Proceedings; Utah State Horticultural Association Annual Convention
Jan. 27-28, 1998
Provo, Utah

Tree Fruit Root Systems and Soils

Dr. Ron Perry
Department of Horticulture
Michigan State University
East Lansing, MI 48824

Fruit growers through out the world are aware of the importance of deep, uniform and friable soils which are necessary to support bountiful crops for many years. Through the root system, the soil must provide adequate moisture and nutrients to satisfy canopy foliage and crop needs. These ingredients plus oxygen are also necessary to encourage good root development. When any of these ingredients are lacking, the root system and subsequently, the canopy suffer and it is expressed as stress symptoms. The characteristics of the soil profile, which refers to the vertical cross-section of the soil from the surface into the underlying unweathered material, plays an important role in fruit tree performance and longevity. A soil profile (agricultural) is made up of three layers, or horizons: A, B and C (Millar, 1965). The A horizon (topsoil) is the surface layer where components have been removed. The B horizon (subsoil) is the part of the profile where materials from the A horizon have accumulated (fine soil particles, iron, aluminum, lime and colloids). The C horizon is the geological substratum and, in Michigan, consists of unconsolidated mineral deposits of glacial origin: pure sand, sand and gravel, friable sandy clay, silt and compact, massive clays. In the west, the C horizon is most often bedrock which can include limestone, gypsum, and sedimentary rock. A desirable orchard soil profile possesses a deep (6 feet or more), uniform A and B horizons with gradual, vertical changes in physical characteristics. These conditions foster root development which encourages roots to forage the full depths for nutrients and water. Soil and root work on apple in the 1930's by Batjer, indicated that fruit trees needed a minimum of 3 feet of unobstructed soil profile for satisfactory production.

In Michigan and in other areas, where soils have been derived from glacial action, the characteristics of the B horizon can change drastically, both vertically and horizontally, from one tree to the next. This situation is becoming very common among declining cherry orchards in Michigan (Perry, 1984). Among these orchards, trees are obviously stressed due to limited root development caused by the excessive or inadequate moisture and oxygen. There are generally three common soil scenarios which limit root growth: 1. fine-textured soils with poor internal drainage throughout the profile, 2. panned soils with dense, compact, or cemented subsoils or layers (claypans, hardpans, fragipans), and 3. layered soils with abrupt significant changes in soil texture which causes "wetting-front instability" (Perry, 1984). Wetting-front instability" is defined as disruption of water movement from a fine textured layer to a coarse layer which percolates in concentrated locations as in finger-like protrusions through a profile. Hill and Parlange (1972) postulate that this phenomenon is caused by an instability at the air/water interface which is gravity driven and is more pronounced as the pore size of the coarser sand increases. In the orchard, where this situation exists, water movement into the sand is slow and appears to temporarily “hang-up” (perch) at the interface until several inches of soil above the boundary is saturated. The location and development of sinker roots in these soils can often be found in the “fingers”. This phenomenon can cause root rotting above the interface in the wet spring and/or a moisture deficit in the sand layer below during the summer.

These physical limitations in the soil profile can have devastating results on tree longevity and productivity (Neja, 1977, Micke, 1983, Morris, 1981). Shallow soils inhibit depth of rooting. During the summer a tree may experience serious stress if the root system can not satisfy the demands to provide water and nutrients to developing fruits and nuts and to the foliage (Greacen, 1968).

Methods to Reduce Limitation Effects

Site Selection. Obviously, proper site selection is the most effective means to avoid the aforementioned problems. Unfortunately, an orchardist may not have this option and is relegated to making the most of a marginal site.

