JOURNAL OF
ARBORICULTURE

September 1982
Vol. 8, No. 9

ROOT DISTRIBUTION OF NURSERY TREES AND ITS RELATIONSHIP TO TRANSPLANTING SUCCESS

by G.W. Watson and E.B. Himelick[1]

Abstract. The natural root distributions of seven species of shade trees (Norway, red and sugar maple, green ash, redbud, ginkgo, and pin oak), growing under nursery conditions were characterized. The north quadrant of the root systems of these trees was more developed than any other quadrant. In general, the vertical distribution of the major roots showed the greatest development at the soil depth of 13-38 cm, with limited growth in the top 12 cm, and decreasing development at depths below 38 cm. The fibrous root densities were usually greater in the upper 10 cm depth than at the lower depths. Tree spades, commonly used to transplant nursery trees, reduce the root system by up to 98 percent. Since regenerated roots originate primarily at the severed ends of the roots cut during digging, location of these severed roots, with respect to the new soil profile is an important factor in the re-establishment of transplanted trees.

Rapid regeneration of the root system is essential for successful re-establishment of transplanted trees. Transplanting techniques drastically reduce the root systems of nursery stock and consequently the amount of soil exploited to gain nutrients and water is also reduced to only a small fraction of what it was when growing in the nursery. To maximize survival, a favorable root-shoot ratio must be re-established rapidly. Since a new root system must regenerate from the remnants of the original root system, it is important to know the pattern of distribution of the root systems of nursery-grown trees. It is for this purpose that the study was initiated.

The amount of root growth and the type of root distribution are subject to several external and internal influences. Perhaps the greatest external influence is exerted by the physical and chemical properties of the soil environment. Vertical and horizontal root penetration is dependent upon soil texture, composition and profile, and depths of the soil horizons (4, 9, 10, 14). Soil moisture and aeration, which are inversely related, also have a major impact on root growth. Optimum root growth varies with species, soil texture and depth, and oxygen diffusion rates (6, 12, 14). Because tree roots will grow in soil temperatures from just above freezing (7), to nearly 35°C (4), root dormancy and top dormancy may not coincide. Soil fertility may also influence root growth (5, 15, 18).

The physical and chemical characteristics of the soil in combination with the inherent genetic characteristics of each species affect root distribution by causing a reduction in root development from the surface down to the C horizon and a reduction from the base of the tree outward (1, 8, 9, 17). The small fibrous roots which absorb water and nutrients are more highly concentrated in the fertile topsoil and occasionally in bands of richer soil at greater depths (14, 16).

Methods

Eighty-eight trees of 7 species (Table 1) growing in the Natural History Survey arboretum, Urbana, Illinois, were dug with a Vermeer 44 mechanical tree spade and the root systems examined. The wall of the cone-shaped hole was examined for roots of 1 cm diameter and greater. The location, depth and size of the severed roots were plotted on a map representing the outer sur-

[1]Specialist, MSU-DOE Plant Research Laboratory, Michigan State University and Plant Pathologist and Section of Botany and Plant Pathology, Illinois Natural History Survey, Urbana, IL. This work supported in part by grants from the Horticultural Research Institute and the cities of Highland Park, Lake Forest, Oak Park, and Park Ridge, Illinois.

face of the root ball. These data were compiled for all trees of each species, with respect to soil depth and quadrants relative to north.

Table 1. Number of trees of each species studied to determine vertical and directional root distributions.

Species	*Number of root systems examined*
Norway maple *(Acer platanoides)*	16
Red Maple *(Acer rubrum)*	16
Sugar maple *(Acer saccharum)*	12
Redbud *(Cercis canadensis)*	16
Green ash *(Fraxinus pennsylvanica)*	12
Pin oak *(Quercus palustris)*	8
Ginkgo *(Ginkgo biloba)*	8
Total	88

The distribution of fine root development was determined by a core sampling method. Three species, Norway maple, green ash and ginkgo, were sampled in July, 1980. The soil cone dimensions were 7.5 cm in diameter and 20 cm long. Each tree was sampled on four sides at the edge of the original root ball. On one side of each tree, randomly selected, a second core was taken immediately below the first, to a depth of 40 cm. The soil-sampling procedure was repeated for another ring of cores adjacent to the outside edge of the first ring of cores. Each of the upper samples was divided into equal upper and lower portions. For each tree, root samples of similar locations and depths were combined and treated as one sample.

