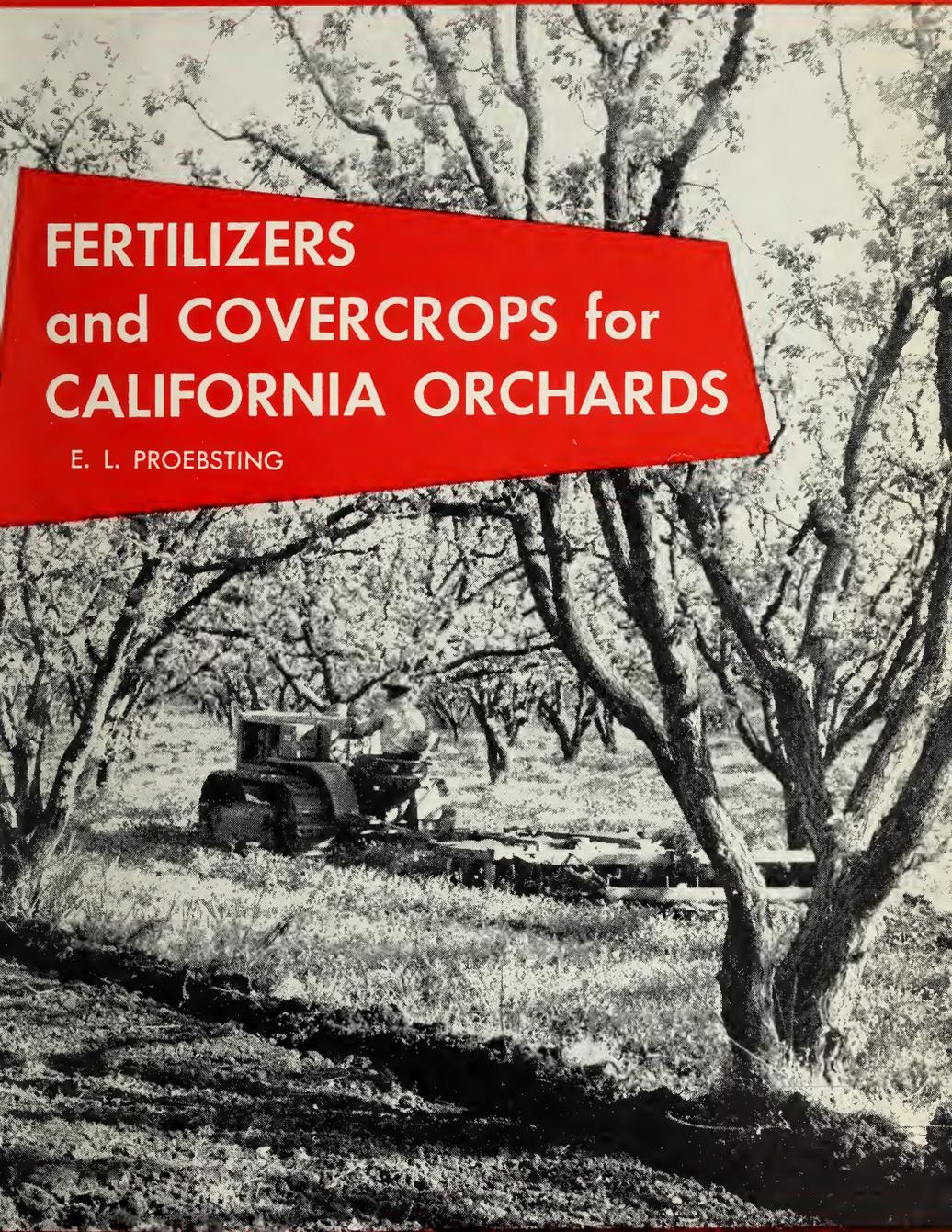




Division of Agricultural Sciences  
UNIVERSITY OF CALIFORNIA

# FERTILIZERS and COVERCROPS for CALIFORNIA ORCHARDS

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## An Orchard Fertilizer Program . . .

must take into account the condition of the soil, the species of fruit, and any nutrient deficiency symptoms shown by the trees. Since all these factors vary with individual orchards, no quick and easy method is available for determining whether fertilizer is needed.

This circular suggests ways for finding out whether an orchard would profit by fertilization, describes nutrient deficiency symptoms, and indicates application methods.

Covercrops are discussed both as sources of organic material and as aids for maintaining good soil structure.

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Photograph at left shows liquid fertilizer being applied in an almond orchard.

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## Roots, soil, and water affect the fertilizer program

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THE SUCCESS of a fertilizer program for the orchard depends upon a rather complex root-soil-water relationship. A mature tree has a system of permanent roots extending throughout the available soil, plus many small, temporary feeder roots. The latter grow, die, and are replaced by new roots one or more times each year. During growth, the surfaces of these feeder roots absorb water and mineral elements necessary for the normal nutrition of the tree.

Many factors influencing the absorption of nutrients are concerned with the soil—its fertility, depth, texture, moisture, temperature, drainage, and aeration.

