
<th>Treatment no.</th>
<th>Taproot dry wt (g/plant)</th>
<th>Taproot growth rate in subsoil (cm/day)</th>
<th>Lateral root dry wt (g/plant)</th>
<th>Dry wt of various size fractions of lateral roots in subsoil (&gt;0.5 mm, &lt;0.5 mm, &lt;0.25 mm) (mg/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.2a*</td>
<td>8.4a</td>
<td>0.83a</td>
<td>0.39a, 1.2a</td>
</tr>
<tr>
<td>2</td>
<td>3.1a</td>
<td>8.9b</td>
<td>0.70ab</td>
<td>0.50ab, 1.20a</td>
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<td>3</td>
<td>4.1b</td>
<td>12.1c</td>
<td>0.76a</td>
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<tr>
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<tr>
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<td>3.85b</td>
<td>11.9c</td>
<td>0.39c</td>
<td>0.87d, 1.26a</td>
</tr>
</tbody>
</table>

*See Table 1 for fertilizer and lime treatments and soil pHs.
1 Average growth rate for taproots growing in subsoil over a 24-day period from 10 to 34 days after planting.
2 Mean separation in columns by Duncan’s multiple range test, 5% level.