SITE EVALUATION AND SOIL PHYSICAL MODIFICATION

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Pistachios are similar to other nut crops in that high yields and pistachio quality are best achieved on deep, uniform loam soils. These soils provide the optimal combination of permeability with sufficient water-holding capacity and root zone aeration. However, acquiring these deep alluvial soils are more expensive due to their limited availability, so many new orchards are being developed on soils with limitations.

Site evaluation has two major objectives:

1. Evaluate the quality of the soil and water with respect to acceptable salinity and fertility for long-term profitable production.
2. Evaluate any soil physical limitations with respect to layering and drainage that may restrict root development.

Later chapters in this manual address fertility and salinity management. This chapter discusses soil physical limitations, pre-plant site evaluation recommendations, choices among irrigation methods, land leveling, and selecting effective tillage methods. **The first goal of a good site physical evaluation is to identify any potential limitations and if modification is truly necessary**. Avoid expensive deep tillage operations if they are not needed. **The second goal is to take corrective action before planting when it is most feasible.** Correcting a physical soil limitation after orchard establishment is usually not nearly as effective.

EVALUATING SOIL PHYSICAL LIMITATIONS

Evaluation and appropriate modification of orchard soils provides the following benefits:

1) Reduced physical barriers to drainage and root development.
2) Increased uniformity of water infiltration and water-holding characteristics.
3) Improved leaching of excess salts.
4) More uniform and increased vigor in young orchards and less time to achieve full production potential.

Surface and subsoil variability

Orchards with soils that vary from sands to clay texture are subject to variable water stress across the orchard because of different water-holding capacities of the soils. Layers of different soils in the rootzone can cause water logging by slowing water movement through the root zone and creating temporarily saturated soil layers. These injure roots by depriving them of oxygen and enhancing conditions that favor root diseases. Some subsoil layers can form physical barriers to roots that simply cannot grow through hard, dense, or compacted layers. The result is nonuniform orchard growth and production, especially under surface irrigation where infiltration rates can vary considerably from one area to the next.

Soil survey data

The best place to begin your evaluation is with the **USDA Natural Resource Conservation Service soil surveys**. There are 170 published surveys for California alone – starting with the first Fresno County survey in 1900 to the most recent Western Tulare County survey in 2003. Many of these surveys are revisions of earlier surveys, changing and adding to earlier soil series descriptions. The surveys published since 1970 have the best maps (Plate 1.) and soil series detail.

On-line access: Unfortunately, only a small number of these surveys are available online. Use the following links to obtain information:

List of all California soil surveys:
http://www.soils.usda.gov/survey/printed_surveys/california.html

Full surveys published online:
http://www.ca.nrcs.usda.gov/mlra02/

- Colusa County, CA
- Intermountain Area, CA
- Mendocino County, CA, Western Part
- Napa County, CA
- Santa Cruz County, CA
- Stanislaus County, CA, Western Part
- Tulare County, CA, Western Part
- Yolo County, CA

For georeferenced spatial and tabular data available for California (more difficult to access and requires use of GIS software):
https://soildatamart.nrcs.usda.gov/County.aspx?State=CA

For locating NRCS offices in the US:
http://offices.sc.egov.usda.gov/locator/app

For most areas it may be necessary to contact the local NRCS office and consult the area conservationist and a paper hard copy of the survey. Most current surveys are supposed to be online by 2008.

Identifying physical limitations

The soil survey, along with aerial images and personal observation of row crops previously grown in the field is very useful for identifying "zones" that should be sampled and viewed separately. Commercially available equipment (i.e. EM-38 and VERIS equipment) that use electromagnetic or conductivity sensors and global positioning systems technology can also map soil variability. When properly calibrated, the sensors detect changes in soil salinity and major differences in water holding capacity. Figure 1 illustrates the potential variation one might find in a possible 160 acre orchard development in Western Kern County.