Trees may secure as much from a good soil only 4 feet deep as from a poor one twice that depth, but they will rarely perform satisfactorily on a shallow soil even if it is a good one, properly irrigated and fertilized. In very coarse or very heavy soils, root branching may be unsatisfactory, and roots may fail to extract nutrients efficiently from a given volume of soil.

Roots will not grow in dry soil nor will most species grow in saturated soil. Such conditions reduce the active root surface and probably the efficiency per

unit of root surface, thus limiting nutrient absorption.

This absorption is also dependent on the correct soil temperature as determined for various species. For trees, the lower limit is probably near 45° F, the maximum rate of activity, near 70° F. Above 90° F there is little activity, and at slightly higher temperatures the roots will die.

In order to grow and function, tree roots need oxygen. Saturated or tight soil through which the air can move only slowly will not provide a good environment.

Other factors affecting nutrient absorption are the species of tree and its rootstock. Different species have different habits of root growth. Some branch profusely, some very sparsely, under the same conditions. Different roots also have different abilities to extract nutrients from a given soil. It has been found, for example, that the same variety of apple growing on two selections of rootstocks in a potassium-deficient soil have shown deficiency symptoms on one stock and not on the other.

In order that any added fertilizers may be absorbed, they must be brought into areas where the roots can come in con-

tact with them. The depth to which they must penetrate will depend on conditions in the orchard. If there is sod, for example, the roots may grow to within an inch of the surface, whereas in some clean-cultivated orchards there may be but few roots in the top foot of soil. In the latter case, the fertilizer must be a kind that will penetrate with rain or irrigation water, or else must be placed in the root zone mechanically in order to be absorbed by the tree.

Not all fertilizers, though soluble, will move downward with water. Most soils have the ability to fix some of the common fertilizers. Potassium (potash, or K) is fixed—that is, taken out of solution and held—by most California soils. Even on sandy soils with a fixing power less than that of the heavy soils, large surface

applications are necessary for penetration into the root zone. Phosphorus (phosphate, or P) also may be retained in large amounts by the surface soil. Some of the nitrogenous fertilizers, including all ammonia compounds, are fixed temporarily, but are changed by soil bacteria to nitrate, a form in which nitrogen is free to move to the root zone.

In light or shallow soils subjected to heavy rainfall or excessive irrigation, loss of nitrogen may be serious because the nitrate may be washed through the root zone and lost in the drainage water. Loss may also occur in soil that remains saturated for a considerable period, a condition suitable for the destruction of nitrogen compounds. This so-called denitrification process results in release of gaseous nitrogen to the atmosphere.

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## How to determine whether your orchard needs fertilizer

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To insure maximum production, the grower must know the condition of his orchard's soil. Many California orchards are on soils capable of supplying all the required nutrients. In such cases, addition of fertilizer is not profitable. However, some soils may have had low initial reserves of one or more nutrients, or may now be depleted of their original supply. These soils will require fertilization.

Many factors other than the actual supply or nutrients in a soil affect their absorption by a particular kind of tree. Because of this, no single, quick, and easy method is available for determining whether a soil requires<sup>1</sup> fertilizer. Some progress has been made with several methods, four of which are discussed below: soil analysis, plant analysis, deficiency symptoms, and orchard plot trials.

### Soil analysis

A complete soil analysis is of little or no value in determining fertilizer requirements because it includes all nutrients present in a given soil without indicating how much of each is actually available to the plant. However, various laboratory tests have been developed for determining available nutrients. These, too, are not completely satisfactory because they may show the approximate total supply of an element that a plant can use, but not the rate at which it may be available for a particular crop. If the supply is found to be large, it may be assumed adequate; if exceptionally low, presumably nutrients should be added. Also, no field is uniform in composition, and soil varies in character at different depths. To be of any value, a soil sample

must be taken near the roots, and must be representative of the area. If the change in soil character over the area is great, samples from each type of soil must be taken.

Several types of kits for determining available soil nutrients are on the market. Tests with these kits are not reliable for deciduous fruit trees although good results have been obtained with some field crops. No soil test used so far, whether field or laboratory, has proved satisfactory for either nitrogen or phosphate determination. The Neubauer test for potassium is slow and expensive, and while useful, is not reliable in the range near a slight deficiency.

### **Plant analysis**

Both laboratory and field methods have been developed for analysis of certain tree parts. As with soil analyses, results vary, depending on modifying factors affecting the tissue tested. For example, leaf composition changes throughout the season. The nitrogen content of apricot leaves in one orchard was found to drop from 3.75 per cent in April to 2 per cent in August. The character and rate of change differ for the different elements and will be modified by size of crop, seasonal conditions, and cultural practices, such as pruning, as well as by the available nutrients. The success of this method depends on experience and a knowledge of the fruit concerned.

### **Deficiency symptoms**

The mineral elements known to be necessary for plant growth fall into three groups:

1. Commercial fertilizers—nitrogen, potassium, and phosphorus. These elements are used in large amounts by plants, and are often deficient in many soils throughout the world.

