FERTILIZATION OF THE SOIL AS AFFECTING THE ORANGE IN HEALTH AND DISEASE.

By H. J. WEBBER,
Assistant in Division of Vegetable Pathology, U. S. Department of Agriculture.

Probably the most important question which concerns the orange grower is how to fertilize his trees. In Florida, where the orange soils are mostly very sandy and sterile, and require to be fertilized regularly, it is highly important to understand what elements should be used in fertilization and in what forms it is best to use them. No plant will long withstand improper treatment. In case of slow-growing plants like the orange, where proper treatment prolongs growth and productiveness for centuries, it becomes particularly necessary that correct methods of manuring be used. The condition of tree reflects largely the cumulative treatment of years; in crops which are replanted each year, however, the effect of improper fertilization is probably less noticeable, especially so far as the development of disease is concerned.

In growing annual plants one can early notice results and may profit by experience. A few seasons will suffice to determine about the kind and quantity of fertilizer necessary for them on a particular soil. In the fertilization of the orange, however, the matter is not so easily determined; only the observations of a series of years will give results which can be depended upon. An orange grower may fertilize with one element one year and get good results, but this is no evidence that the same element used the next year or year after year will prove beneficial; it may, indeed, in prolonged treatment, lead to deterioration and disease. It is this difficulty in experimenting and drawing correct conclusions that accounts for the present poor understanding of rational methods of manuring the orange.

The orange appears to be very sensitive to methods of treatment and fertilization, and several of the most serious diseases are either caused or aggravated by errors in these. The present paper is based largely on the experiences of intelligent orange growers and upon such observations as the winter has been able to make in the course of investigations of orange diseases.

FERTILIZING FOR GROWTH AND FRUIT.

Primarily the orange grower desires to know how to fertilize so as to stimulate either growth or fruit production. With oranges, as with many other agricultural plants, one may fertilize in such a manner that

excessive growth is stimulated at the expense of fruit production. A strong nitrogenous fertilizer results usually in much growth and little fruit. This seems to be particularly true if the ammonia is added in an organic form. While trees are young it is probably well to favor the growth of wood principally, but at an age of seven or eight years from the bud, the tree, if it has grown properly, will have attained sufficient size to begin to produce a fair quantity of fruit. It should then be given a slightly modified fertilizer, containing more potash and phosphoric acid and less nitrogen, to stimulate fruit production as much as possible. The so-called chemical manures appear to be much more active in stimulating fruit production than organic manures.

EFFECT ON QUALITY OF FRUIT.

The experience of many orange growers indicates that the quality of the fruit may be largely controlled by fertilization. As oranges are purchased very largely on their appearance and quality, this becomes an important consideration in manuring. Many intelligent growers are coming to believe that the best results can be obtained by giving the trees an application of that element only which seems to be lacking, and not using, as the majority do, a complete fertilizer, in definite proportions, regardless of whether all the elements are needed by the plant or not. If it can be determined by the appearance of the tree and fruit what element is lacking, this would seem to be the most rational way to fertilize.

It seems reasonable to suppose that by careful study pathological characters induced by starvation might be found, which would serve to indicate clearly the lack of any particular element. Some growers claim to be able to recognize these characters now, and are fertilizing largely on this modified plan, taking advantage of what we might call the sign language of the tree. Some of these characters will be mentioned below under the consideration of the different elements used.

EFFECT ON SOIL MOISTURE.

In fertilization at least two factors must usually be considered, the element of plant food supplied and the effect of this upon the soil as aiding it in supplying the plant with moisture. The heavy application, in late fall or early spring, of an organic manure, like blood and bone, which is extensively used in Florida, is liable to lead to injurious effects during the spring drought, if the trees are on high and dry land. On the other hand, such soils might be ameliorated by using substances which attract water and increase the surface tension of soil moisture. Nitrogen, for instance, used in the form of nitrate of soda, and potash, in the form of kainit, would tend to draw up the subsoil moisture and probably aid largely in supplying the necessary moisture during this trying season. The use of organic manures, on the contrary, would only exaggerate the damage produced by drought. If groves are on very

moist land, as is frequently the case in Florida, where the necessity is to lessen the moisture rather than to increase it, some form of organic manure, as muck or blood and bone, might be found of benefit.

