OPTIMIZING THE RE-PLANTING OF ORCHARDS IN CALIFORNIA INFESTED WITH PHYTOPHTHORA CINNAMOMI

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1. Clonal Rootstock

Clonal avocado rootstocks predominate commercial plantings in California. Avocado growers recognize the potential of clonal rootstocks for greater productivity, uniformity (Bender *et al,* 1991) and benefits of *Phytophthora cinnamomi* (P.c.) resistance, salinity tolerance (Mickelbart and Arpaia 2002) and adaptability to soil stress factors (Bender *et al,* 1991). The majority of clonal rootstocks have performed well when planted in locations free from infestations of Pc. Replanting Hass where avocado trees have declined from Pc root rot can be problematic. Horticultural limitations have been identified that can guide growers when deciding whether or not to replant avocado trees in infested orchards.

Growers have implemented an integrated approach to replanting in root rot infested soils. In spite of this practice, replanted Hass trees may have difficulty becoming established or decline at a later time when stress factors prevail or conditions favorable to epidemic Pc overwhelm trees. California growers utilizing a systematic, pre-screening approach can evaluate suitability for replant success. This will maximize avocado productivity in disease-infested soils or eliminate from consideration locations impractical or too costly to replant.

2. Integrated root rot management approach

Rootstocks alone or intensive fungicidal treatment by themselves can be ineffective unless a holistic integrated approach is used. This system includes sanitary nursery practices, planting clonal rootstocks, chemical control, biological controls through soil modification, orchard sanitation and precise irrigation (Coffey 1987). Sustainable control of this disease can be achieved when all these management practices are applied.

3. Classic crop rotation

Some limiting factors cannot be overcome economically. When any of the following soil and water factors are compromised, or maximum salinity levels exceeded, the grower should consider choosing a less susceptible crop or alternative land use. Although many subtropical plants share a degree of susceptibility to the general soil stress factors to be discussed, avocado are severely compromised by conditions still suitable for citrus or other crops. Few other tree crops, though, are as susceptible to Pc or poor aeration as avocado (Zentmyer 1976).

4. Avocado Adaptability

Avocado trees are quite adaptable to various soil conditions on land that has not been previously planted with avocado trees. In older orchards and soils that have become infested with Pc, replanting of avocado trees is possible only in the most optimum conditions (Coffey 1987). Disease and salinity may preclude further maintenance of avocados with compromised conditions.

5. Soil Drainage and Phytophthora cinnamomi

Pc causes an avocado root rot. Spores move more freely in saturated soils. Pc and avocado roots need oxygen-laden air to grow but saturation enables rapid spread of spores while suffocating avocado roots. If oxygen is not present, roots simply cease to suck water from the surrounding soil. Even without the presence of Pc, avocado roots die quickly when oxygen levels are low (Schaffer, 1992). Saturation and poor aeration is caused when internal soil drainage is impeded by fine clay textures, compaction, layered soil profiles, and intense rainy periods. Air spaces between soil particles are filled with water and air is excluded. Regardless of slopes that may allow for quick runoff, the internal soil characteristics are critical to root health. Although sloped orchards may shed water quickly, excess water still accumulates in root zones with poor internal physical soil characteristics. There is no substitute to fundamentally good soil drainage.

6. Soil texture and structure

Soil is composed of minerals, organic material, gasses and water. The relative particle size determines its texture; large sand particles combined with medium silts and fine clays. Because clay particles are smaller they clump together closer making smaller but more numerous pores. The proportions of sand, silt and clay and high organic material bind the soil structure into clumps that provide for greater pore space for water and air. Soil texture and soil structure are easily measured and are important determinants whether an orchard is suitable for replanting.

7. Water movement and air space

The pores between soil particles provide space for water and air. Water moves through soil by gravity, is taken up by the plant, or is retained in the soil by its attraction to soil particles. Excess water percolates down from pore spaces especially in sand but because of the surface attraction water is held to soil particles. Because clay particles are more numerous and more compact they have more surface area and thus more pore space than sand. But because the pores are smaller, soil/water attraction overcomes gravity so clay holds more water, has less air space and thus low permeability compared to sand. Water movement is much slower through clay than sand because of tighter retention of water in smaller pores so then air cannot reoccupy pores quickly. Finally, with surface evaporation, water molecules migrate to dryer soil particles above and eventually open air spaces below. Meanwhile avocado roots suffocate and cannot function during prolonged period of wetness. Pc spreads rapidly in these conditions.

8. Soil profiles and variability

Soil is variable and may change quickly from one area of the orchard to another often in short distances. Soil texture and structure also changes from the topsoil down through the subsurface profiles. Few hillside soils are deep and uniform and typically have shallow topsoil with a low organic component. Soil profiles often become increasingly higher in clay with depth. Erosion deposits over time make soils layered. Often avocado trees with Pc fail first in low swales before other areas of the orchard because fine, clay-textured soils have eroded over time down to concentrate in the low-lying swales. These areas are often exacerbated by upward flow from groundwater or at least a higher tendency to accumulate excess moisture. However, much of the variability is not visible because it is below the soil surface and cannot be detected except by soil tests.