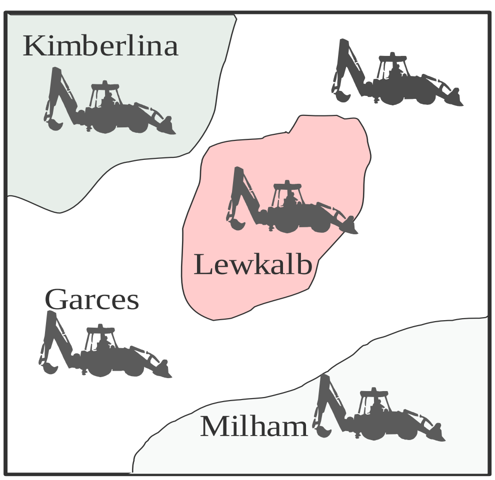

Fig. 1. Soil type variability and required sampling areas for a 160 acre orchard development.

A thorough site evaluation uses a series of backhoe pits in the different zones. Observation pits clearly show the number and types of soil layers, the depth of the layers, and the variability of the subsoil throughout the orchard site. This information can help determine the most economical method of soil modification, how to properly set up and use deep-tillage equipment, and when to what depth tillage is required. One alternative to backhoe pits is the use of a soil probe to pull undisturbed soil cores for evaluation. Special equipment is required for this option if you want to examine the profile down to six feet and it must be done by an experienced agronomist/soil scientist who knows what to look for. Using your farm backhoe or even renting one may be cheaper in the end and will be more revealing as the entire profile can be viewed at once. (See Plate 2. for an example pit.) As a rule of thumb, it is advisable to dig at least one backhoe pit per 20 acres. Where possible, locate backhoe pits in areas of the prospective orchard site that have a history of desirable as well as poor growth, for comparison.

Estimating site evaluation costs

The cost of evaluating the physical soil characteristics of a prospective orchard site and pulling soil samples will range from $200 to $1,200, depending on field size and variability of soil types. This will be about 0.5% of your eventual development cost; far less than the cost of establishing an orchard at a poor site. A backhoe service can be contracted for about $60 per hour, and the work can be completed within a day. Laboratory costs for soil and water analyses, depending on the number, will run $40 to $70 per sample. Samples should be taken in a "composite" manner for multiple depths down to at leas 4 feet. See the chapter on ***Managing Salinity, Soil and Water Amendments*** for a more detailed discussion on sampling and interpreting analyses.

Soil series evaluation guidelines

Extensive soil modification is not always necessary to prepare an orchard site for planting. Some soils are naturally deep and relatively uniform in soil texture and structure, and do not require deed tillage. However, other soils are layered and may need modification. Four types of physical soil limitations may be observed while conducting backhoe site evaluations: (1) stratified soils, (2) claypan soils, (3) hardpan soils, and (4) plowpans. Table 1 summarizes some common soil series in the San Joaquin Valley known to have physical soil limitations.

Stratified soils have layers with abrupt changes in soil texture beneath the surface (Plate 4B, caliche layer, and 4C, clay layer over sandy loam). The layers interfere with the uniform drainage of water, causing zones of poor aeration that may restrict root growth. Correcting layered soils requires mixing the soil layers.

Table 1. San Joaquin Valley soil series having physical soil limitations but that are commonly considered for pistachio orchards

Developed clay subsoil types			
Stratified	Moderate	Claypan	Cemented hardpan
Eastside San Joaquin Valley soils			
Cajon	Borden	Cometa	Academy
Chino	Chiralar	Corning	Dinuba
Foster	Pond	Modesto	Exeter
Grangeville	Ramona	Montpellier	Fresno
Hanford	Ryer	Waukena	Lewis
Kimberlina	Snelling	Milham	San Joaquin
Nord Complex Visalia			Whitney
Westside San Joaquin Valley soils			
Camarillo	Avenal	Herdlyn	Dinuba
Columbia	Twisselman	Olcott	
Mocho	Pleasanton	Positas	
Panoche	Rincon	Solano	
Westhaven	Rossi	Waukena	
Vernalis	Garces	Buttonwillow	

Claypan soils have a concentrated clay layer that restricts water movement downward, thus restricting aeration and root growth in the subsoil. Clay layers can start abruptly at a depth of 12 to 24 inches below the surface, with the clay most concentrated in the upper half of the pan. The lower half gradually changes into a clay loam to loam-textured soil. Modification designed to mix the clay layer with the rest of the soil profile will result in more uniform water penetration, reduce saturation in the upper rootzone and promote extensive tree root growth.

