JOURNAL OF
ARBORICULTURE
July 1990
Vol. 16, No. 7

DIRECTIONAL VARIATION IN GROWTH OF TREES[1]

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A previous study on the root distribution of seven species of shade trees revealed asymmetric root systems (6). The north and west sides of the trees had the largest number of roots greater than 1.0 cm in diameter. No assessment of fine root development was reported. Since the trees used in the study were growing in nursery blocks with a completely closed canopy, the soil environment was consistent on all sides and probably not a factor in the differential root development. Above-ground factors such as light intensity and drought stress were implicated. Asymmetrical differences in the root systems and crowns of trees need to be more fully understood because of the possible relationship to everyday practices, such as watering, in the arboriculture and nursery industries.

Materials and Methods

The study site was a collection of thirty-year-old open-grown shade trees located at the Morton Arboretum in Northern Illinois, USA (elevation 760 ft, 41° 50' N Lat., 88° 00' W Long.). The area has a temperate, humid, continental climate, and the prevailing winds are from the west. The soil in the area is a Markham silt loam (Mollic Hapludalf) with an A-horizon depth of 30 cm (12 in), underlain by silty clay. Trees were planted 15 m (45 ft) apart in east-west rows, also spaced 15 m apart. Trees in adjacent rows were staggered 7.5 m in the east-west direction to minimize shading and crowding by trees to the south. Directional sampling was done due north and south, where there was a greater distance to the nearest tree, minimizing the influence of shade and root competition.

Littleleaf linden *(Tilia cordata* Greenspire) was the primary species chosen for the study. It is widely used as a street tree in northern Illinois and considered moderate in drought sensitivity and shade tolerance. Data were collected for additional species whenever possible.

Littleleaf linden root densities were determined in July of 1987 by core sampling. Four trees were sampled in the north and south directions, from 1.8 m (6 ft) to 7.2 m (24 ft), at 0.6 m intervals (2 ft) from the tree trunk. Each core was 7 cm in diameter and 30 cm deep. Following washing and separation from non-linden roots, the root surface area of fine roots (diameter less than 2 mm) was measured with a Delta-T Area Meter. Root densities are expressed as mm^2 root surface area/cc soil.

Shade pattern of the tree crown and soil moisture levels were determined from four trees. Soil moisture was determined over the root zone to a depth of 30 cm, on Sept. 20, 1989, using the gravimetrics method (% = {fresh wt - dry wt}/dry wt).

North and south crown measurements taken in 1988 included crown radius, length and dry weight of annual growth of 10 branches, and leaf area (blade and petiole) of 10 leaves located third from the terminal bud. In 1989, north and south leaf area measurements were repeated. Total leaf area on the north and south sides of one tree was estimated by collecting and measuring all the leaves in a 0.5m wide vertical section of the crown from the lowest branch to within 1m of the apex of the crown.

Statistical analysis for root, crown, branch, and leaf measurements was by two sample one direc-

[1]Supported, in part, by a grant from the International Society of Arboriculture Research Trust.

tion T-tests using the Solo Statistical System Version 2.0.

Results

Figure 1 illustrates the average fine root densities (mm^2 root surface area/cc soil) for the four littleleaf linden samples in the north and south directions. The north side had more fine root density than the south side, especially 2.4-4.2 m from the tree trunk. The differences were not statistically significant due to typical high variation of individual root sample values. These same trees had a larger crown radius on the north side when compared to the south side. The shade pattern was more extended on the north side due to the position of the sun at maximum height (71° in June). Crown radius of 36 other species were also measured, and north side measurements were greater for 31 species (Table 1). Eight were significantly greater.

Table 1. Average crown radius (m) of trees approximately 30 years old.

Tree	*North*	*South*
Acer campestre	3.30	3.15
Acer ginnala	3.27	3.03
Acer miyabei	1.80*	1.41
Acer platanoides	3.27	2.61
Acer rubrum	3.18	2.91
Acer saccharinum	6.75*	5.10
Acer saccharum	3.30	2.70
Aesculus glabra	2.37	2.10
Aesculus hippocastanum	2.25	2.25
Alnus glutinosa	3.48	2.97
Celtis occidentalis	2.85	2.52
Cladrastis lutea	3.24	3.30
Fraxinus excelsior	6.09	5.34
Fraxinus excelsior 'Hessei'	3.78*	2.64
Fraxinus pennsylvanica	3.75	3.18
Fraxinus quadrangulata	3.24	2.70
Fraxinus tomentosa	2.28	2.19
Gingko biloba	0.63	0.45
Gleditsia triacanthos	3.66	3.36
Gymnocladus dioicus	3.60	3.63
Liquidambar styraciflua	3.30*	2.43
Liriodendron tuliperfera	4.50	4.20
Magnolia salicifolia	1.59	1.59
Malus 'Snowdrift'	3.06	2.97
Ostrya virginia	3.00	2.58
Platanus occidentalis	4.08*	3.12
Pyrus calleryana	3.09	3.09
Quercus coccinea	3.48	3.03
Quercus imbricaria	2.94	2.67
Quercus palustris	5.07*	4.56
Quercus robur	2.79*	2.25
Quercus rubra	4.17*	3.42
Tilia cordata	4.14	3.84
Tilia X euchlora	3.27	2.91
Ulmus Green King	3.24	2.64
Ulmus carpinifolia Koopmannii	2.16	2.04

*Indicates a significant difference between north and south at the .05 level

Soil moisture was considered atypical in 1988 because of the extreme drought and was not used. The more typical weather in 1989 revealed no significant difference in soil moisture between the north and south sides. Figure 1 illustrates the average soil moisture pattern seen on Sept. 20, 1989.