9. Soil and salinity

Exacerbating the drainage problem is salinity toxicity. All soils and waters contain salt. When soil dries out because of evaporation the salts become more concentrated in the remaining water. The plant thirsty for water sucks up the concentrated solution and salts concentrate in the borders of the leaves. Since they have no efficient way to escape the leaves they poison the tissue. The normal remedy for salinity is to leach the soil thoroughly to wash out the salts. The paradox is leaching by excessive irrigation in a soil with poor drainage, causes prolonged saturation problems, ineffectual leaching from lack of percolation and further build up in salinity. Toxic ions including sodium and chloride can be unmanageable in poorly drained soils. Avocado trees under salinity stress are even more susceptible to Pc root rot (Borst 1970).

10. Assessing soil characteristics

It is impossible to assess soil characteristics from the surface appearance. To better understand soil drainage impediments, pits should be dug 1.5 to 2 m deep to observe the soil profile and sample the soil textures. Pits allow observation of changes in color and texture, of distinct layers if they exist, and of potential high water table problems. If access to the sites makes it impossible to dig pits, boring for soil samples is sufficient. In uniform small orchards a few sample sites may be enough to get a good understanding of the soil variations but larger sites of diverse terrain require enough sample sites to be able to identify and map the changes in soil characteristics. At each sample site soil samples should be taken from the topsoil below surface litter and separate samples at .5 m and 1 m. The topsoil samples from the same depths from multiple sample sites may combined into a composite sample if they are sufficiently uniform, eliminating small site variations and excessive lab costs.

11. Simple field tests

To identify samples that may have too much clay for avocado growth, remove any rocks and slowly wet a small amount of soil kneading it into a ball in your hand. It must be moist but not too wet or sticky. On a flat surface, roll the ball until it forms a rod. If the rod can be bent into a circle, it has too much clay for avocado. If it is difficult to form into a rod without crumbling, or it cracks when a ring is made, it may have sufficient sand, silt and organic content to provide suitable drainage and aeration. Be sure to do this at all depths of your sampling.

A percolation test hole should be dug 15 cm wide, 60 cm deep and 30 cm wide. Fill the hole with water and let it drain completely. Fill the hole again and time how long it takes to drain. If it drains in less than 12 hours conditions may be suitable for avocados. If it takes 12-24 hours to drain, the soil is best suited to plants that tolerate heavy or clay soils.

12. Whole block replacement vs. phased or single tree replacement

The limiting factors above may preclude replanting an orchard dying of root rot. If these factors can be eliminated or economically managed, special site preparations can then be considered. It is not practical to replant infested areas in stages. The precise watering needs for newly planted trees cannot be accommodated while caring for older, surrounding trees. The older trees maintain a high disease pressure (Zentmyer and Mircetich 1966) and compete for light and water. Invariably, while trying to care for trees of various ages the younger ones suffer. Fifty percent loss of scattered replants in established groves is not unusual. The problem is further compounded when peripheral trees decline in the second year and newly planted trees are on an irrigation regime with two-year old and the original orchard trees. Carry this scenario forward until the orchard has been completely replaced with trees of various ages and a decade is wasted resulting in a non-uniform orchard of unsatisfactory production.

An economic analysis of an older orchard may be done by mapping and quickly rating an impression of the health and productivity of each tree on a scale of 1=healthy : 5=dead. It quickly becomes apparent that beyond the obvious dead and dying trees are many poor trees that are weak and produce unmarketable, small-sized fruit. If the average tree rating results in 3 or higher the block should be completely removed. Now special land preparation such as deep ripping and ridging the tree rows can be done and uniform replanting can be attained. Some clonal rootstock selections are known for their early production enabling better cash flow and quicker return to profitability.

13 The establishment phase of clonal trees

Clonally rooted cuttings have no central tap root and grow from a crown of roots originating from

a relatively short stem close to the surface of the soil. Trees grown by this method are very sensitive to inadequate irrigation and are quick to dry out especially during the establishment phase of the tree, often leading to the loss of the tree. Stressed plants have less resilience and disease resistance. Once clonal plants are weakened and are unable to refoliate, roots die quickly and tree death is predictable. A poorly established clonal rootstock of any cultivar has great difficulty wintering-over the first year. When stressed by cold winds and exposed to heavy rains, loss of roots causes a rapid defoliation when mature leaves are shed in the early spring. One-year-old defoliated clonally rooted trees rarely recover, however, once past the establishment phase, clonal trees are more resilient to environmental stress. Seedling rooted trees, though variable by nature, are not as prone to death following defoliation, but seedling trees do not possess consistent, positive traits replicated by clonal rooting. Once established and wider, deeper roots develop, clonal-rooted trees are not distinctly susceptible to crown desiccation or damage.