2. Elements usually present in sufficient amounts for plant growth—calcium, magnesium, sulfur—but possibly

required in additional amounts to provide good soil structure.

3. Minor, or microelements—manganese, iron, boron, zinc, copper, molybdenum. Plants require minute amounts of these for successful growth.

In addition to chemical tests for availability of these elements, the trees should be observed. Often they will show "deficiency" symptoms that indicate the need for a particular element. These symptoms are not completely reliable by themselves, but are valuable when considered in conjunction with soil or plant analyses. However, where deficiency of an element is suspected, application should be on a trial basis at first (see p. 9) to determine whether large-scale application would be profitable.

Of the elements absorbed by roots and known to be essential for growth of fruit trees, all except phosphorus, calcium, sulfur, and molybdenum have been reported inadequate in deciduous orchards somewhere in California.

**Nitrogen** is the most important element as a fertilizer for trees. To produce maximum crops, trees need additions of this material more than of any other. Every major fruit district in California, and all species, have shown nitrogen deficiency in at least some orchards. Many orchards, however, are plentifully supplied from reserves in the soil. In bearing trees, an acute nitrogen shortage is indicated by pale, yellowish-green leaves, smaller than normal; short vegetative shoots, usually small in diameter; profuse bloom, but very heavy drop, resulting in light set and poor crop; small fruit maturing early, followed by early leaf fall. These symptoms appear in the peach sooner than in most other species. If nitrogen is supplied to a tree in this condition, the first response will be an improved leaf color and better growth. Fruit production may or may not be affected the first season. If the per cent of set is increased, the yield may be



Deficiency symptoms in peach. Top to bottom: magnesium deficiency in leaves; nitrogen deficiency in leaves; copper deficiency in leaves and shoots.

better, and the size improved. The accelerated growth and the larger leaf area will provide a larger and better-nourished fruiting area, thus permitting the setting of more and stronger fruit buds. This development, in turn, should increase production the second season. Sometimes this cycle is repeated with annual increases for four or five years.

**Phosphorus** deficiency symptoms, less clearly defined in fruit trees, have been seen almost exclusively in pot-culture experiments. Under these artificial restrictions, the condition developed is one of stunted growth and dark-green or somewhat bronzed leaves, which may be thickened. Trees grow and produce well on a phosphate-deficient soil in which most annuals fail to make normal development. In a soil having the lowest phosphate-supplying power of any so far investigated in California, the common species of fruit trees failed to respond to added phosphate, although annuals increased growth five to 20 times that of their unfertilized checks.

**Potassium** deficiency has usually appeared as local spots varying in size from a few trees to several acres, and including most of our fruit species. The Sacramento Valley and coastal valleys have shown the most trouble. Treatment has not always been successful, particularly where symptoms are severe. Deficiency may result in leaf scorch and die-back, sometimes with burning and shriveling of the fruit. Leaf scorch, observed in several fruit species, usually appears on the leaf margin, but may also involve most of the leaf blade. It seems likely that the reduced leaf area limits the food supply available to the roots. This, in turn, reduces the absorbing surface and the efficiency of the roots, resulting in further deficiency. The most severe and widespread potassium deficiency has been found with prunes. This has usually been associated with overbearing, and the condition has been markedly im-

Peach leaves showing typical leaf scorch of potassium deficiency.



Manganese deficiency in prune leaves. Note yellowing in areas between veins.



Boron deficiency symptoms in prune shoots, as indicated by dying back of terminals.



Peach leaves showing yellowing as a result of iron deficiency.





Zinc deficiency (little-leaf) of apricot. Treated branch at right.

proved by limiting the crop to about 4 dry tons per acre in the interior valleys, and less in the coastal areas. Peaches and almonds have shown much less damage in situations where prunes have been unprofitable. Early loss of leaves and dying back of the tips, followed by new growth from the last live bud, tend to give a zig-zag growth, short and brushy. Trees which show no deficiency symptoms rarely have responded to added potassium.

**Calcium** deficiency has not been noted in California orchards. However, calcium in the form of gypsum or lime has proved beneficial as a soil amendment in certain areas.

**Magnesium** deficiency is seldom found in California. When it does occur, it is mostly in coastal areas. The basal leaves of affected trees develop brownish blotches and drop off. The tips may continue growth while more leaves drop and a few remain at the ends of bare shoots.

Fruit-bud production may be greatly reduced.

**Sulfur** deficiency has not been reported for fruit trees in California, but the material has been used extensively as a corrective for alkali soils.

**Manganese** deficiency symptoms of a severe nature have been found in several species (notably walnuts) in Ventura, Santa Barbara, and San Luis Obispo counties, and in small areas elsewhere. In mild cases, yellowing occurs in the areas between the veins of leaves. In severe cases, these areas die, and many leaves fall prematurely. Some trees may be practically defoliated by late summer. Milder cases on peaches and apricots, and less often on other species, occur in both the coastal and the interior valleys.