Table 2 lists the average branch length for both 1987 and 1988 growing season. The dry weight for each year's growth was also measured. In both years, the branches on the north side were significantly longer than those on the south side. Dry weight of the north was also greater but not significantly.

Table 3 lists the average area of leaves located third from the terminal bud for both the north and south sides of the tree in 1988 and 1989. Individual north leaves were signficantly larger than the south leaves. Specific leaf area, (leaf area/leaf dry weight) was only slightly higher on the south (Table 4). The north side had fewer leaves but a higher total leaf area. Comparison of fine root surface area to leaf area estimates revealed 25% more absorbing root area per unit leaf area on the north side (Table 4).

Discussion

The data from this study confirm that there are directional root and crown differences in open-grown trees. The north side of the tree developed a more dense fine root system (Figure 1), but the rapid decrease in fine roots with increasing distance from the trunk is not typical. When the

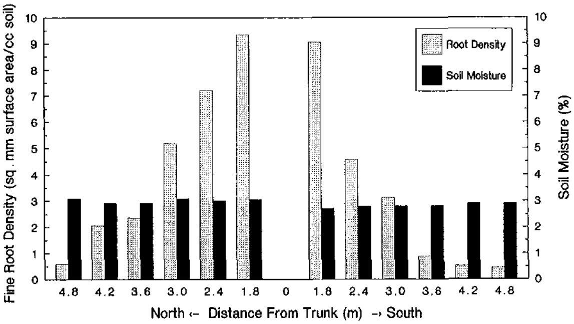

Figure 1. Fine root development, soil moisture, crown silhouette and shade pattern of little-leaf lindens.

soil conditions are uniform over the spread of the root system, the fine roots proliferate nearly everywhere in the surface layers and density is fairly constant over the entire spread of the root system (3, 5, 7). Grass competition can reduce tree root development (8) and the dense linden crowns did minimize grass competition underneath the trees near the trunk, possibly allowing for greater tree root development closer to the trunk. Though the shading pattern may have caused a small difference in grass competition between north and south, it was not considered great enough to account for the large difference in fine root development observed on the two sides.

It is possible that soil moisture differences or some other possible effect of the canopy shading on soil properties could account for the more extensive root system on the north side. The typical area shaded by the tree crown is shown in Figure 2. On the south side, the shade radius was smaller than the crown radius, whereas on the north side, shade extended much farther than the crown edge, and pattern became slightly elongated to the north as the summer progressed. On a site with exposed soil, the canopy shade might have had a pronounced effect on soil moisture and temperature, but the study site had tall grass which is also very effective in shading the soil surface. No abrupt change in soil moisture was observed near the edge of the shaded area, confirming the effective shading by the tall grass. Thus, even though the tree was open-grown, the soil environment was consistent in all directions, and differences in root development are not likely to be attributed to soil conditions.

Could above-ground influences result in differences below-ground? At the latitude of the study area, the sun is always in the southern sky, never reaching directly overhead, even at noon on the longest day. This could lead to differences in sun-shade responses and/or drought stress of the crown with respect to direction. The south side of the tree is exposed to full sun from mid-morning to mid-afternoon when the sun and heat are most intense. Summer winds are often from the south and may contribute to more harsh conditions on the south side. During the summer, the sun rises and sets in the northeast and northwest. The north side of the tree does receive full sun early

Table 2. Average twig growth of littleleaf linden.

Characteristic	*North*	*South*
'88 Length (cm)	26.70*	20.10
'88 Dry wt (g)	1.25	1.05
'87 Length (cm)	30.80*	24.70
'87 Dry wt (g)	4.57	3.08
'87 Lateral growth (cm)	7.10	6.30
'87 Lateral dry wt (g)	1.86	1.51
'87 Lateral growth (cm)	7.10	6.30
'87 Lateral dry wt (g)	1.86	1.51

*Indicates significant difference between north and south at .05 level

Table 3. Average leaf area (blade and petiole) of leaves located 3rd from the terminal bud.