EFFECT OF FERTILIZERS ON THE ORANGE IN HEALTH.

The elements which need to be supplied in fertilization to most Florida orange groves are nitrogen, potassium, and phosphorus; or, using the terms in which they are expressed in most analyses of fertilizers, ammonia, potash, and phosphoric acid. The application of lime would also prove of benefit to many groves. Probably no element of plant food used in the fertilization of orange groves should be more carefully considered, with respect both to form and quantity, than nitrogen. It is the most costly and at the same time the most dangerous element to use, as excessive applications are liable to result in extensive dropping and splitting of the fruit or in the production of the serious disease known as die-back, which will be discussed below.

EFFECT OF NITROGEN.

A grower may with considerable certainty determine by the appearance of his trees the condition of his grove in respect to the supply of nitrogen available in the soil. An abundance of nitrogen is indicated by a dark green color of the foliage and rank growth. The fruit shows the effect of an abundance of nitrogen by being, in general, large, with a thick and comparatively rough rind. If the trees have a yellowish foliage, with comparatively small leaves, and show little or no growth, there is probably a lack of nitrogen. In this case there is but little fruit formed, and that formed is small and usually colors early. If the tree is starving from a lack of nitrogen, the foliage will become very light yellow and sparse, and the small limbs will die, as will also the large limbs in extreme cases. If the starvation is continued, no fertilizer being added, the tree will finally die back nearly to the ground and probably die out entirely. The extreme symptoms of general starvation from lack of all elements are probably nearly the same. The nitrogen used in fertilization is commonly derived from mineral or organic sources. Of the former, sulphate of ammonia and nitrate of soda are the forms most used; of the latter, muck, dried blood, blood and bone, cotton-seed meal, tankage, fish scrap, stable manure, etc., are the forms most commonly employed.

INJURIOUS ACTION OF MUCK.

Muck is very commonly applied in considerable quantities either in a raw state or composted with sulphate of potash, etc. Many growers rather fanatically hold to what they term natural fertilization. By this is usually meant giving the tree nourishment in the form in which they suppose it to be derived in nature. It is contended by many that muck is principally decaying vegetable matter, and that as this is the form

of nourishment which the trees obtain in nature, it must be a good fertilizer to use in cultivation. But it must be borne in mind that orange trees as we cultivate them are decidedly not in a state of nature, except that by the cultivation of centuries we have made cultivation and manuring natural conditions which the plant demands. Trees in nature bear fruits for seed to reproduce the species; on the contrary, we grow fruits for market and favor a seedless variety. We want a smooth, thin-skinned, tender, juicy fruit that will sink in water. Nature does not pay particular attention to these characters, so we watch for freaks and sports, abnormal plants, which have the characters we desire, and when found we render these characters permanent by budding. Our aim in cultivation is not to produce the fruit we find in the wild state, but to modify that fruit to suit our purpose. One of the most efficient methods of accomplishing this is to vary the fertilization.

While it can not be denied that muck has in some cases given excellent results, it must be conceded that its extensive use has usually been of doubtful benefit and often has done positive injury. Groves which have had liberal dressings of muck are frequently much diseased and produce light crops; the oranges are usually coarse, thick-skinned, and sour; the productiveness is often lessened by extensive premature dropping of the fruit; the tendency seems to be to bring on die-back, a disease which is of frequent occurrence in groves heavily fertilized with muck. What has been said of muck applies to a greater or less extent to the various forms of organic nitrogen used. The tendency of all organic manures rich in nitrogen is to produce a large growth which is weak and sickly. Growth and not fruit is stimulated, and the fruit resulting is usually of poor quality, inclined to be large and rough, with a thick rind and abundant rag.[1]

STABLE MANURE OF DOUBTFUL UTILITY.

