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PREDICTING ROOT SPREAD FROM TRUNK DIAMETER AND BRANCH SPREAD[1]

by Edward F. Gilman

Abstract. Trunk diameter and branch crown spread were linearly correlated with root spread in honeylocust (*Gleditsia triacanthos* var. inermis), green ash *(Fraxinus pensylvanica),* poplar *(Populus x generosa),* red maple *(Acer rubrum)* and southern magnolia *(Magnolia grandiflora)* but not in live oak *(Quercus virginiana).* Maximum root spread (excluding live oak) ranged from 1.68 times the dripline for ash to 3.77 for magnolia. Mean maximum root spread was 2.9 times the dripline. Roots growing farthest from the trunk were consistently near the soil surface.

Résumé. Une corrélation linéaire fut établie entre le diamètre du tronc et l'étendue des racines, de même qu'entre l'étendue des branches et l'étendue des racines chez le févier sans épines (*Gleditsia triacanthos* var. *inermis*), le frêne rouge (*Fraxinus pennsylvanica*), les peupliers (*Populus* X *generosa*), l'érable rouge (*Acer rubrum*)et le magnolia à grandes fleurs (*Magnolia grandiflora*), mais non chez le chêne vert (*Quercus virginiana*). L'étendue maximale des racines (excepté pour le chêne vert) variait de 1.68 fois l'étendue des branches pour le frêne à 3.77 fois l'étendue des branches pour le magnolia. L'étendue maximale moyenne des racines était de 2.9 fois supérieure à l'etendue des branches. Les racines poussant le plus loin du tronc étaient toujours près de la surface du sol.

Traditionally, tree roots were thought to spread to the branch tips (dripline) with fibrous roots concentrated at the dripline (15). This historical information has been accepted by most engaged in the tree care industry, without supporting scientific evidence. Numerous field excavations and soil coring studies in the forest, orchard and tree nursery settings clearly indicate that roots spread well beyond the dripline (15). Fertilizer applications were based on these assumptions. Portions of tree ordinances pertaining to the distance from the trunk protection fences should be erected around trees at construction sites may also be subtly influenced by this erroneous perception.

Stout's (19) extensive studies on forest tree root excavation in a closed-canopy stand showed that roots of several oak, hickory and other genera grow to well beyond the dripline. Open-grown trees in forest clearings also have roots extending to outside the branch tips (10). Roots of trees growing in a nursery setting extend to about 3 times the trunk to dripline distance (4, 21). Orchard-grown pear *(Pyrus)* and apple *(Malus)* roots extend from 2-3 times the branch dripline (17).

Recent evidence that nursery-grown tree roots grow beyond the dripline lead to calculations of the percentage of roots growing within the dripline compared to outside the dripline. Watson (23) found that about 60% of Colorado blue spruce *(Picea pungens)* root surface area and weight on 8-year old trees were outside of the dripline. Gilman (4) excavated honeylocust *(Gleditsia triacanthos)* green ash *(Fraxinus pensylvanica)* and poplar *(Populus* x *generosa)* and found 59%, 54% and 77% of the total root length, respectively, outside of the dripline on 3-year-old plants.

Roots in field plots have been studied in a variety of other ways. On four species, root weight within a Field-Gro container was similar to root weight within the same soil volume of a field-grown tree without a Field-Gro container (12). Two species had a greater number of roots within the Field-Gro container. Watson (22) and Gilman (4) independently determined that 91 to 98% of tree roots of nursery grown plants are left in the

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nursery after digging plants not previously root pruned. Root pruning may increase the percentage of roots harvested within the root ball (8, 23). Nursery, forest and orchard excavations and soil corings indicate a concentration of roots near the surface with most roots present in the top 50 cm of soil (1, 6, 13, 15, 19, 22). Roots are likely to be significantly shallower in urban soils (7). Root distribution patterns change with age, differ among genera, species, varieties and soil types, and can be modified by soil management practices.