**Iron** deficiency, or so-called "lime-induced chlorosis," is common on highly calcareous soils. A deficient area along the southern end of San Francisco Bay

has been known for many years, and other such areas have been noted over the state. The lack of iron causes yellowing of leaves (except the network of veins) and, in some cases, complete loss of green color. The soils on which trees develop these characteristics are not usually low in iron, but the excess lime renders the iron unavailable.

**Boron** deficiency was first noted in California in the olive, with the following symptoms: death of terminal buds; scorch of leaf tips; greatly reduced set of fruit; and deformed fruit known as "monkey-face." The apple and pear in the Sierra foothill area may show "blast" of blossoms, dying back of shoots, and the development of hard, brown, corky areas in the flesh of the fruit. The latter symptom seems much less common in coastal counties. In the European plum, brown, dry, pithy areas may develop in the fruit flesh. There may also be dying back of terminals. The prune in Sonoma County has shown a witch's broom effect called "brushy branch." The walnut shows poorly developed leaves, often misshapen, usually accompanied by die-back and chlorosis. So far, no evidence of boron deficiency has been found on the Japanese plum, even when growing among European plums with marked deficiency symptoms. In the coast counties, deficiency and excess situations occur within a few miles of each other.

**Zinc** deficiency is responsible for a trouble long known as "little-leaf," "rosette," or "corral sickness." (Corral sickness has also been used to designate copper deficiency.) Extensive zinc-deficient areas have been found in the San Joaquin and Sacramento valleys and in smaller spots elsewhere in the state. The most common symptom is a tuft of small, often deformed, yellowish leaves at the ends of shoots. Symptoms vary somewhat with the species. Fruit abnormalities are common, and crops are usually very small.

**Copper** deficiency is rare, but has been found associated with zinc defi-

ciency in some corral spots and old Indian camps, as well as in small areas of pear and apple orchards in the central coast district. Symptoms resemble those of zinc deficiency, but leaf scorch and roughened bark may also occur. Almonds in San Luis Obispo County show severe gumming on the trunk.

**Molybdenum**, although essential for plant growth, is needed only in minute amounts. On the basis of present information, deficiencies seem highly improbable, and have not been observed in California orchards.

### Orchard plot trials

The need for fertilizer is indicated by the condition of the trees, as determined by observation of symptoms, and by soil and plant analyses. If these factors point to the need of a particular element, the grower should try it on a limited scale. Suitable fertilization practices can be developed if the plot test shows a profitable response.

The grower must have clear objectives before laying out a test plot. He may wish to know whether *any* fertilizer will pay, or what element is needed, or how much of a needed material should be used.

Plots should be chosen carefully to represent the average of the block because individual trees vary in their responses to the same treatment. Each plot should contain at least 10 trees.

To insure success, plots must be properly compared. Detailed records are rarely necessary, but some measure should be made. In addition to observable symptoms, a count of the number of boxes of fruit per tree is usually an accurate enough index. Observation alone may not be adequate in evaluating differences ranging up to 20 per cent.

For help in planning orchard test plots, consult your University of California Farm Advisor.

# How to apply the fertilizers your orchard needs

## Nitrogen

The most common problems of nitrogen fertilization concern source of the element, time of application, and amount to use. The chart below summarizes the characteristics of the most common sources of nitrogen. (Organic sources, other than synthetic urea, are not included. Manure and covercrops constitute the primary sources of organic materials, although sewage sludge, blood meal, tankage, fish emulsions, bone meal, and seed meals contribute to the total. These materials are largely by-products from other manufacturing processes, and their nitrogen content is usually rather low compared with that of the inorganic sources listed.)

All of the materials in the chart have been used successfully in orchards as sources of nitrogen. For most growers, the price per unit of actual nitrogen will determine the choice. In special situations, however, other factors are important. For example, it would be unwise to use sodium nitrate where sodium toxicity is a danger. A material with an acid residue is to be preferred in an alkaline soil and to be avoided in a highly acid soil.

Experimental plots with different sources of nitrogen have been compared. The trials normally extended over a five-year period. These trials showed that the tree response was the same for a given amount of actual nitrogen regardless of the source.

**Nitrogen is necessary** at the time of bloom and of spring growth to insure an adequate per cent of set and proper vigor in the new growth. The leaf area

developed on this new growth manufactures the food which is necessary for further vegetative growth of both top and roots, and for fruit development. Soon after blossoming, the stimulus is given to fruit-bud formation for the next year's crop, and nitrogen is required for this process. It seems logical to assume that the need for a supply of nitrogen is

## Here Are the Pri

NAME	Compound formula
Anhydrous ammonia	$\text{NH}_3$
Ammonia solution	$\text{NH}_4\text{OH}$
Ammonium sulfate	$(\text{NH}_4)_2\text{SO}_4$
Ammonium nitrate	$\text{NH}_4\text{NO}_3$
Ammonium phosphate-sulfate (16-20) mixture	
Ammonium phosphate	$\text{NH}_4\text{H}_2\text{PO}_4$
Calcium nitrate	$\text{Ca}(\text{NO}_3)_2$
Urea	$\text{NH}_2\text{CONH}_2$
Sodium nitrate	$\text{NaNO}_3$
Calcium cyanamide	$\text{CaCN}_2$