Barn manure is largely used by many growers, who still hold to the tradition that chemical manures are injurious to the plants. The benefits of barn manure in an orange grove are in serious question. The fruits produced by nitrogen from this source are, as above stated, usually large, coarse, thick-skinned, with abundant rag, and of inferior flavor. If barn manure is used—and most growers have a limited quantity and desire to use what they have—it should be spread over the grove lightly, so that each tree receives only a small amount. Where such manure is depended upon as the main element of fertilization, liberal dressings of potash should be occasionally applied; this will tend to correct the evils of an overbalanced nitrogenous fertilizer. What has been said as to the effect of muck and barn manure on the quality of the fruit applies equally to the effects produced by cotton-seed meal, blood and bone, tankage, etc.

[1] A term applied to the pithy axis of the orange fruit and the membranes separating the sections.

In general, organic fertilizers do not stimulate fruiting to the same extent as the mineral fertilizers. It is probably better economy to apply such fertilizers to annual crops, cereals, garden truck, etc.

MINERAL NITROGEN.

The mineral nitrogen manures, nitrate of soda and sulphate of ammonia, apparently stimulate production of fruit more than organic manures and yet promote a fair general growth. The fruit produced by fertilization with these salts, used in correct proportions with the other elements which it is necessary to apply, is usually of good quality, being solid, juicy, and rich, with thin skin and little rag. Sulphate of ammonia has the effect, growers testify, of sweetening the fruit to a considerable extent. There seems to be little doubt as to the correctness of this view, but why it is so remains in question. The sweetening is probably more marked if there is a slight deficiency of potash. The use of very large quantities of either sulphate of ammonia or nitrate of soda may result disastrously, acting as "chemical poison," killing the trees outright and causing them to throw off their leaves. Here again the exact action is not, to my knowledge, understood. The following may be the explanation: It is well known that plants growing on the seacoast, in soil saturated with the salty sea water, are, in some respects, under almost the same conditions as in deserts, having great difficulty in obtaining sufficient water, though surrounded by water. The root hairs have difficulty in extracting the water from the strong salty solutions. The plants thus have various devices to prevent excessive evaporation or transpiration of water from the leaves, similar to those developed by desert plants. The injurious effect of the nitrogen salts may in this case be caused by simply producing such a strong solution of the salt in the vicinity of the plant that the roots are not able to absorb the necessary moisture, and thus the plant is compelled to cut off its leaves to prevent the transpiration of the water which can not be replenished by further absorption.

Sulphate of ammonia has been very widely used among orange growers. Nitrate of soda has been but little used thus far, but is apparently growing in favor. Its insecticide and water-attracting properties are probably much greater than those of sulphate of ammonia.

POTASH FERTILIZERS.

In fertilizing the orange, potash is most frequently used either in the form of the sulphate or of wood ashes. While sulphate of potash has been most widely used, there is apparently little evidence that it is in any way superior to other forms. Muriate of potash, containing the equivalent of about 50 per cent of actual potash, the form probably most used in the apple and peach orchards of the North, has been little used in orange groves. Apparently those who have used this form have obtained uniformly good results. Kainit, or German potash salt,

which is a crude double salt of magnesium sulphate with calcium chloride, containing the equivalent of from 12 to 14 per cent of actual potash, is a form much used in Northern orchards and is promising for use in orange groves. Its very active effect in increasing the surface tension of the soil moisture and thus attracting water to the trees, might make it an excellent form to add in early spring to aid the plant in withstanding the spring drought, which is so frequently injurious to the orange tree, and sometimes fatal to the fruit crop. Growers not supplied with facilities for irrigation would, undoubtedly find it profitable to consider carefully points of this nature in fertilization. The noticeable effect of potash on the orange tree appears to be its aid in completing and maturing the wood. Apparently an insufficient amount of potash is shown by an excessive growth of weak, immature wood, which does not harden up as winter approaches and is liable to be injured by frost.