Hardpan soils are similar to claypans, except the soil particles are glued together by hard mineral matter that will not soften, even when wet. The hardened layer is usually an absolute barrier to root growth and water percolation. Modification of hardpan soils requires fracturing and breaking rather than mixing.

Plowpans can be found in some orchard sites. Plowpans are the result of tilling a soil at the same depth repeatedly. A soil with a plowpan does not necessarily have different textural layers like those of stratified, claypan, or hardpan soils. Instead, plowpans are usually shallow (10-18 inches below the surface) and require only fracturing, rather than mixing, to correct the problem.

IRRIGATION SYSTEMS & GRADE LIMITATIONS

Selecting an irrigation method

Selection and design of the irrigation system will be influenced by site topography and soil types. It will also be the main driver behind final land leveling and tillage requirements. Properly designed and managed microsprinkler, surface drip, subsurface drip, and sprinkler systems help minimize physical soil limitations more than surface irrigation systems.

Cost considerations: The advantage of choosing a flood or furrow irrigation system over a pressurized irrigation system is reduced initial capital cost. The disadvantage, especially with a permanent crop like pistachios that takes 8 to 11 years to reach full maturity, is the 1 to 1.5 ac-ft/year of additional water required to compensate for increased evaporation and percolation losses compared to the micro system. At water costs of $50 to $150/ac-ft this extra water is a significant additional cost.

System uniformity: Uniform application of water with a pressurized irrigation system depends more on hydraulic design, emitter application patterns and system maintenance than on variable soils. If a low-volume micro system is selected, uniform field slope is not as critical. Microsprinklers and surface drip systems apply water at low, controlled rates that are usually less than the soil infiltration rate. Uneven ponding of water and runoff are usually not a problem. Also, irrigation water is applied in small quantities at high frequencies that closely match the rate of crop water use.

For furrow or border irrigation, however, the uniformity of applied water, and subsequent pistachio water use, largely depends on variable infiltration and retention characteristics of the different soils in the orchard. These factors cannot be engineered and adjusted into a set irrigation application rate as is the case with pressurized systems. Thus, it is virtually impossible to design a surface irrigation system with the same uniformity as a well managed pressurized micro system. However, the following design and operational guidelines will help maximize the uniformity of your surface irrigation system.

Surface irrigation system guidelines

1. Irrigate in small orchard blocks sharing similar physical soil characteristics to achieve more uniform water infiltration and storage.
2. Provide one water discharge valve per tree row.
3. Design the surface system so the field length is short enough to rapidly advance water across it, given the available water flow rates.
4. Grade to uniform slopes to avoid low and high spots.
5. Install a tail-water return system, steps taken to improve irrigation uniformity of applied water by furrow or flood irrigation may result in more tailwater.

Larger irrigation sets are often more attractive to growers to minimize per acre costs. Unfortunately, flood or furrow systems with large acreage per set usually include more soil variability. This results in lower uniformity of applied water.

Leveling the land

Orchard soils that are flood or furrow irrigated must be graded to a uniform slope. Prior to the leveling activities, heavy crop and weed residues or brush and stumps from a previous orchard must be removed. This is especially important in areas where large piles of organic debris could eventually be buried by soil from cut areas. Incorporating organic material into soil is usually beneficial. However, it can be detrimental when a large mass of material is buried deeply in a compacted soil. After irrigation, the organic residue can remain wet and begin decomposing in the absence of air to produce methane gas, concentrations of reduced manganese and iron, and other organic compounds. The methane and manganese can build up and become toxic to plant roots, killing the trees. Burning, where permitted, is effective in removing excess crop and weed residues. The remaining vegetative residue can then be incorporated into the soil by discing. Stump removal is best achieved with a backhoe or chipping machine grinder.

After the site has been cleared, some important factors need to be considered prior to leveling. Consideration must be given to the desired final grade, the optimal time to do the leveling, the maximum depth of cuts to be made, and the type of scraper to use.