\* There is no serious trouble with the physical pro

most critical at this stage of the growth cycle. To insure this supply, most growers apply nitrogen in the dormant season. If it is in the form of nitrate, the timing may be as late as a month before bloom. Time must be allowed for rains to carry the nitrate into the root zone. Nitrate may be applied earlier unless the soil is very light or shallow, in which case leaching may reduce the effectiveness. If the nitrogen is in the form of ammonia, whether combined with other substances (for example, ammonium sulfate) or not, it will be "fixed" by the soil. That is, it will combine with a certain portion of the soil in a form that prevents its movement into deeper layers. At ordinary rates of application, am-

monia will be practically completely removed from solution in 2 inches or less of soil. Soil bacteria then act on the ammonia to change it into nitrate, in which form it is free to move. It is necessary to allow at least a month for this process if nitrate is to be in the root zone when it is needed.

There is evidence that nitrate can be absorbed by roots before top growth begins if the soil temperature is not too low. It appears that most of the nitrate used in the growth cycle is absorbed fairly early in the season. Late applications, during the growing season, may increase the absorption and give a nitrogen response, but do not take the place of available nitrate in the early spring.

## Principal Commercial Sources of Nitrogen for Orchards

Per cent nitrogen	Advantages	Disadvantages*
82	High nitrogen percentage; ease of application; no residue; little danger of leaching	(a) In irrigation water: Uneven distribution if irrigation system not adapted to its use. Cannot be used with sprinklers. (b) Dry injection: Some loss if ground is trashy or cloddy
usually 20	Easier to handle than anhydrous; no residue	Same as for anhydrous
21	Acid residue (for alkaline soils); little danger of loss by leaching; ease of handling	Acid residue (for very acid soils). Delayed availability during nitrification
33	High N percentage; no residue. Half immediately available, half delayed	
16	Same as ammonium sulfate. Carries phosphate if needed for covercrop	Same as ammonium sulfate
11	High phosphate content where needed for covercrops	Low N percentage
15.5	Calcium residue (for acid or high sodium soils). Immediate availability	May be leached
42	High N percentage. Is not fixed if irrigated at once, before conversion to ammonium carbonate. No residue	May be toxic in high concentrations
16	Alkaline residue (for acid soils); immediate availability	Sodium residue undesirable on high sodium soils. May be leached
24	Alkaline residue (for acid soils). Calcium residue	Danger of burning, especially at high rates or in growing season

\* of any of these materials unless they are stored too long or under poor conditions.

**Comparisons of tree behavior** in plots receiving nitrogen at different times of the year showed that timing is very important during the first year of application. Dormant applications were best, with spring applications next. After the experiments were established, however, there was enough carry-over from one year to the next so that timing seemed of secondary importance except in the case of early shipping fruit. It was found that the same amount of nitrogen applied immediately after harvest gave less response than at other seasons. With an application at this time it was possible to obtain a response in leaf color, time of leaf fall, condition of fruit buds, and tree condition without delay in maturity.

Some growers split their nitrogen fertilization, putting on a part in the dormant season and a part in the spring. The size of the second portion is regulated by the condition of the tree at the time. If the crop is heavy, a little more is used, and if light, less. Some material is saved but the extra labor may offset the saving. For most conditions where leaching is not a problem, a single application has been satisfactory.

**The fixation of ammonia** influences timing of fertilization in irrigation water during the growing season. Fertilizers differ in their behavior when applied in this way. For example, calcium nitrate will move into the soil with the water, and may cause greening of the leaves in a few days. Ammonia will be held back, and ordinarily will not be available until it has been nitrified and moved into the root zone with the next irrigation. A compound such as ammonium nitrate will do both. Half of the nitrogen, as nitrate, will move down immediately; the other half will be held back for later use.

**The choice of application method** in orchards seems to be mainly a matter of cost. Trials have shown a slightly greater uptake of nitrogen when it is

applied in a ring the diameter of the branch spread than when the same amount is distributed over the whole area, but the response did not differ. There seems to be no difference in response between broadcasting and drilling. Material dissolved in irrigation water is spread about as evenly as the water. In basins with a good head, distribution is very even. In furrows there is more likelihood of uneven distribution, especially with small heads and long runs. This is particularly true with ammonia, which tends to be fixed by the soil in the furrow at the upper end of the run. Noncorrosive, nonvolatile materials can be used in sprinkler systems.