Tap roots are most prominent on seedlings and large seeded species such as oaks and walnuts (20) and deep sinker roots (20) frequently grow from shallow horizontal roots but neither have been described as characteristic on landscape plants (15). Horizontal, shallow roots extend farther from the trunk than deeper tree roots. (3). In field studies, root surface area (23) and root cross-sectional area (14) have been correlated with dry weight.

Shallow, established tree roots compete with turf and other ground covers (24). Soil oxygen and carbon dioxide concentrations have been correlated with root length and shoot growth of *Tilia americana* (5). Several tree species adapt to low soil oxygen environments by producing a shallow, adventitious root system (6, 11). Roots in compacted soil are very shallow (18) and more branched (16) than in non-compacted soil.

Though it appears that tree root systems have been thorougly studied, the relationship between root spread, trunk diameter and branch spread has not been investigated for open-grown landscape trees. A study by Tubbs (21) showed that dbh, crown radius and root spread radius were highly intercorrelated for yellow birch (*Betula nigra)* and sugar maple *(Acer saccharum)* in a closed canopy forest. A number of professional groups will benefit from a better understanding of tree root spread. For example, researchers planning tree fertility field trials could provide adequate space so roots will not overlap during the study. Forestry researchers have been made aware of the potential for root overlap in field trials with *Populus* species (9). Trees could be better protected by municipal ordinances if the extent of root systems on construction sites were known.

These studies were designed to establish the correlation between tree root spread and branch (crown) spread and between tree root spread and trunk diameter.

Materials and Methods

Six replicates of honeylocust *(Gleditsia triacanthos* var. inermis), green ash *(Fraxinus pensylvanica)* and poplar (*Populus* x *generosa)* were planted bare-root in a Sassafras sandy-loam in East Brunswick, N.J. in a randomized block design April, 1978. Three honeylocust and ash were 2-year whips, and 3 were 3-year old saplings. Three poplar were rooted cuttings, 3 were 2-year old saplings. Trees were spaced on 3 m centers and maintained with 1.82 kg N/m^2 (4 lbs. N/1000 sq. ft./year) in three applications broadcast over the entire plot. A 60 cm diameter circle was maintained weed-free around the base of each plant with glyphosate herbicide. Other portions of the plots were mowed weekly during the growing season. Trees were overhead irrigated only during the first growing season to bring the total rain and irrigation water to 2.5cm/wk.

Twenty-five live oak *(Quercus virginiana),* red maple *(Acer rubrum)* and southern magnolia *(Magnolia grandiflora)* were planted from 3-liter containers in a fine sand near Gainesville, FL. The oaks and half of the magnolias were planted in September, 1983, maples in April, 1984, and the other half of the magnolias in September, 1984. Trees were maintained with 4.5 kg N/m^2 (10 lbs. N/1000 sq.ft.) as Woodace 18-5-10 in 3 applications broadcast over a 1 m diameter circle around each tree. A 60 cm diameter circle was maintained weed-free around the base of each plant with glyphosate. Other portions of the plot were mowed periodically during the growing season. Trees were drip irrigated daily during the summers with one emitter/plant to supply about 1 liter/plant. Irrigation in the winter was on an as needed basis.

In the spring of 1981 and the fall of 1986 the New Jersey and Florida-grown trees, respectively, were excavated with hand trowels and shovels. The 4 largest roots on each tree were located by excavating around the trunk base. Each major root was unearthed until it branched; the largest diameter root at the branch was followed until the next branch. The excavation continued until the end of the root was exposed. The straight-line measurement from the trunk to the most distant portion of each of the 4 roots was recorded as root radius. The dripline was projected onto the soil surface by suspending a lead weight from a nylon string against the outermost edge of the crown. The distance between the trunk and the branch dripline was measured in 8 equal-spaced compass directions (including north) on each tree and averaged. Trunk diameter 15 cm above the soil surface in the north-south and east-west directions was recorded and averaged for each tree.

Results and Discussion

Branch crown spread and trunk diameter were both linearly correlated with root spread (Tables 1 and 2) for all species in both New Jersey and Florida except for live oak. Similar correlations were previously shown for honeylocust growing on refuse landfill cover soil (7) and may also occur for forest-grown trees (2).

