

Root Systems – How they transport nutrients

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Soil scientists around the world have looked at what parameters determine access to soil nutrients for over 40 years. In this article we will look at three structural components of the plant root systems, and then three dominant mechanisms of nutrient transport that moves nutrients from the soil into the plant.

First parameter is the size of the plants root system, whether it is robust extending deep and growing with excellent lateral extension thusly exploring more of the soil that will extract more moisture and nutrients or small and short lived as those of an onion. Second parameter is the architecture or character of design of the root system. For each crop known to be cultivated for its produce, wood, fiber, grain or fruit, we know the layout of the roots pattern into the soil material. The most usual classification of roots referred to a developmental order, known as axes and laterals, primary then secondary, tertiary and so on was set by two scientists Cannon, 1949 and Rose, 1983. See figure 2. Third, specific morphological properties of roots; root diameter, rooting hair formation, root length, branching and root tip dimensions.

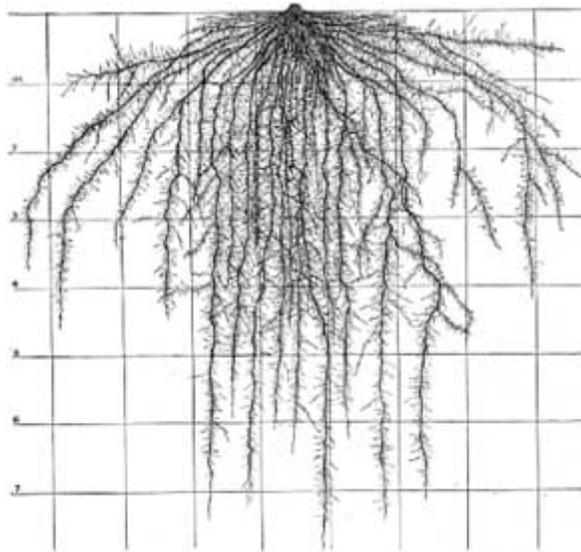


Fig. 1. Mature corn root system in Iowa, 1949

Along with the three parameters that dictate root size, spatial concept, growth and exploration of the soil medium – what are the mechanisms of nutrient transport? There are three; Mass flow – the convective movement of nutrients in soil solution from bulk soil towards the root. Approximately 76-78% of the nutrients are supplied via mass flow. This distance is short compared to the overall root dimensions of a corn plant let's say as for example. The distance ions will move may only be one to four millimeters away from the physical root. Second, Diffusion – is the spontaneous movement of ions caused by thermal agitation. This is found with many of the more immobile ions such as potassium (K), phosphorus (P), and zinc (Zn). Approximately 20% of the nutrients are gained by roots in this manner. Mass flow and diffusion work interdependently. Barber (1962) said that the transport of nutrients into the plant root is linked by mass flow and diffusion provides us a basis for understanding the interactions between root and soil. And last is actual Root Interception – where roots grow into contact with nutrients, soil pores with solutes. Approximately 2% of all nutrients gained by the crop root system come via this physical contact. More of the interception is from the actual root hair growth below the 7-8 inch depth. The root hair may protrude and extract nutrient ions from a distance away from the root 40 to 100nm (.0001 of a millimeter), pretty small, dinky distance one would say.

Uptake of nutrients also is affected by the root tip with the mucigel material produced to help the root tip slide deeper and downward into the soil profile. This substrate of complex carbohydrate attracts microorganisms like a magnet. The microbes colonize in this rich food source and they absorb and breakdown complex molecules

and release nutrients into the interface called the rhizosphere. As the root extends the mucigel is sloughed off and stays immediately close to the root for microbes to flourish and help feed the root. This is a small percentage but plays an active part in sustaining the biological functions around the root itself.