**The amount** of nitrogen necessary in a particular orchard can be determined only by experience, and the rate of application must be based on tree condition and response, the kind of fruit, age of trees, vigor, type of pruning, water supply, climate, and character of soil. For example, the peach is likely to respond to nitrogen under conditions in which some other species will have an adequate supply. Trees that bear normal crops and at the same time make vigorous vegetative growth probably require little or no treatment. In soil of a high initial fertility, young trees may grow vigorously without nitrogen addition, but may show deficiency after some years of bearing. Trees which are heavily pruned usually require lighter applications of nitrogen than do trees lightly pruned. Trees suffering from an inadequate water supply may have a somewhat higher need for nitrogen than those with a normal water supply. The same variety, in the same kind of soil, may respond differently in different climates. Apricots, for example, require less nitrogen in the Santa Clara Valley than in the interior valleys. The supply of nitrogen in a light soil is often limited, and becomes exhausted sooner than that in a heavier soil. Trees making weak growth because of lack of nitrogen may need, on an

average, 60 to 100 pounds of actual nitrogen per acre—equivalent to 300 to 500 pounds of ammonium sulfate or 360 to 600 pounds of calcium nitrate per acre. Higher rates of application are rarely profitable. The amounts indicated above are suggested for those species with a high nitrogen requirement, such as peaches and almonds. Under the same growing conditions, other stone fruits require less nitrogen for best results. Apples and pears likewise have considerably lower nitrogen requirements than peaches.

In many orchards it should be possible to obtain an unusual spread in time of maturity by fertilizing part of the area more heavily than the rest. This practice will delay maturity on the more heavily fertilized portion, and smaller picking crews may be able to handle the fruit. The rate of nitrogen application should be coordinated with other orchard practices.

**Excessive use** of nitrogen is not common, and should be avoided. In certain cases, fruit quality has been impaired and maturity delayed by heavy applications. Moderate excess leads to a few days' delay in maturity, with some fruit in the lower and interior parts of the tree failing to attain satisfactory color. Further excess may give softer fruit of poorer color and flavor over the whole tree. Uneven ripening of fruit halves in stone fruits and a delay in maturing of wood in the fall have also been noted with high nitrogen.

### **Phosphorus**

Although tests to date show that California orchards are not deficient in phosphorus, this material can be applied with profit to encourage growth where covercrops are beneficial and need phosphorus for satisfactory growth (see p. 15). Superphosphate is the standard source of phosphorus. Apply when a covercrop is planted, at about 50 to 100 pounds per acre.

### **Potassium**

This element should be applied in orchards as potassium sulfate (sulfate of potash) rather than the chloride (muriate). California soils are frequently high in chloride, and the addition of more should be avoided. It has been found that a single heavy application of potassium sulfate is more effective than the same amount used as a mixed fertilizer applied over a period of years, and will last for a number of years. The amount required varies with the soil type. Trees growing on a few soils with low fixing capacity have responded to as little as 5 pounds of potassium sulfate per tree. More commonly, 15 to 25 pounds are necessary, and on some heavier soils with high fixing capacity, 50 pounds were required.

Where symptoms and leaf analyses indicate potassium deficiency, it is suggested that the grower treat a few trees with different amounts of potassium sulfate to determine the most economical level. Placing the material in bands just below the usual depth of cultivation reduces the amount required to give response.

### **Boron**

Deficiency has usually been corrected by addition of borax at the rate of 50 to 100 pounds per acre, broadcast evenly on the soil. Response in the spring usually follows applications made the preceding fall. More rapid response results from spraying borax at 1 pound per 100 gallons during the growing season. Applications much in excess of the above rates are likely to produce toxic symptoms.

### **Iron**

This was the first minor element deficiency to be identified, and has been the most difficult to correct. Soil treatment has usually been unsatisfactory. Organic salts of iron, such as the citrate, tartrate, or oxalate, placed in holes in

the trunk, have given correction for as many as three years, but have damaged trunk tissue. Various sprays have been used, the most promising being various iron chelates at the rate of 1 pound per 100 gallons.

### **Magnesium**

This element has been supplied as magnesium sulfate (Epsom salts) or Dolomitic limestone. The former is used in neutral or alkaline soils, the latter under acid conditions. Rates between 10 and 40 pounds per tree have been recommended. On soils low in potassium, use of large amounts of magnesium may induce potassium deficiency and vice versa. A spray of 20 pounds Epsom salts per 100 gallons of water has also been used for more rapid response.

### **Manganese**

On most species, manganese deficiency can be corrected by spraying with a mixture of 2.5 to 8 pounds manganous sulfate, 5 pounds lime, and a spreader, per 100 gallons. Spray in late spring or early summer. Correction of symptoms should

follow in a few weeks. Annual sprays are likely to prove necessary. Manganous sulfate can be added to the soil in holes or trenches, but more material is required with this method. Broadcasting is not satisfactory because the chemical is fixed by most soils. An experimental method of injecting dilute solutions into holes bored in the trunk or main branches has given good results, but the holes may also admit destructive fungi. Acidification of soil with sulfur will usually correct the deficiency, but may be too expensive.

### **Zinc**

This element is used to correct little-leaf. The application method must be adapted to the species concerned. Treatments have been made by means of sprays, pieces of zinc or galvanized iron driven into the trunk, holes bored in the trunk, and direct application to the soil.

For nearly all fruits (except sweet cherry and walnut), the most satisfactory method of zinc application is spraying. For severe cases, zinc sulfate sprayed during the dormant season at the rate of

Fertilizer spreader being refilled in prune orchard.