Rootstock Selection. For some crops, growers can use rootstocks which possess genetic tolerance to wet soils. Generally, apples and pears are considerably more tolerant of wet and heavy soils than stone fruit (Rowe and Beardsell, 1973). Under these conditions for apple MM.111, Mark and M.7 are superior to M.26 and MM.106. Bud.9, M.9 and Mark would be best where Phytophthora is serious. Mark rootstock appears to be extremely sensitive to dry soils, and therefore requires irrigation, especially in the arid west (Fernandez, et.al., 1992). Plum root is superior to peach for compatible stone fruit in heavy soils (Perry, 1984). Almond hybrid rootstocks are serving well for peach and almonds where soils are droughty or calcareous. For pecans, seedlings of *Carya aquatica* are highly tolerant of wet soils and can be top-worked to scion varieties for commercial production (Brison, 1974). We conducted a root distribution study of cherry rootstocks at two sites in Michigan; Clarksville (heavy soil) and Traverse City (sandy soil) in 1990. Rooting intensity was less in the sandy soil and differed little among rootstocks (Longstroth and Perry, 1991). At Clarksville, more roots of MXM 2 were found to a 4 foot depth of the 10 year-old trees than Mahaleb, Mazzard and Colt. By far, soil characteristics had the greatest influence on rooting behavior. Rooting of Mahaleb was more intense where clay textured soil resided n the strata of the B horizon. We have found this to be valid in peach root distribution studies (Layne, 1986). MXM 2 appears to be the most impressive cherry rootstock regarding performance and survival in physically limiting soils as observed in controlled and long term field studies in Michigan. Vigorous trees or rootstocks which possess deep intensive root systems, often have the capability of penetrating soils with hardpans (Perry, 1983).

Tile Drain Systems. Drain systems which are properly designed can alleviate prolonged periods of wetness. They are most effective in fine-textured soils. These systems have a questionable track record in panned and layered soils. Water may continue to perch above lateral lines (usually set at 4-5 feet) and percolate slowly.

Subsoiling. Deep ripping 3-4 ft. and subsoiling or chiseling (plow) (2-3 ft.) can be effective in breaking up panned, and to a certain extent layered soils. The most convenient time to perform this practice is prior to planting. Once the trees have been planted, plowing is restricted to row middles and near canopy drip-lines. Unfortunately, subsoiling is a temporary aid in encouraging deeper root growth and improved moisture drainage. Depending upon the makeup of the soil, sealing of a fractured pan can occur within a few months to a year afterward. Most soil scientists suggest that this operation best be performed when the soil is dry. We studied roots in Germany in cooperation with Prof. Gruppe, Justus Liebig Univ. (the author of the Gisela rootstocks) in 1985 (unpublished). Many Hedelfingen trees were propagated on several *P. cerasus x avium* rootstocks and they were planted in a Loess soil that had been deep tilled with a moldboard plow to a depth of 24 inches, 20 years previously. We observed that the rooting density appeared to be positively affected by deep tillage. Rooting intensity followed the outline of the moldboard plow in the exposed soil profile face. Rooting was not as intense or deep in the non-tilled portion of the field.

Soil Mixing. Soil mixing is becoming popular in California for panned and layered soils as a preplant operation (Micke, 1983). This practice is performed by using either a slip-plow or a back-hoe. A slip plow is a large deep (6 ft.plus), angled plow, which is pulled by a large power source. The A and B horizons are mixed rather than momentarily fractured as in subsoiling. The same beneficial effect can be gained by digging a trench 3 ft. wide, 5-6 ft. deep and 6 ft. long with a back-hoe prior to planting. A field study in the Willamette Valley , reported by Miller, et. al. , in 1990, showed that Napoleon trees planted on 3 rootstocks produced more fruit and had more vigor after 8 years, when the trees were planted in holes prepared with a backhoe. Trees planted in augured holes were inferior. Fumigation added to backhoed holes made little difference.

Deep tillage and mixing treatments can also be useful in stratified soils, where soil textural classes differ greatly. Sandy subsoils can often be deceiving and be void of roots and water and nutrients (Layne, et.al., 1986). Trees planted on these sites often times make a 100% increase in growth over undisturbed sites. Commercial almond and walnut growers are finding that the $700 to $1000 per acre investment in California pays back productive dividends in newly established class III land.

