4 Soil management

Introduction

Soil plays the role of a growing medium for perennial, deep-rooted citrus trees. It provides not only mechanical support for the tree, but also air, water and all the required nutrients for the roots (Fig. 4-1). Soil properties control the availability of soil nutrients and the nutrient uptake by roots. They have a major influence on the growth of citrus trees and the quality of their fruit.

Good soil management is always the basis for successful citrus production. Optimizing the use of irrigation water and fertilizer enhances tree growth, fruit production and citrus quality.

Applications of fertilizer which are badly timed, or which use too much fertilizer or too little, are a waste of resources. They waste the farmer's money, and will have an adverse effect on the yield and quality of the fruit.

Guidelines for site selection

Provided the soil is well drained and aerated, and has no hardpan to prevent root penetration, citrus trees can grow in a wide range of different soils. The ideal soil conditions and soil management techniques for commercial citrus production are as follows.

Soil texture

Ideally, the soil should be a sandy loam or loam. The soil should be more than one meter deep, and should have moderately porous soil layers for good drainage.

In selecting the orchard site, priority should be given to drainage. During the rainy season, citrus roots which are growing in poorly drained soils may become immersed in stagnant water, thus inducing disease.

To preserve the environment, and to maintain or improve the productivity of the soil, care must be taken over the following points.

- **The orchard site selected must be appropriate, and growers must take care to maintain the productivity of the soil.**
- **The soil surface should be kept covered with grass or mulch, to avoid the loss of water and prevent soil erosion.**
- **Irrigation and drainage facilities should be installed, so that the citrus trees can be irrigated on time with a reasonable quantity of water.**
- **If possible, soil testing and plant analysis should be carried out, to monitor the nutrient status of the orchard. The results can then be used as the basis for working out the best fertilizer program, and to identify the soil amendments which may be needed.**

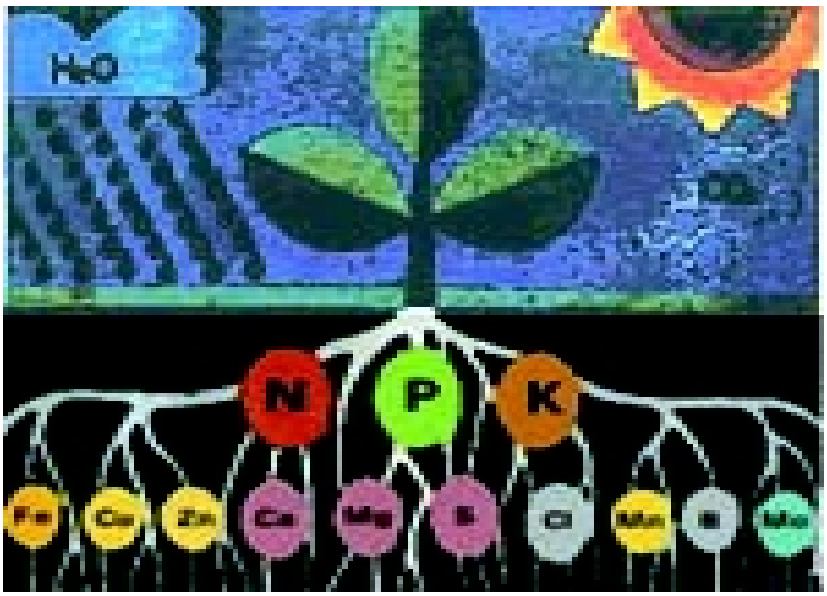

Fig. 4-1. Soil provides mechanical support for citrus trees, and supplies citrus roots with all the nutrients required for growth.

Drainage of soil

The main reasons for poor soil drainage are a high water table, compacted soil, soil with a high clay content, or an abrupt change in soil texture in the soil profile (e.g. a sandy loam layer beneath a clay loam. A hardpan is a good example of this). Any site with any of these conditions should not be used for a citrus orchard, unless the soil can be reclaimed to some extent.

One way of improving the drainage is to plant the trees along a raised ridge. Other methods are to dig drainage ditches, or install drainage pipes or tiles. These will drain any excess water from the orchard soil.

If soil erosion is allowed to occur on sloping land, the soil will become shallow and dry. Therefore, soil and water conservation practices should be carried out.

Irrigation of soil

On gravel soils or sandy soils, frequent irrigation and fertilization are needed. Coarse-textured soils have poor capacity to retain water and fertilizer, although they have good aeration. This may reduce the profitability of the orchard.