50 pounds per 100 gallons of water is recommended. For cases of moderate severity, half that strength is sufficient; and for mild cases, as little as 10 pounds per 100 gallons may be used. Summer sprays must be much more dilute, not more than 6 pounds per 100 gallons, and must contain 3 pounds hydrated lime or soda ash to prevent burning. A more satisfactory summer spray is zinc oxide with a spreader, but this spray will injure fruit. Zinc chelates now being used experimentally have given good control.

Metallic zinc points or pieces of galvanized iron driven into the tree will correct little-leaf for a long period of years in most species. This is the most satisfactory method for walnuts and sweet cherries. An area around each piece of metal will be killed, and if these areas merge, the trunk or branch will be girdled. To prevent this, stagger the points or place them in a spiral. About four to six pieces per inch of circumference are recommended. Results will be better if branches are treated rather than the trunk.

A treatment with dry zinc sulfate in gelatine capsules (size 000), placed in holes about 4 inches apart around the trunk, will correct the symptoms for three years or more. (The same objection to boring holes in the tree that applies to manganese also applies to the use of zinc or other minor elements—rot may develop.)

Direct soil application requires large quantities of zinc sulfate, and the rate of transmission is too slow for rapid recovery. Because the zinc is fixed by the soil, it must be applied in holes or a trench in the ground.

### Copper

Copper deficiency has not been found where trees are sprayed with bordeaux mixture for the control of disease. When bordeaux is not used, dry copper sulfate in capsules may be added through holes in the tree, as with zinc. Because of the higher toxicity of this material, however, greater care in application is necessary. The copper must be kept away from the bark, cambium, and younger sapwood. Adding copper sulfate in a trench about 4 to 8 feet from the tree at the rate of 5 to 20 pounds per tree has also been successful.

Growing alfalfa in orchards having either zinc or copper deficiency has proved beneficial: mild cases have been entirely corrected, and severe ones greatly improved. Just how the alfalfa functions is not understood. Whether or not the practice is feasible must be decided for each orchard. Alfalfa is not suitable for such crops as prunes or almonds because it hampers harvesting operations. Also, other cultural practices may require modification if alfalfa sod is maintained.

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## Covercrops are good for some orchards, bad for others

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Any crop grown between the trees and turned under may be considered a covercrop, even if it is a weed that volunteers. Such crops affect the problem of fertilization and the trees' response to fertilizers.

**The first objective** in planning a covercrop is the addition of organic matter, not only as a source of nitrogen that will be released over a long period in the soil, but also as a major factor in maintaining good tilth, or soil structure. With



continuous cultivation, organic matter tends to disappear. It can be restored either by bringing it in from other sources, such as manure or bean straw, or by growing it in place and working it into the soil. Manure or other suitable material is not often cheap enough to warrant the use of adequate amounts. In many orchards the growing of covercrops has tended to replace manuring.

Actual field data regarding the effect of covercrops on soil structure are scanty. However, much laboratory work has been done to show the effects of adding covercrop material under controlled conditions. The decomposition rate of different materials under varying moisture and temperature has been studied, together with the effect of these processes on the formation of soil granules. Certain factors important in the orchard are difficult to study in the laboratory—for example, the formation of root channels through plow sole, or the cracking of certain soils. Since information on many of these points is still fragmentary, present opinions may be changed later. It seems certain that, in many soils, water penetration is better after a few years of covercrops. The action of covercrops in improving water penetration may lie in either of two zones. One is the prevention of "surface sealing" which occurs in some southern California soils when they are wet. The other is the improvement of the compacted layer below the depth of cultivation, known as the plow pan or plow sole. At Davis, for example, the latter effect was so great that the water from a 6-inch irrigation disappeared from the surface of a covercropped basin in less than 24 hours, whereas across a levee, in an adjacent, clean-cultivated check, the time required was more than a week. More economical use of water and a better supply to the roots will result in the absence of plow pan. The use of covercrops is not, how-

ever, a substitute for careful soil handling. Cultivation when the soil is too wet will puddle many soils so badly that years of good care may be required to repair the damage. Good soil structure can be developed, moreover, and maintained without covercrops if sufficient care is taken to avoid compaction. Whenever such care is impossible because the soil is too wet, covercrops may be of great benefit.

A distinction should be made between the improved soil-water relations resulting from better penetration, and those from increased water-holding capacity of the soil. Under cool, humid conditions the soil's organic matter can be increased by annual covercrops, and with it the total nitrogen and perhaps the water-holding capacity. Under hot, semiarid conditions, this is not the case: the rate of destruction of organic matter is so great that there is little, if any, net accumulation. At Davis, 30 years of annual covercrops of three types—winter legume, winter nonlegume, and summer legume—have failed to change the moisture-holding capacity of the soil measurably. This factor, therefore, can probably be ignored in California orchards.