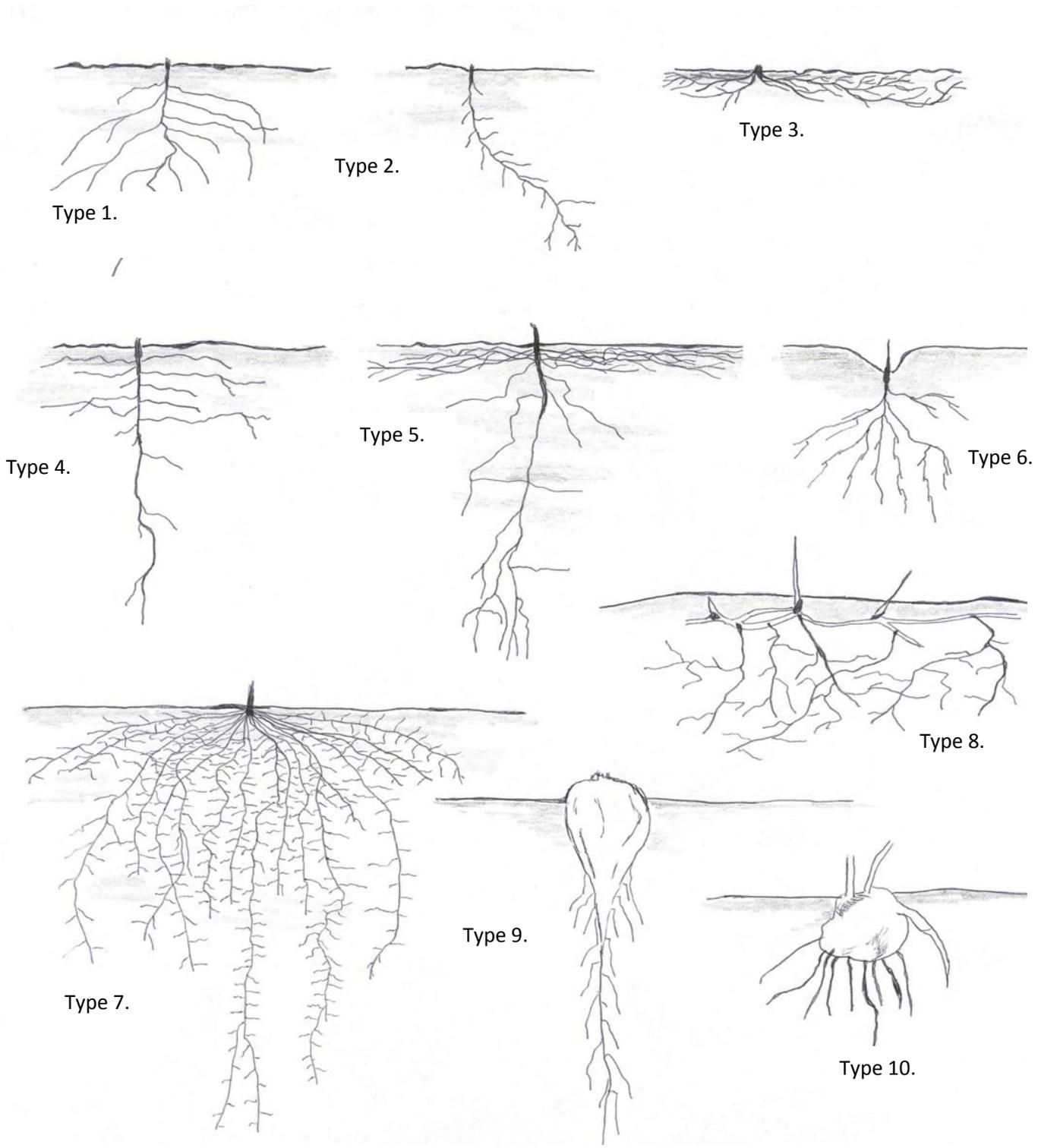


Fig. 2 Examples of root systems from tentative classification of root systems

Sites where adsorption of water and nutrients take place in the plants root system.

It is still a debate of where initial uptake takes place and where along the root the release of ions and water flows into the xylem cells. There are several sites along the root epidermis that adsorb nutrients and water, those being apoplast pores, root hairs, associated mycorrhizae hyphae and the roots epidermis.