Fine-textured clay soil, on the other hand, is characterized by very poor aeration and drainage which will restrict the development of the root system. Therefore, the best choice of soil for a citrus orchard is a medium-textured sandy loam, or a loam which includes porous soil layers for good drainage.

Frequent irrigation for citrus production on shallow soils is not economic. The texture of the topsoil should be uniform, with a soil depth of more than one meter. The water table should be lower than one meter, to allow good penetration by the citrus roots.

Soil pH

The soil pH (whether a soil is acid or alkaline) is an important property. It affects the availability of nutrients, and also the activity of microbes and other tiny creatures in the soil.

In general, the best soil pH for citrus trees is between 5.5 and 6.5. If the pH falls below 5.0, aluminum toxicity and manganese toxicity often occur in citrus roots. A low pH also causes a deficiency of nutrients such as calcium, magnesium, and phosphorus (which are easily fixed by soil particles), and molybdenum.

Liming with limestone or dolomite is the usual action taken to reclaim soil with such problems. Growers should also avoid applying too much ammonium, in the form of nitrogen fertilizers such as urea or ammonium sulfate. This is because there is a danger of making the soil more acid.

If citrus trees are growing in soils with a pH higher than 7.5, they often suffer from a deficiency of micronutrients such as iron, manganese, copper and zinc. A foliar spray of fertilizer can be applied to supplement the micronutrients.

In addition, ammonium sulfate can be applied as a nitrogen source, and sulfur applied to modify the soil pH to 6.5. The techniques used to apply sulfur can be the same as those used to apply lime (see below).

Liming

Lime materials should be applied if the orchard is on sloping land from which the soil cations have been leached, and where the soil pH is lower than 5.0, indicating strong acidity.

Selecting the liming materials

Limestone and slag (an industrial by-product) are normally applied to acidic soils of citrus orchards where there are no symptoms of magnesium deficiency. However, if magnesium deficiency is observed, growers are strongly recommended to supplement the magnesium with dolomite limestone.

Liming materials can be compared and evaluated in terms of their neutralizing value (or calcium carbonate equivalent, CCE). If the neutralizing value (%) of pure limestone ($CaCO_3$) is considered to be 100%, then the corresponding values for other lime materials are:

- 179% for burnt lime (CaO);
- 135% for slaked lime ($Ca(OH)_2$;
- 119% for magnesium carbonate ($MgCO_3$);
- 100-119% for dolomite limestone ($CaO+MgCO_3$).

Other sources of lime

Other liming materials with a low neutralizing value, such as industrial by-products of limestone, including slag, silicate slag and oyster-shell powder, can also be used on acidic soils.

The finer the particles of the liming material, the more effectively the lime materials reacts with acidic soil. Fine limestone materials with a particle size smaller than 60 meshes (0.15 mm in diameter) are usually considered the best choice.

Application of liming materials

In orchards where the soil pH is found to be below 5.0, liming materials should be applied after the fruit is harvested. They should be incorporated into the soil at a depth of at least 15 - 30 cm, since lime has poor mobility in the soil.

In terms of quantity, 5 to 7 kg per tree is normally recommended. Another way of calculating the application rate is one metric ton per hectare for sandy loam, 1.5 metric tons per hectare for silt loam or loam, and two metric tons per hectare for clay loam.

Mixing manure or compost with the lime materials is recommended. This helps to keep the soil aerated, and avoids compaction. Chemical fertilizers should not be applied at the same time as lime, since this would reduce the fertilizer efficiency of the nitrogen. Inorganic fertilizers may also be applied separately, one month after applying the lime materials.

Routine soil monitoring of soil pH is needed to determine whether there is a need for lime materials. Growers should not apply lime unless it is needed.

Not only is it wasteful, but micronutrient deficiencies may occur if growers apply too much lime. For this reason, annual lime applications should be discontinued when the soil pH has been modified to more than 6.0.

Fig. 4-2. Conserving soil organic matter to ensure good soil properties for sustainable land use

Fig. 4-3. Grass cover for conservation of soil and water

Maintaining the soil organic matter

Soil organic matter is often referred to as humus. This is the product of the decomposition of crop or animal residues by soil microorganisms. It is a dark-colored and relatively stable material which is resistant to further rapid degradation.