Much the same situation exists with regard to total nitrogen as with moisture-holding capacity. Leguminous covercrops with proper inoculation of nitrogen-fixing bacteria have given increases of total nitrogen in cool, humid sections; but neither summer nor winter legumes has done so at Davis. There probably was some fixation of nitrogen, but either it has been used, and therefore does not appear in analyses, or the amount is too small to be detected. In sandy soils, where heavy rains might leach nitrate below the root zone, its absorption by the covercrop, with later release as the crop rots after being turned under, may save important amounts for use by the trees.

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Left: tractor-drawn disk and harrow disking under a mustard covercrop in walnut grove.

When organic material is incorporated into the soil, most of it is decomposed by soil bacteria and fungi. These organisms, like other plants, need mineral nutrients for their growth and functioning. During the first part of the period of decomposition, the soil microorganisms are increasing in number, and may use nitrate from the soil solution as well as nitrogen from the decaying covercrop. The nitrate concentration is thereby reduced in the soil solution, leaving less for the trees. The extent of this depletion depends on the supply of the material in the soil (especially nitrate), the condition of the covercrop or other organic material turned under, the moisture supply, and the temperature. Of these factors, the most important, usually, is the character of the organic material. If it has a high nitrogen content, as in a succulent covercrop that is not mature, decomposition is rapid. Because of this, nitrates are released sooner than with a material lower in nitrogen. The organisms can therefore secure most of the nitrogen they need from the material itself, and less from the soil. Strawy material, high in carbohydrates and low in nitrogen, may cause a depressed nitrate level for months after being turned under.

Obviously, any tendency toward nitrate deficiency in a soil will be much increased by the incorporation of large amounts of low-nitrogen organic matter. Additional amounts of fertilizer will then be needed to supply both the soil organisms and the tree. Covercrops, furthermore, absorb nitrate while growing, and during that period may compete seriously with the tree. An attempt should be made to correlate the timing of the growth of the covercrop with the fertilizer program and with the needs of the trees.

Covercrops may play an important role on slopes that are subject to erosion. They increase the rate of water penetration, thus reducing runoff, and their

roots tend to hold the soil in place, reducing the amount washed down by the water that does flow away. A crop to be used for erosion control must be one that establishes a root system quickly throughout the surface soil, unless a permanent sod is already established. Various crops of this type have been tried in most districts, and information about their use can be obtained from the local University of California Farm Advisor.

**Annual covercrops** may be divided into four groups: winter legumes, summer legumes, winter nonlegumes, and summer nonlegumes. Among *winter legumes*, the most widely grown are bitter clover or annual yellow sweet-clover (*Melilotus indica*), the vetches, and bur clover. Horse beans, fenugreek, lupine, and field peas have been successful in more limited areas. The following crops have had some use as *summer legumes*: cowpeas; velvet, mung, tepary, and mat beans; soybeans; sesbania; and Hubam clover. The most widely used *winter nonlegumes* are: mustards (common, black, and Trieste) and cereals (rye, oats, barley), together with volunteer weeds. Where *summer nonlegumes* are desired, orchardgrass, Sudangrass, and summer-growing weeds have proved satisfactory.

In addition to these crops, an increasing number of growers are using permanent sod. This system eliminates the cost of cultivation, and is the most effective check on erosion. It permits orchard operations when the soil is wet that are not feasible under clean cultivation. On the other hand, this method requires more water, increased use of nitrogen (even with a leguminous sod), and more rigorous efforts in pest control. It provides cover for mice and gophers. It is not suitable for species whose fruit is harvested from the ground—for example, prunes, almonds, walnuts, or figs. Alfalfa has been widely and successfully used for permanent sod, and perennial rye-

grass has also proved satisfactory. In some areas, throughout the year, volunteer weeds provide a succession of plants which, though containing few perennials, serve adequately.

Despite the advantages to be obtained from covercrops, they can be harmful in certain orchard areas. Nonirrigated orchards in regions of low rainfall need all the moisture available to take them through the season. The use of any considerable portion of the supply by covercrops may result in failure to mature the fruit and, during very dry years, in severe damage to the trees. Any covercrops used in such areas must be turned under early enough so that the late winter rains will restore the water used

by these plants in the early winter. Under these conditions, large tonnages of covercrops cannot be expected, and conditions may keep the grower from turning the crop under in time to prevent some moisture depletion. The increase in rate of moisture penetration and the decreased loss by runoff may compensate for the water used when the practice has been carried on long enough to be effective. Since covercropping must be practiced for several years before water penetration can be noticeably improved, this is still a hazardous program in nonirrigated areas. Furthermore, the growers of stone fruits have found a higher incidence of brown rot in orchards having covercrops at blossoming time.

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“At all times, the Department of Pomology has standing requests for promising personnel, with the promise of several firms to make openings for recommended students if no openings already exist. Some year we hope we'll be able to supply the demand.”

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For study and research, facilities also include a packing house, complete sun-drying and dehydration equipment, a cold-storage plant, lath-houses and green-houses, and laboratories equipped with apparatus for fundamental studies.

The staff of the department includes specialists in fruit breeding, pruning, pollination, spraying, irrigation, fertilization and plant nutrition, soil management, physiological plant diseases, propagation, varieties, harvesting, handling, and storage of fruits and nuts.

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