After removing all soil and the roots of herbaceous plants and other woody species, total length measurements were taken on each sample. Newman's line intersection method (13) was used for estimating the total length of root in the sample. This method is based on the principle that as the length of a sample increases the more intersections will be made with a predetermined set of lines, and the actual length can be calculated mathematically by counting these intersections.

Root System Measurements

Directional distribution of major roots. Based on the cumulative root distribution data, five of the seven species developed the highest count of roots in the northern quadrant with ginkgo and ash roots being as/more abundantly formed in the east quadrant (Fig. 1). Combined totals for all seven species showed that the north quadrant contained the highest root counts. Individual species showed wide variations for root distributions in the east, south and west quadrants. It should be noted that ginkgo was the only tree species growing in a different section of the nursery and was planted with different spacing. The ginkgo were spaced 1.5 m X 2 m with the 1.5 m spacing running north and south and the other species were spaced 2.5 m X 2.5 m.

Vertical distribution of major roots. For all seven species, the vertical distribution measurements of total roots 1.0 cm in diameter and larger, showed the greatest development at the soil depth of 13 to 38 cm (5-15 in) with limited growth in the top 12 cm of soil and with rapidly decreasing root development at depths below 38 cm (Fig. 2). These data were adjusted to allow for variation in the circumference of the cone-shaped root ball at each sampling depth. It was noted that for some species this pattern differed slightly. Red maple root density was higher in the top 13 cm sampling layer than any other species. Green ash and redbud produced more root growth below 38 cm than the other five species.

Vertical distribution of small fibrous roots. For the three species sampled, Norway maple, green ash and ginkgo, core samples showed that the greatest small fibrous root density (meters of root length/liter of soil) of undisturbed nursery-

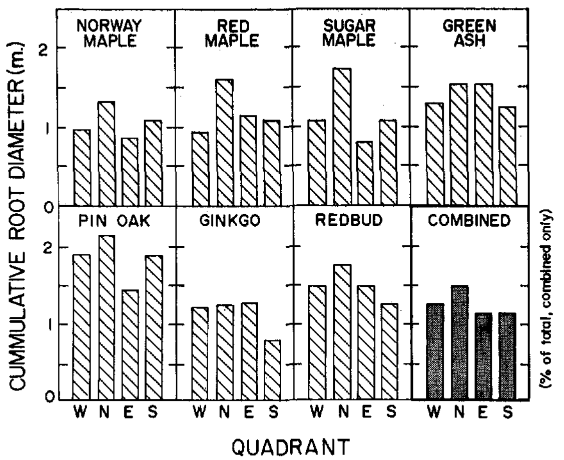

Fig. 1. Directional distribution of major roots of nursery grown trees.

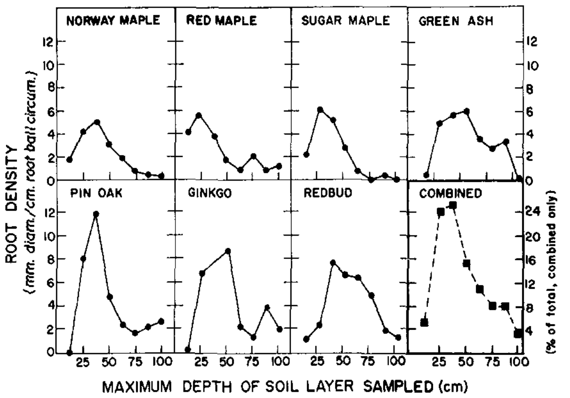

Fig. 2. Vertical distribution of major roots of nursery grown trees.