The apoplast is a system of pores and wall surfaces outside the plasma membranes of the epidermal, cortical and stelar parenchyma cells (Clarkson, 1978) and are considered one of the major points of entry for ions and water. These pores are no larger than 4 nm and are wide enough to allow unrestricted entry of hydrated inorganic ions, water, and some small organic molecules a zone such as sugars and simple amino acids. Electrostatic charges within the cell walls and around the apoplast can restrict diffusion of positive charged ions (ie: K^+ , Ca^{++} , Mg^{++}) into the root and on into the xylem tissues. This slows down the diffusion process due to the interactions of positive charged cations with fixed negative charges in the root cells and near the apoplast. Research has determined that diffusion coefficients within the cell walls are only one-tenth or one-hundredth as great as what occurs in a free solution of cations and anions (Walker and Pitman, 1976). The amount of exchangeable anions in and around the root apoplasts is very low due to these charge affinities and low concentrations near the plasma membrane. It is suggested then that anions such as phosphate are absorbed at the root epidermis in most circumstances (Walker and Pitman, 1976).

Root Growth

There are many differences in root development among plant species (Kasperbauer, 1990; McMichael, 1990; Klepper, 1992; Zobel, 1992). Within a plant species root/shoot ratio, decay, regrowth, and distribution in the soil profile are dynamic and depend upon environmental conditions such as soil structure, amount of sand, silt and clay, mineral stress, temperature, gases, internal drainage, availability of nutrients and water and spectral distribution of light used for photosynthesis. All or part of these conditions may interact with a particular genetic character of the plant being observed. Photosynthate allocation and performance of the plant between shoots, leaves and roots affects the nature of rooting (Smucker et al., 1984). Those root responses to allocation of photosynthates include:

1. Total length of the root system
2. Maximum root depth obtained in a growing season (cultivated crops)
3. Root system modification in each horizon; lateral root development and branching
4. Root diameter
5. Volumes of roots and surface area within volume of soil
6. Total volume and surface area for the entire rooting system observed
7. Frequency of branching for each branching level
8. Total length of each level of branching
9. Distance of root hair formation from the root tip
10. Maximum length of root hairs
11. Rhizosphere area – square area of root saturation within soil-root profile

In my years of looking at roots for crops grown in the Western and Central Corn Belts (1980 to present day-2010) I have observed with early plant and root growth we can see cultivated crops thrive and yield more

produce when the root system is given a good start. By that we are speaking of the tillage to prepare the seedbed, placement of nutrients, resident moisture at planting, effects of seasonal soil profile warming and subsequent rain or irrigation to complete the lifecycle of the crop. Far too often farmers have thought the soil in order to prepare the seedbed was to be turned, broken down into the smallest size, packed/firmed and all crop residues buried to be out of the way of the next seeded crop. Modified methods have come along with minimum tillage methods such as vertical tillage, strip-tillage, zone tillage and direct seeding.

At Orthman Manufacturing we believe that strip-tillage has tremendous benefits of getting the seedbed vertically shattered, mulched without incorporating coarse sized fragments of residue from the previous crop so the following planter can place the seed in clean soil and maintain good seed-to-soil contact for another years crop. With a good start a crop has the best chance to reach nutrition and extend roots down and laterally for more water and nutrient uptake throughout the season. Our field research has observed with deeper root systems, we are obtaining better yields, healthier crops, and less need for large amounts of added fertilizer because we are exploring more of the soil profile below the upper 12 inches, down to depths of 60 to 80 inches.

With those of you considering what it will take to gain better crop yields, better rooted crops, less fertilizer that has to be used, less irrigation water (for those that irrigate) – we urge you to contact a dealer that knows something about the strip-till system and has the right tool to sell and to help you get using Strip-Tillage right.



Fig. 3 Strip-Tilling wheat stubble in Southern Michigan (2009) with an Orthman 1tRIPr

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