Raised Beds. Also known as growing trees on ridges or mounds, this technique is gaining popularity in many areas of the world. Farmers for hundreds of years have long reported the benefits of growing trees in marginal soils on raised beds. The growing of crops on raised beds or ridges is not a new practice, as it can be found in archaeological literature dating back to pre-Roman times in Europe and England (Du Preez, 1985). In South and Central America, raised fields prevented waterlogging of roots of potatoes and grain crops between 1000 BC and 400 A.D. Peruvians dug a series of parallel canals and piled earth between them to form long, low mounds 1 meter high, 4-10 meters wide and 10-100 meters long. The canals, filled with water, were thought to provide warmth and release heat at night to help avoid frosts (Bray, 1990). Over 2000 years ago, Aztecs in Mexico grew crops in rectangular raised garden beds to keep roots above the water table on shallow lakes. The ridged field concept was used in South America in the pre-Colombian period in savannas and highland basins where soils are seasonally inundated with water. Closer to home, records show that American Indians in Michigan, Wisconsin and Mississippi, grew crops on raised beds dating back to A.D. 700-1500 (Denevan, 1970). Today, over 350,000 acres of citrus are commercially grown on multiple tree-row beds in South Florida, where the water table is less than 3 feet in depth most of the year (Sites, et.al., 1964). Deciduous fruits are commonly grown on raised beds in South Africa (Du Preez, 1985) Australia (Adem and Tisdall, 1986), New Zealand and in northern Germany. Growers in New York, Michigan, southern Illinois and in Kentucky (Brown, 1981) have long produced fruit on raised beds.

Surprisingly, there has been little research conducted to empirically assess the virtues and ramifications. Beds are formed by continued plowing or by the use of land moving equipment. Root systems appear to benefit from a doubling of top soil components down the tree row and from the surface drainage effect into adjacent troughs. Beds can divert water from around the crown of a tree and help avoid Phytophthora root rot infestation, which is associated with poorly drained soils.

We established a raised bed experiment at the Clarksville Horticultural Experiment Station in 1981 to study the benefits of raised beds for growing fruit trees. Redhaven peach on Halford, Montmorency cherry on Mahaleb seedling and Redchief Red Delicious apple on MM.106 were grown on control or Flat treatments and compared to growing trees on two bed designs. The beds were formed with a construction road grader with trees spaced at 10 feet by 20 feet. The 2 acre site is made up of a Riddles Sandy Loam soil series which is described as being fairly uniform through most of the site and moderately well drained. Most of the plot had an A horizon of loam to a depth of 7-10 inches over a compacted 40 inch thick B horizon. A sandy Bt horizon began at about 50 inches. The A horizon in the southwestern portion of the plot was 14-16 inches deep over a less compacted B horizon. The soil in the High bed treatment was formed with a high narrow crown at 12-15 inches wide and 18 inches above normal ground line. The Low bed treatment had a flat crown of 4-6 feet wide and 12 inches above normal ground line. The trees and beds were arranged in an experimental design so that there were four replications of each bed treatment and crop. Twelve trees of each fruit crop were arranged in three rows for each bed treatment and the center two trees were considered the data trees. All trees were trickle irrigated until termination of the experiment in 1992. Only the western (guard) row of trees were not irrigated for additional soil moisture studies.

Experimental results**.** As of 1983, it was apparent that the young apple and cherry trees showed preference for the wide low bed design and peach performed best in the flat or control treatment (Perry, 1984). Cherry and peach guard trees had succumbed only in the flat treatments, adjacent to bed treatments which likely had shed surface drained water into the neighboring trees in the flat treatments. Cause of death was not differentiated between physiological stress due to anaerobiosis (flooding) or by root rotting pathogens such as Phytophthora species. Raised beds reduced the incidence of Phytophthora and increased plant vigor and yield of raspberry in New York (Maloney, 1993). At that point in the trial, it was apparent that trees planted on the high bed benefitted from supplemental irrigation to avoid drought stress.Soil temperatures monitored during 1983 indicated that beds tended to be slightly colder and that this phenomenon was closely linked to soil moisture content. In the spring of 1984, two peach trees in the High bed treatment of one replicate were found dead. Following closer examination, it appeared that death was caused by winter injury to the root system in the top 12 inches of the soil.

