Bolstering the Soil Environment—Site Preparation

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Like most investments, establishing an orchard is a financial risk, with growers having little control over the adverse effects of climate and fluctuating market conditions over long periods of time. Coupled to this, there are orchards in all tree fruit industries that are under-performing in terms of tonnage potential and fruit quality. Very often this poor performance is related to soil factors. Bolstering the soil environment by correcting adverse soil properties prior to establishment will enable growers to jump-start their new orchard and develop the canopy required for early and sustained high production of quality fruit. The approach discussed below is one which has been developed in South Africa and is now accepted commercial practice in the SA tree fruit industry.

INVESTIGATING THE SOIL

The best way to start is to conduct a proper investigation of the soil and site at least two full years before planting. This will require someone who has experience in soil-related aspects of orchard establishment. A soil investigation normally requires 4 test holes per hectare at the site, dug on a 50 x 50 m (164 x 164 ft) grid. If the soils are highly variable, the grid can be tightened. The nature of the terrain and the limitations within each soil profile are recorded and the individual soil units are classified and representatively sampled on a layer basis for fertility analysis. A separate set of samples can be drawn for testing for replant disease and nematodes, if required. One or more of the following limitations are most often present: 1) insufficient topsoil depth, 2) impenetrable subsoils (fragipans, compacted clays, weathering bedrock, etc.), 3) rising water tables on low lying soils, 4) perched water moving down slope above a restricting subsoil layer, 5) pronounced stratification in alluvial soils, 6) limited water holding capacity, 7) low cation exchange capacity, 8) soil acidity (especially acid subsoils), 9) salinity, 10) macro- and micro-nutrient imbalances, 11) replant disease, nematodes and 12) toxic elements such as arsenic.

The required soil preparation is determined by the occurrence and severity of these limiting soil factors as well as the depth requirement for the root system of the orchard. One or more of the soil physical problems listed above and replant disease are often the most serious limiting factors. The important thing to remember is that these limitations can be effectively corrected only prior to establishment.

ROOTING DEPTH REQUIREMENTS

Tree fruit root systems have a basic gravitropic growth habit, i.e., they exhibit a strong tendency to grow downward. The soil depth to which tree roots can penetrate is primarily a function of subsoil properties and their effect on root activity. Secondary influences are the vigor of the rootstock/scion combination and orchard management practices such as the presence of cover crops and mulch, herbicide use, irrigation frequency and volume, etc. Dwarfing rootstocks can have

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deep, healthy root systems if subsoil conditions are conducive to high root activity. From an orchard management point of view, keep the following in mind when establishing an orchard:

1. the effective rooting depth of the soil in its present condition in relation to the desired depth of rooting,
2. the requirement for anchorage in relation to the presence or absence of permanent tree support,
3. soil moisture availability in relation to climate and water (rainfall and irrigation) requirements of the tree,
4. protection against adverse fluctuations in soil temperature and moisture,
5. protection against mechanical or herbicide damage to shallow roots.

It is obvious that a deeper root system is a safer investment. As a general rule of thumb, a minimum rooting depth of 60 cm (24 inches) should be considered a basic essential soil requirement. This means that the tree root system must be able to penetrate to this depth with ease.

GETTING RID OF EXCESS WATER

The degree of waterlogging in a wet year and the approach to soil drainage should be considered before any manipulation of the soil is undertaken. Excess moisture in the root zone impacts negatively on root activity by restricting gas exchange in and out of the soil, keeping spring soil temperatures low, contributing to frost heaving, forcing new roots to grow just below or even on the soil surface, making the root system more susceptible to attack by soil pathogens and contributing to the old problem of tree leaning. The choice and design of a drainage system are functions of the soil type, slope and, most importantly, the degree of waterlogging in a wet year. How many sub-surface drainage systems are there in orchards in your area that do not remove excess water in the root zone rapidly and effectively enough? A very effective way of estimating the depth and duration of waterlogging is to install a number of simple well points on the land. Rigid, perforated drainage pipe works well. Subsurface drainage systems are often deployed ineffectively on sloping and undulating land when the design incorporates a fixed-interval drain spacing, ignoring the fact that some areas are wetter than others. Consider the following options carefully:

1. Cut-off (stone) drains for preventing surface water, or water perched on an impermeable subsoil layer, from moving laterally down-slope into a lower lying orchard. A critical aspect of installation of these drains is that the trench be dug and the drainage pipe laid at least 20 cm (8 inches) into the impermeable subsoil material so as to prevent slippage under the drain. Always cover the drainage pipe with fine stone and then back-fill with larger ones.
2. Deep (1 to 3 m; 3 to 6 ft) subsurface systems for deep, porous soil materials with a rising water table. These systems should be properly designed and can be installed one or more years in advance as long as the depth of installation is below the planned depth of sub-soiling or deep ploughing.
3. Shallower subsurface systems for the removal of perched water tables between depths of 30 and 90 cm (1 and 3 ft). These drains are normally spaced closer together and can be installed after subsoiling, taking care not to re-compact the freshly loosened soil along the tree row. For effective removal of excess water, these drains have to be installed at closer spacings than the deeper systems mentioned above. A point is reached where these drains are too shallow and closely spaced to be economical and some form of surface modification should be considered.
4. Surface modification (ridging, berming or landscaping) in very shallow, fine textured and/or slow draining soils. In cases where the topsoil depth is limiting and the subsoil cannot be utilized (i.e., heavy, clay horizons with no structure and permeability, bedrock, other hardpans, etc.), soil depth and drainage can be improved with a form of surface modification. Excess surface water is re-directed away from the base of the tree line, into the driveway and out of the orchard, which should always be planted with a row direction conducive to surface drainage. Surface modification can make orchard management slightly more difficult, but the investment in additional topsoil depth and drainage on these shallow soils ultimately gives a better orchard, both in terms of productivity as well as tree uniformity.

In soils which are prone to periodic waterlogging, it is critical that the required drainage be correctly installed prior to establishment. This will ensure that the additional root zone depth created by deep soil manipulation remains free of excess water.

SOIL FERTILITY

The lime and nutrient element requirement of the soil is determined by the soil analysis. Recommendations based on the soil fertility norms for tree fruit in your area should always be fully incorporated into the soil before planting. This will ensure the right soil chemical environment in which newly formed tree roots can function and explore the full depth of the root zone. The most effective way to accomplish this is to first remove all surface vegetation and make sure the topsoil is in a friable condition. The required lime and fertilizer are then broadcast as uniformly as possible on the soil surface before any physical manipulation of the soil is undertaken. Lime, if not incorporated, reacts with the soil at the surface only, raising the pH in the immediate vicinity of the lime particles. Because the solubility of lime decreases roughly 100 fold with each unit increase in pH, the dissolving process is considerably retarded. The result is a sharp and undesirable pH gradient with depth. To counter this effect, make sure that the lime is free of lumps, finely divided and uniformly broadcast before mixing it with the soil. Apart from the neutralizing effect on soil acidity, lime is also a source of calcium and magnesium. Make sure that the right form of lime is applied to ensure the correct balance between these two nutrients.

Phosphorus (P) is not very mobile in soil and also needs to be uniformly spread and mixed into the soil to the desired depth. If left on the soil surface, P can also react with lime, further reducing the solubility and mobility of these ameliorants. Potassium (K) is more mobile but can take time to leach into heavy soils. Potassium can be applied together with phosphorus if this is the case. On coarse textured soils with low cation exchange capacities, K can be applied post-plant, together with nitrogen.

DEEP PHYSICAL MANIPULATION OF SOIL

Some form of deep soil manipulation is often required and is used to 1) break up restricting subsoil layers, 2) loosen and mix top- and subsoils and 3) mix in any required lime and fertilizers to the desired depth. To ensure effectiveness and permanence of the action, it is important that this be done at optimum soil moisture content. A soil moisture content just below field water capacity, when the soil is most friable, is often required. However, structured clay subsoils and hardpans often need to be slightly drier to ensure the maximum amount of fragmentation and loosening. Only a visual, physical inspection of the soil profile will reveal this. Sub-soiling a wet soil is a waste of time and money and can negatively affect the potential of the soil as a growing medium.

The choice of the implement used should always match the desired effect on the soil. The implement must also be capable of reaching the required depth, normally between 60 and 100 cm (24 to 40 inches). Three basic actions or a combination thereof are normally considered:

1. Subsoiling or ripping: A ripper

shank, normally mounted behind a Caterpillar tractor with sufficient horsepower, is used for breaking hardpans and fracturing weathered bedrock materials.