The final orchard grade for flood or furrow irrigation depends on the soil infiltration characteristics, the length of the field, and the discharge rate of the available water supply. Generally, the final grade for medium to fine-textured soils should be 0.1 to 0.5 feet per 100 feet depending on run length and average set times.

Land leveling should be done under fairly dry soil conditions to minimize soil compaction and the breakdown of soil structure. The maximum depth of cuts depends on the initial slope of the land. If required cuts exceed 0.6 feet, the total cut should be accomplished by making two separate, shallower cuts. Two types of scrapers are available for leveling: paddle type and push loading. Paddle type scrapers create less compaction than do push-loading scrapers, but the former tend to pulverize the soil to a powder-like condition that does not settle properly in fill areas. After completing most of the land leveling, two final questions need to be resolved: Is the grade stable? How should the cut and fill areas be managed?

Settling time is required to allow the grade to become stable. Where cuts exceed 0.6 feet, the main cuts should be made the first year and the final grade the following year, after an annual crop has been grown. A second year of annual cropping is even more preferable, to ensure that the final grade has stabilized.

After land leveling, nutritional deficiencies in the cut areas must be resolved. Nitrogen, phosphorus, potassium, zinc and sulfur are commonly lower in exposed subsoil than in the original surface soil, because of their lower organic matter content. These deficiencies can be corrected by adding fertilizer and manure and by incorporating plant residues. The exposed cut areas may not have as desirable a soil structure as the original surface soil did. In time, cropping, wetting and drying, and the addition of organic matter, will rebuild the soil structure and establish desirable soil tilth.

Fill areas may present more difficult problems than cut areas. A given volume of soil scraped off a high spot in a field will not fill the same volume in a low area; an additional amount of soil is needed due to the fact that soil structure has been destroyed and soil bulk density increases. Clay loam to loam soils may require the volume of cut soil to be about 25% more soil than the intended fill space, to level the low area. In coarser, sandy soils, low areas may require 50% more soil volume. Fill areas are more compacted than the original surface soils. Such compaction can cause water penetration and root growth problems detrimental to establishing a productive orchard.

Filling should, therefore, be done when the soil is fairly dry (to reduce compaction in the fill areas), but not so dry that the soil becomes powdery. The soil should have small clods, which indicate maintenance of some soil structure. After leveling, the fill areas may require ripping to below the depth of the original soil surface. If the fill is deep, ripping after partial leveling is desirable. If the costs of additional ripping and re-leveling seem prohibitive, consider the loss of production, replacing trees that have not progressed or have died, and managing an orchard that never produces to your initial expectation.

CROP RESPONSE TO DEEP TILLAGE

Deep tillage prior to planting is critical for orchard sites that are to be irrigated with surface systems. Thorough soil mixing improves water infiltration and drainage, promotes more extensive root growth, and creates more uniform water storage within the root zone. These factors contribute to a more manageable and productive orchard under a flood or furrow system.

Flood irrigation: Table 1 illustrates the production and root development responses reported from one tillage study, in which a claypan soil was modified before planting almonds to be grown under border strip irrigation.

Table 1. Responses to modifications of claypan soil in terms of yield, trunk circumference, and root count (furrow-flood irrigation).

Tillage Method	*Yield (lb/acre)	*Trunk circumference (in)	+Root count (per 3 cu ft)
None	1,009	14.8	78
Ripper	1,120	16.6	94
Slip plow	1,185	16.7	118
Moldboard plow	1,433	17.0	175

+Measured during fourth year of production.
*Measured during eighth year of production.

Reference:
E.L. Begg, G.L. Huntington, and W.E. Wildman. Evaluation and Modification of Soils. Chapter 6. Pp. 51. Walnut Production Manual. Publication 3373. University of California Division of Agriculture and Natural Resources. 1998.

Under flood irrigation, production increased over 40 percent and the root count increased over 120 percent after using a 4 foot moldboard plow to thoroughly flip and mix the clay layer prior to planting. The increased production would be valued at $300 to $800 per acre annually, depending on the market price. It is unclear why slip plowing did not produce more of a response in this trial. Similar data are not available for pistachio. Given the pistachio's ability to send roots long distances and the longer development time to pistachio maturity it is hard to predict the response of these trees to these types of tillage treatments under flood irrigation.