Soil and leaf water potentials were monitored during the growing season of 1987 of peach and cherry. Leaf water potentials were more negative (more plant stress) on non-irrigated ridges than irrigated. In a mid-July sampling, leaf and soil water potentials were more negative in ridges than in the flat treatment. Less available soil moisture was also found in non-irrigated and bed treatments in the planting. Our experience in this study on soil moisture stress of trees on raised beds mirrors results and experiences in other fruits and locations. As expected, the crowns in raised beds are first to dry out and thus citrus trees grown on sandy soils in the center of a multi-row bed have a tendency to experience drought stress if the water table isn't increased to compensate (Obreza, 1989). Du Preez (1985) in South Africa states that irrigation of orchards on ridges is a must for success. Insufficient irrigation is the single factor responsible for poor performance of orchards on beds. They recommend microjet and trickle systems. Sprinkler systems, wetting the entire surface area, causes great water losses and causes excessive erosion of the beds. South African researchers contend that part of the increased rate of evaporation on ridged soils is due to the fact there is a larger soil surface area exposed to irradiation by the sun and wind. They found that, depending on the shape and the height of the ridge, the length across the crown down to the flat basin is 4% -10 % longer than the horizontal.

Tree survival at Clarksville over the 12 years that the study was conducted was analyzed for data trees (2 trees for each crop and bed treatment) and all trees (total of 12 for each crop and treatment). Unfortunately, one replication of peach data trees became seriously infected with X disease starting in 1987, which confounded our survival records. Also, low soil temperatures in the high beds during the winter of 1983-84 killed roots and subsequently trees. However, when all trees were analyzed, more trees were lost in the flat treatment than the high and low beds (Fig. 1). Cropping over the years was greatest in the high beds for peach and best in the low bed treatment for cherry. Peach yields were doubled for trees grown on beds over 7 years in Tatura, Australia (Adem and Tisdall, 1986). In 1992, rooting was visually assessed and soil bulk density determined in the beds. Rooting depth in the beds was concentrated in the newly formed horizon of the beds. Soil density was highest in the flat treatments as expected (Fig. 2). Formation of the beds doubled (low bed) and tripled (high bed) the volume of the potential rooting zone. Our experience with growing stone fruit on raised beds was positive and that growers are encouraged to use them where dense or wet soil limitations exist in Michigan. Apples grown on flooding sensitive MM.106 rootstock did not benefit from bed treatments. In fact, after 12 years little to no differences were found for yield and survival.

Orchard Floor Management Effects on Root Systems. Root systems of trees can also be affected by the proximity of roots of other trees and of other plants. Atkinson (1980) has shown that apple trees in close spacing have a tendency to confine themselves and develop a more narrow and deep rooting pattern. This was not apparent in peaches in a study conducted by Layne (1986). In that study, the presence or absence of the sandy alkaline C horizon had more effect on rooting distribution in depth than all other factors. Peach rooting in that study was heavily affected by soil moisture. Root intensity in the A horizon was higher with the highest soil moisture and irrigation regime after 13 years. Soil moisture and rooting can also be affected by the width of the herbicide strip and the type of vegetation grown in the alley-way. Parker (1993) found that peach tree root distribution was negatively affected by the presence of tall fescue. Roots have a tendency to congregate in the weed-free zone and develop a deep pattern out in the vegetation inhabited alley-way (Atkinson, 1980). Trees are more vigorous when managed in orchards that have a wide weed-free zone to alley-way (vegetation) ratio. Many orchardist use this knowledge to help control tree vigor by either widening the weed-free zone or allowing more sod encroachment and compete with tree root systems to reduce vigor.

References

Adem, H.H. and J.M. Tisdall. 1986. Automatic laser-levelling and tractor guidance for the Tatura permanent bed system of cropping. Proceedings, Conference on Ag. Engineering, Adelaide, Australia, 24-28 August, 1986, pg 1-8.

Atkinson, D. 1980. The distribution and effectiveness of the roots of tree crops. Hort. Rev. 2:424-490.

Bray, W. 1990. Agricultural renascence in the high Andes. Nature. 345(6274):385.

Brown, G., J. Strang, C. Chaplin, R. Averett, J. Hartman, R. Stuckey and R. Scheibner. 1981. Growing peaches in Kentucky. Univ. of Kentucky Extension Bulletin HO-57, 23 pp.
Brison, F. 1974. *Pecan Culture.* Capital Printing, Austin, TX. 292 pp.

Denevan, W.M. 1970. Aboriginal drained-field cultivation in the Americas. Science. Vol. 169(3946):647-654.

Du Preez, M. 1985. Ridging of Orchard Soil. Deciduous Fruit Grower. Jan: 22-31.