grown trees is in the upper 20 cm of soil, where soil aeration and soil structure would most likely be optimum for fine root development. Furthermore, the fibrous root densities of the Norway maple and the green ash were greater in the 0-10 cm soil layer than in the 10-20 cm soil layer (Fig. 3). Fibrous root growth of ginkgo was limited in the upper 10 cm of soil. This reduced shallow fibrous root growth appeared to correspond to competition from dense turf and other surface vegetation.

Discussion

The evidence that the north side of the tree develops a more extensive root system is convincing, on the basis of the total data compiled on the seven tree species. The fact that ginkgo developed an equal amount of roots in both the north and east quadrants (Fig. 1), probably resulted because these trees were growing in an area where the space between trees was less to the north and south than east and west. The ash developed stronger lateral growth at greater depths than the other species studied and root competition apparently was not an influencing factor. Thus, root competition between trees may have played an important role. Factors which may cause this asymmetric root development of evenly-spaced trees seem most likely to be environmental in nature, such as sun orientation or wind direction. Until the exact nature of the cause of this asymmetric distribution is determined, replanting trees in the same directional orientation would seem advisable. This would minimize the environmental changes above and below the ground surface.

The literature on root distribution consistently reports the highest densities of roots in the upper soil horizons and the results of this study are in agreement. The large number of roots encountered at depths as great as 38 cm can be attributed to the deep loam soil conditions in the nursery where these studies were made. Since most root regeneration originates near severed root ends, vertical distribution appears to be an important influence for regeneration in particular soil types. It is reasonable to expect that most tree species tending to be more deeply rooted would not be as tolerant to heavy clay soils having seasonal high-water tables, a condition which exists in many urban soils. Also, shallow-rooted tree species would not be ideally suited to soil conditions where the upper soil layers are subject to long periods of low water potential. These generalities are especially true for recently transplanted trees; however, after a few years growth, most trees that survive transplanting develop a substantial root system able to tolerate rather severe environmental soil conditions.

The shallow nature of the fibrous root distribution of these nursery trees prior to transplanting is in agreement with other reports of root distribution (2, 3, 16). These data add to the growing evidence of the shallowness of the development of smaller roots of certain species and the need

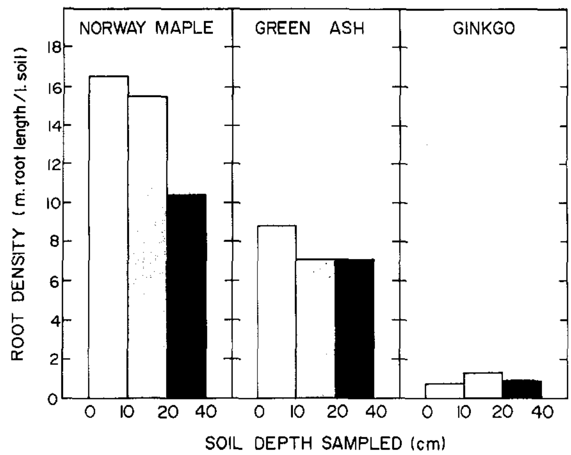

Fig. 3. Fine root distribution of nursery grown trees.

for minimal disturbance (physical or environmental) of the soil around trees to avoid extensive injury to the root system and the ultimate loss of the tree.

Ginkgo fibrous root density in the upper 10 cm of soil was lower than root densities at the 10-20 cm level. Heavy herbaceous vegetation, primarily blue grass, occurred in this area. Apparently grass root competition was an important factor. This evidence indirectly supports previous work in which mulching the soil around trees increases root growth by reducing or eliminating grass competition and by helping maintain adequate soil moisture and aeration in the upper soil layer (11, 19). Grass competition would be especially detrimental to trees growing in areas where the topsoil is shallow and consequently fine root growth is already somewhat restricted by the nature of the soil.