Soil organic matter is very important for sustainable soil management in citrus production, because it enhances the formation of soil aggregates. These in turn help to maintain a good soil structure for drainage and aeration. Humus also increases the cation exchange capacity, strengthening the soil's ability to hold fertilizer (nutrients) and water. It also serves as a nutrient reservoir, because part of the organic matter is being decomposed by a continuous soil mineralization process. In the process, it supplies crops with different kinds of nutrients, including nitrogen, phosphorus and sulfur.

Hot humid weather conditions accelerate the decomposition of soil organic matter. As a result, the level of organic matter in citrus orchards in tropical and subtropical countries is often very low. For example, the soil organic matter level in 60% of the citrus

orchards in Taiwan is less than 2%. The way to improve this situation is to apply manure, and to increase the area planted in grass cover.

In view of the bulky nature of compost and its high cost, it is not realistic to try and increase the level of organic matter in orchard soils by applying organic fertilizers alone, especially if the cost of transport and application is taken into account. We need to apply at least 20 metric tons of organic fertilizer to the soil if we are to increase the soil organic matter level by 1%.

The use of grass cover and plant residues is a practical and economical way of increasing or maintaining the level of soil organic matter in orchards (see Fig. 4-2). If organic fertilizers with a high nitrogen (N) content are being used, and growers do not reduce the quantity of chemical fertilizer, the excess N will have an adverse effect on production. There will be excessive leaf growth in the summer or autumn flush, and relatively few fruit. These will be late in changing color as they ripen.

Growers should not apply fresh livestock manure. Citrus roots may be injured by incompletely decomposed manure. Large quantities of readily available organic matter can be supplied by the roots of grass cover, grass mulch from mechanical weeding, and pruned twigs which have been shredded into small pieces.

All three practices are recommended for soil management, especially in countries with a warm, humid climate. Growers must endeavor to keep the soil organic matter content above 2%.

Orchard management can also include green manures. These act as a source of organic matter. They also add landscape value to the orchard, as well as conserving soil and water. Common green manure crops in citrus orchards are various legumes such as perennial peanut, Berseem clover and Chinese milk vetch.

Grass cover

The rate of soil formation is very slow. One inch of soil may take thousands of years to form through weathering and deposition. However, if no conservation methods are used, it only takes one heavy rain to wash soil away and leave a bare land surface.

Grass cover and mulches can effectively reduce soil erosion and runoff, and subsequently increase the infiltration rate of water (Fig. 4-3). Thus, in spite of the labor cost needed to keep the area around the trunks of trees weeded, grass cover is a good technique for citrus orchards, especially in sloping land or mountainous areas. If the orchard is sown in grass, the amount of nitrogen fertilizer should be increased by 20-30% in the first few years, to allow for grass growth.

Improving soil fertility

Soil testing should be used to monitor the status of soil fertility. Important points are the level of phosphorus available in the soil (it should be more than 80 mg/kg soil), the level of exchangeable potassium and magnesium (both should be more than 100 mg/kg soil), and the level of exchangeable calcium (it should be more than 1000 mg/kg soil).

Fertilizer management

Avoiding the accumulation of salts

Too high a level of soluble salts in the soil solution will inhibit the grow of citrus trees. This is the result, not only of the toxicity effect, but also of reducing the water available for uptake by the roots through the action of osmotic pressure.

The measurement of electrical conductivity (EC) of a soil extract usually indicates the total salt concentration in soil. Since citrus trees are sensitive to soluble salts, the EC value of the saturated soil solution should be less than 1 dS per meter.

In areas such as Taiwan which have heavy precipitation, the implementation of reasonable fertilizer management based on leaf analysis and soil testing in well-drained orchards can effectively avoid salt accumulation in the soil from the overuse of chemical fertilizer.

Soil moisture

Details about water management for citrus orchards are given in the next chapter (see Chapter 5). However, in managing the soil of their orchard, growers must remember that the soil must always hold enough water to meet the needs of their trees.

The canopy size of citrus trees, and the transportation of nutrients in the tree, largely depend on the water supply. Soil moisture status greatly influences citrus growth, fruit yield and citrus quality. It is especially important during the growing season.

We must understand the distribution of precipitation and evapotranspiration during the year, and how these overlap with the distribution of dry and wet seasons. Trees need proper irrigation during the dry season, and a good drainage system during the rainy season. These will help ensure a good-quality crop, and a stable yield of citrus fruit.