Maximum root spread (excluding live oak) ranged from 1.68 times the dripline for green ash to 3.77 for southern magnolia (Table 1). This is indicated by the slope values for each species. For example, a magnolia with a 1 m crown spread diameter would have a 3.77 m root spread diameter. The slope value for oak was not significantly different from zero and hence there was no relationship between crown spread and root spread. Slopes for the other 5 species were not different from each other (P .05) and were greater than zero (Figure 1). Therefore, a mean slope was calculated (2.9) from data including all trees from the 5 species indicating that roots of open-grown trees extend from the trunk an average of 2.9 times the branch dripline. This coincides almost identically with a generalized root spread model proposed by Watson (22) showing root spread as 3 times branch spread (dripline).

It is difficult to attribute the lack of correlation for live oak to a morphological characteristic except for crown shape which is more spreading in live oak than the other 5 species excavated. However, the spreading nature of this species appears to be somewhat unpredictable. Two trees had a broad crown similar to the form regarded as typical for older growth live oak. The other 4 replicates had a more upright oval crown form. Though variability in crown form may account for the lack of correlation between branch spread and crown radius, it does little to explain the lack of correlation between trunk diameter and root spread. Perhaps root morphology varies among trees within a species and is unpredictable for certain species. Further study is needed on this topic.

Slopes of the trunk diameter vs. root spread radius equations formed 3 statistically separate groups (P .05): magnolia (.53); maple (.38), honeylocust (.35); ash (.30); and poplar (.20)

Table 1. Straight line equations for the relationship between branch crown radius and root spread radius.

Species	b_0	b_1	*r*
Southern magnolia	-0.53	3.77a	.98**
Live oak	1.61	0.36b	.23
Red maple	-0.16	3.06a	.97**
Honeylocust	-1.02	2.95a	.99**
Poplar	-0.63	3.08a	.74*
Green ash	0	1.68a	.99**

$y = b_0 + b_1 x$ where: y = root radius (m), b_0 = y intercept, b_1 = slope of line, x = crown radius (m), r = correlation coefficient

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Table 2. Straight line equations for the relationship between trunk diameter and root spread radius.

Species	b_0	b_1	*r*
Southern magnolia	-0.62	0.53a	.99**
Live oak	0.92	0.20c	.41
Red maple	0.17	0.38b	.82*
Honeylocust	0.42	0.35b	.79*
Poplar	1.13	0.20c	.83*
Green ash	0.10	0.30b	.97**

$y = b_0 + b_1 x$ where: y = root radius (m), b_0 = y intercept, b_1 = slope of line, x = trunk diameter (cm), r = correlation coefficient

*Significant at the 0.05 level.

**Significant at the 0.01 level.

*Significant at the 0.05 level.