Micro irrigation: Unless some form of hardpan has been identified close to the surface, deep tillage may be unnecessary for orchards irrigated with pressurized systems. Field research conducted in both walnut and almond on marginal soils on the west side of Colusa County found little response to deep tillage when drip or microsprinkler irrigation is adopted. Early trials in almonds under drip irrigation showed no positive affects from deep soil modification on a layered clay soil. Recent experiments in microsprinkler irrigated almonds have provided similar results (Table 2).

Table 2. Almond Slip Plow Evaluation, Nickels Soils Lab Arbuckle Calif.

Year	Tree Age (years)	Nut Yield (lb/ac) Slip Plowed	Non Slip Plowed
2000	4	894	830
2001	5	1070	1243
2002	6	2725	2761
2003	7	2165	2323
2004	8	1869	1865
*Cumulative Yield		8723	9022

*Edstrom, J., S.Cutter. 2004. Nickels soil lab projects – Deep tillage slip plow affects on almonds. 2004 Conference Proceedings, CA Almond Board. Pp.75-76.

This soil is a Class II Arbuckle sandy loam 30-60 inches deep, underlain by a dense clay layer 10 to 15 inches thick, returning to a gravelly sandy loam below. Slip plowing to 6 feet was done on a 10x10 foot grid spacing to mix these layers. Despite the fact that this soil has the physical layering that might limit tree development, this field trial showed that deep slip plowing gave no improvement in almond tree size, yield or crop quality after eight years compared to no deep tillage.

In another long term study in drip irrigated walnuts, soil excavations at a test site revealed substantial mixing of stratified soil layers and deeper walnut root development following slip plowing but no yield or nut quality improvements were found. The low volume applications of water and nutrients at higher frequency with the micro-irrigation system appear to overcome many limitations of marginal soils without expensive deep tillage. While similar studies have not been conducted in pistachio, it is believed a similar response may be expected.

Shallow soils located in high rainfall environments, (excess of 15 to 20 inches of average rainfall with a high likelihood of rainfall just prior to and during leafout), or located in floodplains represent two conditions where deep tillage may be beneficial even when microsprinkler or drip irrigation is used.

MODIFYING SOIL PHYSICAL PROBLEMS

Several methods are available to accomplish deep tillage prior to planting pistachios. Available equipment includes rippers, slip plows, moldboard plows, disc plows, backhoes and trenchers. Selecting the most cost-effective method of deep tillage or soil mixing requires evaluating the type and severity of the soil problem. Remember, the purposes of modifying a soil prior to planting are to encourage uniform movement of water through the root zone, to maintain adequate aeration, and to increase the volume of soil available for root growth. Therefore, select the method that will most economically achieve those goals. Table 3 lists most options and the estimated cost.

Table 3. Approximate costs for different methods of soil modification. (Based on 2005 prices.)

Method	Soil depth (ft)	Cost ($/ac)
"Cotton" Ripper[1]	2 - 3	60-120
Ripper[1]	4 - 6	250-500
Slip plow[1]	4.0-6.0	400-800
Moldboard plow	4.0	600-800
Trencher[2]	3.5(w)x4.0(d)	1400-1600
Backhoe pits[3]	4.0x4.0(w)x6.0(d)	450-700
Backhoe pits[4]	4.0x4.0(w)x6.0(d)	600-900

[1]Includes straddle pass with 2 ripper shanks 3 to 5 feet on either side of the initial pass down a 20 foot tree row.

[2]Trenching costs assume a 3.5-x-4.0-foot trench down a 20 foot tree row spacing and a charge of $1.30-$1.40 per cubic yard of soil trenched.

[3]Assumes farm backhoe @ $50/hr; this rate is less than is typical, due to the size of the job. Cost is based on 17 x 22-foot tree spacing.

[4] Cost is based on 15 x 20-foot tree spacing.