Fernandez, R.T., R.L. Perry and J.A. Flore. 1992. Physiological responses of young apple trees on three rootstocks to drought stress. HortScience 27:85. Abstr. #030.

Fernandez, R.T., R.L. Perry and D.C. Ferree. 1995. Root distribution patterns of nine apple rootstocks in two contrasting soil types. J. Amer. Soc. Hort. Sci. 120(1):6-13.

Greacen, E.L., K.P. Barley, and D.A. Farrell. 1968. The mechanics of root growth in soil with particular reference to the implications for root distribution. p. 256-269. In: W.J. Whittington (ed.). *Root Growth.* Butterworths, London.

Hill, E.D. and J.Y. Parlange. 1972. Wetting front instability in layered soils. Soil Sci. Soc. Am. Proc. 36:697-702.

Maloney, K.E., W.F. Wilcox, and J.C. Sanford. 1993. Raised beds and Metalaxyl for controlling Phytophthora root rot of raspberry. HortScience 28(11):1106-1108.

Mandoga, R.N. and R.L. Perry. 1987. Effects of soil density on growth of container-grown *Prunus* rootstocks. Proc. ASHS, Orlando, FL (Abstr. #470).

Micke, W. 1983. Effects of back-hoeing and slip plowing on young almond tree growth. Pro. Amer. Soc. Hort. Sci., Workshop: “Orchard Soil Modification”. McAllen, TX.

Millar, C.E., L.M. Turk and H.D. Foth. 1965. *Fundamentals of Soil Science.* John Wiley & Sons, Inc. 491.pp.

Miller, A. , P. Lombard, M. Westwood and R. Stebbins. 1990. Tree fruit growth of ‘Napolean’ cherry in response to rootstock and planting method. HortScience 25(2):176-178.

Morris, J.R. and D.L. Cauthon. 1981. Effect of soil depth and in-row vine spacing on yield and juice quality in a mature ‘Concord’ vineyard. J. Amer. Soc. Hort. Sci. 106(3):318-320.

Neja, R.A., W.E. Wildman and L.P. Christensen. 1977. *How to appraise soil physical factors for irrigated vineyards.* Univ. of Calif. Coop. Ext. Serv., Leaflet 2546. 20pp.

Layne, R.E.C., C.S. Tan and R.L. Perry. 1986. Characterization of peach roots in Fox Sand as influenced by sprinkler irrigation and tree density. J. Amer. Soc. Hort. Sci. 111:670-677.

Layne, R.E.C. and C.S. Tan. 1988. Influence of cultivars, ground covers, and trickle irrigation on early growth, yield and cold hardiness of peaches on Fox Sand. J. Amer. Soc. Hort. Sci. 113(4):518-525.

Layne, R.E.C., C.S. Tan and D. M. Hunter. 1994. Cultivar, ground-cover, and irrigation treatments and their interactions affect long-term performance of peach trees. J. Amer. Soc. Hort. Sci. 119(1):12-19.

Longstroth, M.A. and R.L. Perry. 1991. Cherry rootstock root distributions in two Michigan soils. HortScience 26(6):144. Abstr. #559.

Obreza, T.A. 1989. Water table behavior under multi-row citrus beds. Proc., Fla.State, Hort. Soc. 101: 53-58.

Parker, M.J. and J. Hull and R.L. Perry. 1993. Orchard floor management affects peach rooting. J. Amer. Soc. Hort. Sci. 118(6):714-718.

Perry, R.L., S.D. Lyda and H.H. Bowen. 1983. Root distribution of four *Vitis* cultivars. Plant & Soil 71:63-74.

Perry, R.L. 1984. Working with soil limitations for orchard crops. Proc. Ontario Hort. Conf., 1984, Ministry of Agric. and Food, Ontario, p. 164-171.

Rowe, R.N. and D.V. Beardsell. 1973. Waterlogging of fruit trees. Horticultural Abstracts 43(9): 534-548.

Sites, J.W., L.C. Hammond, R.G. Leighty, W.O. Johnson, and K.D. Butson. 1964. Information to consider in the use of oils of flatwoods and marshes for citrus.Univ. Florida. Circ. S-135-A.35 pp