Using the data presented here in conjunction with field observations from the partial excavation of roots of these trees and other studies, a model of a typical nursery-grown tree was constructed (Fig. 4). This figure illustrates the drastic loss of total root system which occurs when the tree is dug from the nursery. In this model, the original root system was exploiting approximately 20 cubic meters of soil to absorb its water and nutrients. After transplanting, the soil volume available to the tree is 0.35 cubic meters (the volume of the root ball). The root ball then represents 2% of the original soil volume. It is easy to understand why rapid regeneration of the root system of transplanted trees is essential for survival and for re-establishment of a favorable root-shoot ratio.

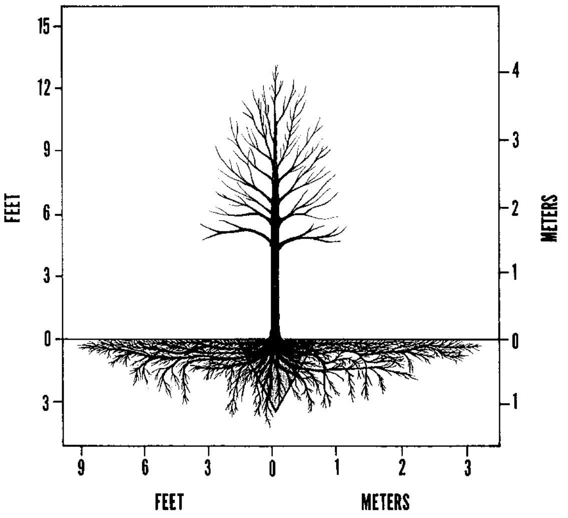

Figure 4. Illustration of a typical root system developed by using field data collected from trees growing in a nursery. The shaded area represents a tree spade soil ball 112 cm in diameter and 102 cm deep. The tree illustrated has a trunk diameter of 4 inches measured at 6 inches above ground height.

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Section of Botany and Plant Pathology
Illinois Natural History Survey
Champaign, Illinois

ABSTRACTS

Ellis, M.A. and D.C. Ferree. 1981. **How powdery mildew affects apple photosynthesis and transpiration.** Ohio Report 66(5): 67-70.

Interdisciplinary research was initiated to determine the effects of powdery mildew infection on photosynthesis and transpiration in apple leaves. The results of this study demonstrate several important considerations in the development of such a model for powdery mildew in apple. Leaf age at the time of infection and timing of fungicide applications after infection appear to be important factors. When leaves are infected early in development, they will never attain their full photosynthetic capability. However, timely application of a fungicide to eradicate the fungus may allow development of new leaves. Leaves develop some form of resistance to powdery mildew as they mature. Therefore, the rate of infection and subsequent reduction in photosynthesis is greatly reduced with age. When mature leaves are infected, timely application of fungicide to eradicate the fungus appears to stop further reduction of photosynthesis and transpiration.

Preaus, Kenneth B. and C.E. Whitcomb. 1981. **How does the digging method affect tree transplanting success?** Am. Nurseryman 154(4): 9-10, 18-20.

Tree spade manufacturers make many claims about transplanting success with their machines. But few studies have been done to compare tree spades with conventional B&B techniques for survival rates and for costs per amount of time needed. To determine the merits of the various transplanting methods for trees, four digging and planting treatments were compared. Ball glazing from the tree spade is not as serious as was originally thought, at least when loose backfill can be placed in intimate contact with the face of the ball following transplanting. On the other hand, when a tree dug with a tree spade is placed in a hole dug by a tree spade, air spaces are likely to be left in numerous places around the ball. Removing enough soil from around the top of a hole dug with a tree spade to provide loose backfill down as far as the major roots in the ball dug with a tree spade may increase survival and growth. Digging machines can be used about as successfully as B&B techniques. The pull method deserves more attention, particularly for transplanting large trees.