	Leaf area (mm^2)	
Tree species	*North*	*South*
1988		
Tilia cordata	3554*	2869
Tilia x euchlora	8816*	6577
Fraxinus pennsylvanica	7832	7353
Acer platanoides	10853*	9337
Acer rubrum	7659*	6376
Acer saccharum	7904*	6153
Quercus palustris	3303	2941
Quercus rubra	8755	7142
1989		
Tilia cordata	3069*	2394
Trilia x euchlora	2240*	1719
Fraxinus pennsylvanica	8223	8530
Acer platanoides	13113*	10700
Acer rubrum	5507	4780
Acer saccharum	7120	6199
Quercus palustris	3934*	3275
Quercus rubra	7792*	6453
Quercus robur	3356*	2415
Fraxinus excelsior	3442*	2903
Liquidambar styraciflua	6931*	5952

*Indicates a significant difference between north and south at the .05 level

Table 4. Comparison of leaf area and root surface area ratio on opposite sides of littleleaf linden. Measurements represent only a narrow portion of the tree directly north and south, but identical tecnhiques were used to sample both sides.

Character	*North*	*South*
Number of leaves	6608	6805
Leaf area (m^2	10.28	8.97
Specific leaf area (m^2/g)	.0180	.0169
Root surface area (cm^2)	26.76	18.62
Relative root area-leaf area ratio	1.26	1.00

and late in the day, but is partially shaded during mid-day when the sun is in the southern sky.

These differences in sun exposure of the crown do apparently affect the above-ground development of the tree. Linden branches had longer annual twig growth on the north side (Table 2). Dry weight was also greater on the north side indicating more growth rather than simple elongation from increased shade. If growth was greater on the north every year, it would lead to differences in crown radius over time. North side crown radius was greater than the south side for 31 of 36 species measured (Table 1).

The north side of the crown had fewer leaves, but the total leaf area exceeded that of the south side. Individual north side leaves were larger than south side leaves (Table 3). Specific leaf area (leaf area/leaf dry weight) changes in response to sunlight, and increases as sunlight decreases. In other words, shade leaves have more surface area for the same weight. Increases of 250 percent have been reported (1). The small increase of 6% (Table 4) from south to north observed in this study, would indicate that shade was not primarily responsible for differences in leaf size. As with twig growth, the data indicate that there is more growth on the north side, not just a change in morphology in response to shade.

Water stress might also be responsible for north-south differences. More direct sunlight and higher transpiration rates during leaf expansion may have created higher levels of water stress on the south side causing reduced leaf size. It is possible that partial shade on the north resulted in less water stress, better growing conditions, more larger leaves and increased photosynthate production, which in turn, could have lead to more growth above- and below-ground.

Kramer (2) cites several studies which have found that over 50% of the photosynthate production goes into root growth. The study of carbon allocation in white oak indicates that more photosynthate produced in the lower canopy is available for translocation (4). The amount of absorbing root surface area per unit leaf area is 25% greater on the north side. This greater capacity to absorb water from the soil could be an important factor in minimizing drought stress and maximizing growth on the north side. Conversely, the absorbing root system of the south side was more limited, perhaps predisposing this side to increased drought stress, reduced photosynthesis, and reduced growth both above- and below-ground.

Conclusion

It is clear that the north side of trees grows faster in the Midwest where water stress can be the most limiting growth factor. In similar climates in the southern hemisphere, the pattern should be reversed. In climates where temperature or sunlight are limiting factors, different directional growth asymmetries may exist.

With more growth expected on the north side, planting locations might be shifted slightly to give proper clearance from sidewalks and wires. This is not necessarily true near buildings, since shading, reflected heat and light and other factors are nearly always altered by the structure itself. Higher drought stress on the south side of trees would seem to warrant more watering on that side

Figure 2. Typical profile of little-leaf linden showing longer branches on the north (left) side.

during dry periods.

Caution must be advised when considering the practical implications of directional differences described in this study. Though the differences are real, they are not pronounced enough to recommend radical changes in everyday procedures. It might be tempting to conclude, for example, that root balls should be larger on the north side of the trunk where root densities are higher. In reality, the increased root surface area in the root ball would be minute, and the south side of the tree would probably be under even greater stress as a result of the reduction of roots. A more appropriate use of this information would be to keep the tree in the same directional orientation (keep north the same) in its new location in the landscape.

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ABSTRACT

GILL, STANTON. 1989. **Cleaning up insects with insecticidal soap.** Grounds Maintenance 24(7):34, 38.

In these days of heightened public concern about pesticide use, pesticide applicators are under more scrutany than ever before. The revival of insecticidal soap has resulted from this search for non-traditional methods of control. Insecticidal soap's appeal comes from the selectivity of insects controlled and low mammalian toxicity of the material. Because insecticidal soaps control a narrower range of insects, they're less likely to inadvertantly kill beneficial insects. This characteristic, as well as low persistence in the environment and low mammalian toxicity, make soap a promising tactic for use in integrated pest management programs. Various types of soaps have been used for insect suppression since the last half of the 19th century. Before 1940, researchers described the mode of action and efficacy of these soaps. Insecticidal soap is composed of potassium salts of several fatty acids. According to the popular theory, the fatty acids disrupt the pest's cellular membrane which causes the loss of cellular contents and cell death. I tested the efficacy of insecticidal soap on azalea lace bug and the Eastern tent caterpillar. Timing was critical for lace bug control because you want to kill the nymph. The key to good caterpillar control was the ability of the sprayer to severely damage tents, thoroughly covering the caterpillars inside the webbed nest, as well as those on the branches and leaves.