Stratified/layered soils

Digging backhoe pits for each tree site is the most effective means of modifying layered soils with stratification down to 4 to 6 feet. Backhoeing is more expensive than other tillage methods, because the process is slower. Typical costs range from $4 to $6 per hole, depending on the skill of the operator and the farm machinery budget. The expense of digging backhoe pits rises with increased tree density. For example, an orchard planted on 17 x 22-foot spacing will require 116 backhoe pits per acre, while an orchard planted on a 15 x 20-foot spacing will require 145 backhoe pits per acre. The required dimensions of the backhoe pits depend on the extent of the soil layering. Generally, a pit 4 feet square and 8 feet deep is the maximum that is required and affordable. Old field research using flood irrigation has indicated that the larger the pit, the more successful the results in stratified soils, but as mentioned earlier, this may not apply to microirrigation.

Trenching along the intended tree row is an alternative method of mixing abrupt soil layers. Access to equipment may be limited. Trenching is suited to soils with layering problems within 4 feet of the surface and the soil below this depth being more uniform in texture. This is because trenchers that can trench deeper than 4 feet are seldom available.

Slip plowing is the most common method of mixing stratified soils. This device uses a heavy steel beam set at a forward angle of 30 to 40 degrees with a hard-faced steel shoe on the bottom of the beam that may be 12-18 inches wide and 24 inches tall. The forward angle of the plow sucks the shoe deep into the soil; shattering and lifting the soil in its path up along the beam, thoroughly mixing the layers along the depth of the pass. The depth of mixing is only limited the length of the shank, traction/stability of the field surface and the power of the track layer (Caterpillar) pulling the implement. It usually takes a D-9 or two D-8 equivalents to reach a 6 foot depth. If the soil is extremely alkaline throughout the profile this is an optimum time to apply sulfur to help free calcium and reduce pH. Band the sulfur along the path of the slip plow. This band will be "sucked in" behind the slip plow and mixed within the top 2 to 3 feet of the profile. Some slip plows have a following "foot" attached to the point shoes and chained to the steel frame above ground to improve mixing of layers (Plate 4).

Moldboard (Plate 5) **and disc plowing** provide more thorough mixing than slip plowing but the depth of their mixing is limited to 3 or 4 feet. **Ripping** is less beneficial in correcting layered soils because it is designed to fracture rather than mix soils. Layered soils eventually reform after ripping.

A thorough mixing of layers is especially desirable when a heavier soil overlays a lighter texture. In this setting the upper layer must become saturated before water percolates into the coarser layer below. This makes for worse disease problems and can cause poor root development in the upper part of the profile (See Plate 3).

Claypans

Since claypans typically occur near the soil surface, the moldboard plow and the disc plow are effective methods of thoroughly mixing the pan with the rest of the soil profile; they are also adaptable to larger acreage. Slip plowing is an alternative to moldboard or disc plowing for modifying claypans, but it will not mix the entire soil surface, only strips of soil that are 4 feet or more apart. Ripping a claypan soil is not advised unless the ripper shanks are spaced very narrowly to ensure severe fracturing of the soil. Many "cotton rippers" used on the heavy soils of the Westside of the San Joaquin Valley are spaced close enough together to accomplish this. However, mixing rather than simple fracturing is still the best way to permanently dilute and destroy claypans. If the soil below the claypan is fairly uniform then deep tillage below 3 feet is probably not warranted.

Hardpans

Orchards should not be planted on hardpan soils unless the layer is shallow enough that deep ripping can completely break through the hardpan into uncemented, permeable soil below. Backhoe pit evaluations are extremely helpful in determining the required ripping depth and shank spacing. It is beneficial to rip down each intended tree row. Slip plowing is generally not recommended in hardpan soils because it requires more energy than does ripping. Moldboard plowing, trenching and digging backhoe pits are usually not advised for correcting a hardpan problem. Thoroughly mixing a hardpan layer with the rest of the profile is unrealistic and expensive if attempted, because of the cemented nature of the layer. Fracturing the hardpan by ripping is often all that is necessary to ensure adequate drainage for excess water and root penetration. If ripping cannot effectively shatter the hardpan, the site should be considered unsuitable for pistachio production, especially with flood or furrow irrigation systems.