**Significant at the 0.01 level.

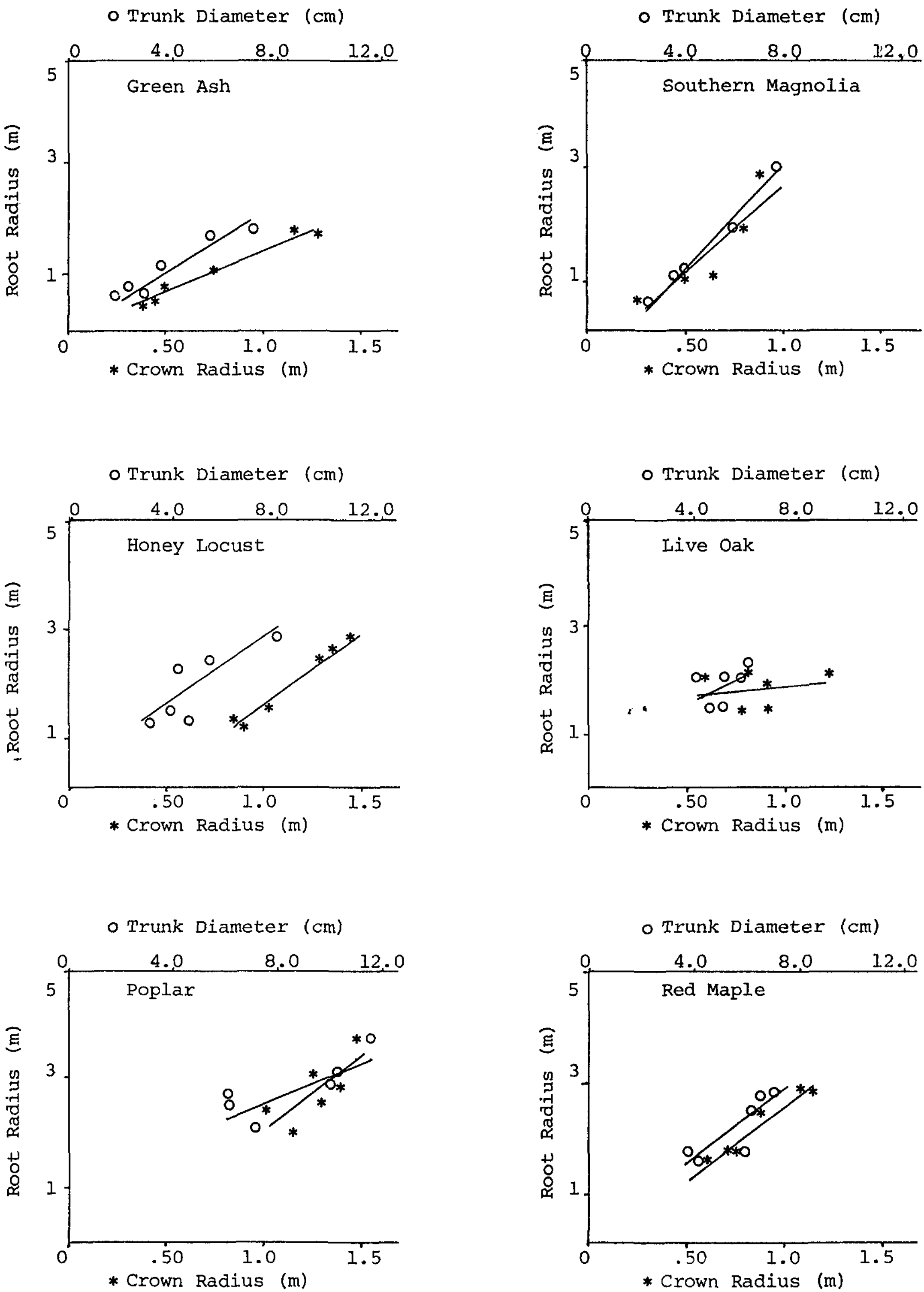

Figure 1. Linear relationships among trunk diameter, crown radius and root spread radius for six tree species.

(Table 2). Live oak slope was significantly different from zero so it will not be included in the following discussion. These data indicate that maximum root spread can be predicted reliably from stem diameter within a species, since r values are significant, but the relationship (i.e.slope) is species dependant.

The steepest slopes for both trunk diameter and crown radius were found for magnolia, indicating small increases in either of these parameters corresponded to a relatively large increase in root spread. Magnolia root systems appeared to be less branched than the other root systems. Although roots were farther from the trunk than other species, root density within a given volume of soil appeared to be less. Green ash at the other extreme, had roots relatively close to the trunk and there was little soil uncolonized between adjacent roots of a plant. The other 4 species had root system morphologies between these two extremes. Root morphology traits may be genetically controlled (13) having ecological significance in the species' adaptive and evolutionary development.

Roots farthest from the trunk were consistently near the soil surface. Deep roots were never found to extend as far from the tree as shallower roots. This has been reported for a number of woody species (3).

It is important to recognize the limitations of this research. Because the same species was not grown on both sites, the effect of soil type on root spread could not be addressed. Future work in this area should compare root spread in different soil types. Although trunk diameter and branch spread were good predictors of maximum root spread for the young trees reported in this study, there is no evidence to suggest that these linear relationships are reliable for older trees.

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Assistant Professor
Ornamental Horticulture Department.
University of Florida, IFAS
Gainesville, FL 32611