14. Irrigation systems

It is known that irrigation, drainage and aeration are most important aspects in replanting diseased avocado orchards. Creating conditions optimum for avocado while minimizing conditions conducive to P.c. epidemic can be accomplished on suitable soils. It is imperative to replant diseased orchards by irrigation blocks so management of the trees can be uniform. Some water districts can only schedule irrigation water deliveries every 2 to 4 weeks and then require the grower to use it for 24 hours. It is not possible to accommodate the tree's needs on a schedule that excessively dries the trees out and then floods the trees with excess water. Both extremes are damaging. If water is not available on demand, reservoir or tank storage is needed to bridge water deliveries. Regardless of the type of water application, whether it is drip, micro-sprinkler or other, systems should be designed to accommodate frequent irrigations with sufficient water applied to bring the root zone to field capacity. (Field capacity is the amount of water held in unsaturated soil pores after a period that excess free water has drained away). A service offered for growers in California is the California Irrigation Management Information System (CIMIS) provides local data on water lost through soil evaporation and plant transporation. CIMIS measurements are calculated to correspond to avocado and when combined with soil moisture measurements in the orchard and even plant measurements can provide precise water requirements.

Hot and arid areas in California may require frequencies of 3-7 days with micro sprinklers, and as often as daily with drip. Sprinklers should be selected that can provide sufficient water to penetrate just below the root zone at slow enough rates to prevent runoff. Trying to store excess water in the soil to accommodate longer intervals between irrigation results in prolonged saturation and ensuing problems.

15. Ridging and drainage systems

Subsurface perforated drain pipe may be required for areas that accumulate excess moisture. The surface must be graded to prevent ponding and to allow for runoff during heavy rain. Ridging or mounding the tree rows can provide greater topsoil depth, enhanced aeration for avocado roots and encourage a quick start for young trees. Native soil should be used, free from pre-emergent herbicides. Ridges should be incorporated well with the floor of the orchard to eliminate any possibility of a soil interface barrier that could inhibit water percolation. This is especially important if imported soils or organic amendments are added. Build the ridges 1/2 to 1 meter high, with 4:1 sloped sides. Ridges should be built well before planting, settled with water and allowed to dry to be friable before planting. Allowing time to for the soil to re-aggregate and rebuild soil structure provides greater porosity and air space. Planting into unstructured muck can eliminate pore space and the aeration effects sought by the ridges. After the tree is planted in a generous hole, leaving the surface of the nursery root ball slightly exposed to irrigation water, settle the tree with a generous flooding irrigation to assure large air spaces are settled and eliminated. These air gaps can dry out roots on the root ball and lead to uneven watering.

Sometime later cover the surface of the soil around the tree with gypsum. The calcium in gypsum retards Pc propagules and enables roots to resist infection (Menge 1998). Then cover the mound with a mulch of coarse vegetative material about 10 to 16 mm thick being careful to keep the mulch from piling up around the trunk. The root ball is best left exposed to accept irrigation water. The calcium in the gypsum inhibits the Pc fungus and the mulch provides an ideal environment for shallow aerated roots to develop. Mounding or ridging soils can somewhat mitigate marginal soils and ensure a faster start for a young tree. Under normal rainfall conditions these better-aerated structures can greatly improve replant success but still may not fully accommodate excessively wet periods in clay soils that later suffocate the tree's roots.

16. Mulching benefits and limitations

Avocados have adapted to low oxygen conditions by developing roots above the surface of the soil that thrive under moist, airy leaf mulch in healthy orchards. Mulching in a new planting is an attempt to duplicate the natural conditions where older trees thrive. It is understood that decomposition of some organic mulches stimulates soil organisms antagonistic to Pc and beneficial to root growth (Menge 1994). (Mulch is a layer of material covering the soil that moderates soil moisture and temperature. Mulch controls weeds by excluding sunlight, and to some extent by providing a physical barrier to weed growth.) Applying mulch is expensive because it requires significant labor especially if mechanical access is limited. However, the better replant success, improved tree health and increased fruit yield from mulching provide substantial benefits. In hot, dry summers mulch promotes abundant surface roots. In cold, wet rainy seasons mulch can keep trees too wet during this relatively inactive period of the tree when relatively little soil moisture is removed by the plant. Lastly, mulch insulates the surface of the soil and prevents radiant soil heat from escaping which can lead to more severe frost damage.

17. Rootstock selection and conclusion

Current commercial clonal rootstock varieties are not tolerant to saturated soils and low oxygen conditions. Avocado breeding programs screen new varieties based on Pc resistance, productivity and salinity tolerance. Virtually no selections have been made to withstand suffocation. Under integrated management practices in use today, it remains critical when replanting in root rot to select locations that have fundamentally good soil drainage and lack of extreme stress factors. All aspects are required for replant success.

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