2. Deep shift ploughing: For loosening and breaking unstable, structured clay subsoils, without bringing these materials to the surface, use deep shift ploughing. Otherwise structured subsoils will slake, crust and form barriers against infiltration and aeration. The shifting-plough moldboard is usually attached to the lower portion of a large ripper shank and operates at depths between 45 and 90 cm (18 to 36 inches).
3. Deep delve ploughing: For deep mixing of applied fertilizers with both the topsoil as well as the subsoil, a larger, higher moldboard is required. These implements often require at least a D7 Caterpillar tractor to provide sufficient horsepower. Two passes are often required to obtain an adequate soil mix, especially if the lime requirement of the soil is high.

Best results are obtained when this soil manipulation is done on a full surface basis. Ripping along the planting line is, at best, second best.

SURFACE MODIFICATION

If soil investigation has revealed that the soil is too shallow and cannot be deepened by sub-soiling, the only alternative is to ridge. Topsoils are always chemically ameliorated, mixed and physically loosened to a friable condition before ridging. The correct way to ridge soil is to mark out the tree rows with stakes at 20 m (65 ft) intervals after this has been done. Work from the future driveway, using a single or double set of offset discs to throw the soil out to either side onto the tree line. This can be done with a tractor of 80 to 100 HP. With the correct action, very little touching up is required. Make sure the final product has no localized dips and depressions which will interfere with the removal of surface water. A gradual taper to the midpoint of the driveway is most often required but, if problems with infiltration are anticipated, the top can be flattened slightly.

The height difference between the midpoint of the driveway and tree row is dependent on the chosen row width, depth of topsoil, degree of waterlogging and amount of slope, but is rarely more than 25 to 30 cm (10 to 12 inches). Row direction must be chosen to facilitate the movement of surface water out of the orchard. It is important in situations where surface modification is undertaken to make sure that the work is completed in time to establish an effective ground cover in the driveway in the fall to prevent soil erosion. Ground covers take time to establish. Use your knowledge of the growing conditions in your area to make the right choices. A most noteworthy benefit of surface modification is the remarkable improvement in orchard uniformity that is obtained on non-uniform soils. Surface modification should never be so drastic as to significantly increase the surface area for evaporation as well as fluctuations in soil temperature.

OLD ORCHARD SITES

Most old orchard soils require fumigation. Correction of soil biological properties, in this case replant disease, is always undertaken after the chemical and physical amelioration of the soil (including ridging, if it is required) has been completed. Make sure that soil temperature and moisture conditions are optimal (±15-18oC; 60-65˚F) and just below field water capacity and that the soil is loose and well aerated. This will give an optimum balance between diffusion of the fumigant through the soil and contact time with the soil matrix, the two important requirements for effective soil fumigation.

Depth of placement of the fumigant is important. In cases were a single probe is used to inject the fumigant, a good rule of thumb is to fumigate at half the depth to which the soil has been loosened. This would normally mean a depth between 30 and 45 cm (12 and 18 inches). Fumigants are expensive and can be justified only when used under ideal conditions.

SPRING PLANTING— GETTING IT ALL TOGETHER

The window of opportunity during which the soil is at the right temperature and moisture content for optimal physical, chemical and biological manipulation can be open for only a relatively short period, especially if the growing season is short. Success can be achieved only with a well thought out plan. Use the checklist in Table 1 as a guide to successful establishment two years in the future. It always pays to invest at the front end and lay a solid foundation for a successful orchard.

TABLE 1

1.	Soil investigation; plan for soil prep and orchard layout	summer of 2000
2.	Order rootstocks/variety	summer 2000
3.	Install deep subsurface drainage, if required	summer/fall 2000
4.	Clear land of any trees; erosion control	fall of 2000
5.	Soil samples	spring 2001
6.	Remove sod, soil surface in friable condition	early summer 2001
7.	Broadcast lime and fertilizers	early summer 2001
8.	Soil manipulation	summer 2001
9.	Cut-off drainage above orchard, if required	summer 2001
10.	No traffic after soil prep; mark out rows	summer 2001
11.	Ridging, berming, if required	summer 2001
12.	Fumigation (if required)	summer/fall 2001
13.	Establish cover crop in drive alley	summer/fall 2001
14.	Planting	spring 2002

ADDITIONAL READING

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