Guidelines for deep tillage

Soil moisture: The soil-water content at the time of deep tillage partly determines the effectiveness of the operation. Although a moist soil requires less draft when tilling, more surface compaction occurs from the heavy equipment, so the soil does not break up and mix as readily. Dry soil conditions break up and mix more readily. Desirable soil water content for clay is 10%, loam 5% and sandy soil 2.5% by weight. These are moisture levels that push most crops into permanent wilting. Soils with a shallow water table (less than 6 feet from soil surface) may never dry sufficiently to effectively modify them without installing drainage first. Growing a crop of safflower prior to fall tillage is the best way to dry out the soil to the greatest depth.

Effective depth and spacing of rippers: Two factors that specifically influence the effectiveness of ripping or chiseling are the depth of the ripper shanks and the distance between them. There are three reliable rules to apply:

1. The shanks should penetrate into the soil 1.5 times the depth of the targeted soil problems.
2. The distance between the shanks should be equal to, or preferably less than, the desired ripping depth.
3. Rip in one direction with narrowly spaced shanks rather than in two directions with a wide shank spacing.

The shank is inserted 50 percent deeper than the desired ripping depth to ensure sufficient penetration through the restricting zone of soil. Setting the shank spacing to a distance narrower than the desired ripping depth is best, because ripping never breaks the soil straight across between adjacent shanks. There is always a hump of undisturbed soil between two ripper channels. The wider the shank spacing, the greater the percentage of undisturbed soil. With extremely wide shank spacing, the zone of undisturbed soil may come all the way to the soil surface. Ripping in one direction with a narrow spacing is more effective than wide spacing and cross ripping.

The practice of **"straddle ripping"** is probably the most common method of deep tillage when preparing to plant an orchard. This is more economical than deep tillage at say 5-foot intervals across the whole field and, in most cases, just as effective.

This is accomplished by marking the tree rows in the field and ripping or slip plowing to the desired depth. This may require one or two passes depending on the depth of penetration. If the soil is dry enough, fracturing will occur at about a 45^{o} angle starting at the point of the chisel or plow going up to the soil surface. A 6-foot penetration will result in some fracturing out to 5 to 6 feet at the soil surface. Dual ripper shanks are then set up, spaced about 10 feet apart and set so they "straddle" the initial pass with about 5 feet on either side. Since some fracturing has already occurred from the initial ripping the "straddle rip" can usually be done in one pass. This ripping is usually about 1 foot shallower then the central pass.

If the central pass was to a depth of 6 feet, the straddle rip penetrated to 5' and the lack of soil moisture was optimal the final fracture zone at the soil surface should be 16 to 20 feet. At the 3-foot depth, fracturing should be complete between all shanks and extend for a width of 12 to 14 feet across the tree row.

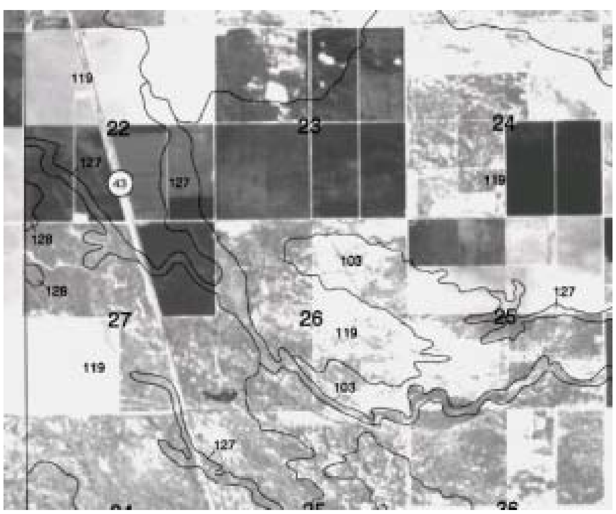

Plate 1. Part of Delano West Quadrangle map from West Tulare County Soil Survey illustrating soil series contours.


Plate 2. Backhoe pit in a Buttonwillow clay soil with a slightly caliche silty clay layer at the 34-45 inch depth. Total depth 80 inches.


Plate 3. A marginally alkali clay loam in the top 2 feet of this almond rootzone overlays a coarse sandy loam layer. Excess moisture in the heavier layer prevented good root development in the top 2 feet.

Plate 4. Slip plow with a following foot to further lift and mix layers.

Plate 5. Moldboard plow capable of penetrating 3 to 4 feet.