An abundance of potash, in the form of sulphate of potash or tobacco stems, is said by many growers to produce excessively sour fruit. That potash is very necessary in fruit production is shown by the fact that the fruit contains a large percentage of this element. An average of fifteen analyses of different varieties of Florida oranges shows 52.05 per cent to be about the usual amount of potash in the ash of the orange fruit. The ash in these fifteen analyses averaged 0.916 per cent, or less than 1 per cent of the total weight of the fruit.

PHOSPHORIC ACID.

Phosphoric acid, which is a very necessary element of fertilization on Florida orange lands, is mostly used in the form of dissolved boneblack, acidulated bone or phosphate rock, soft phosphate, raw bone, guano, etc. The immediate effect of phosphoric acid on the orange tree and fruit is little understood. Several intelligent growers claim to be able to recognize the effect of phosphorous starvation by the appearance of the new growth of leaves. If these, when they first push out or while they are still young and tender, present a slightly variegated appearance, mottled with light and dark green, it is claimed that they are suffering from lack of phosphorus, and that if a liberal application of some soluble phosphate is applied this appearance may be checked. If this can be shown to be true it will prove a valuable index to the available quantity of phosphoric acid in the soil. A similar appearance, may, however, appear in light cases of the so-called "frenching," a disease, or probably more properly a symptom of disease, which is not uncommon. Phosphorous starvation, it is true, may have some effect in inducing this disease.

LIME.

Lime, it is usually supposed, is present in sufficient quantities in most of our soils. It may be questioned, however, whether the common high pine land and scrub land, and indeed much of the flat woods and ham-

mock of the interior of Florida, might not be benefited by dressings of lime. From the superiority of oranges grown on soils which are known to be rich in lime it would seem that this is probably a very desirable and necessary element for the production of superior fruit. The fine, smooth-skinned, and deliciously flavored Indian and Halifax River oranges, with their characteristic aroma, are grown largely on soils rich in lime from shell mounds and coralline and coquina rock. The oranges produced in the noted Orange Bend Hammock, which are of distinctive quality, with delicate, rich aroma, and thin, smooth rind, are produced on a soil underlaid by a marl rich in lime. Lime soils are in many orange countries considered superior for orange growing. Dr. A. Stutzer, in his work on the Fertilization of Tropical Cultivated Plants, writes: "The orange and citron fruits desire a deep, porous, dry soil, rich in lime. If sufficient lime is not present the fruit will be thick-skinned and not have a fine aroma." It appears also that the effect of abundant lime is to hasten to some extent the time of ripening. Fruits grown on soils rich in lime appear to color and become suitable for shipping some-

FIG. 18.—Orange twigs showing effects of die-back.

what earlier than those grown on soils containing but little lime. To secure a good quality of fruit the regular application of lime may be found very desirable in many groves.

FERTILIZATION AS AFFECTING DISEASE.

Probably the most common cause of injury to orange trees is a lack of fertilization, yet it is not infrequent for disease to be induced or aggravated by excessive or improper fertilization. This may, indeed, be of much more importance than we are at present inclined to believe. One of the forms of die-back, a common and destructive disease of the orange, is quite evidently due to errors in fertilization. In other cases the disease appears to be caused by planting in improper soil.

DIE-BACK.

Die-back manifests itself by a number of striking characters. The foliage becomes very dark green, the vigorous growth remains angular and immature and frequently becomes strongly recurved, and the tips turn up slightly, forming S-shaped curves. In the spring trees affected

with this disease start out a very vigorous growth, which may continue for several months. Finally a reddish brown resinous substance exudes on the twigs, forming the so-called die-back stain, which is very characteristic, and they begin to die back. This death of tissues may include the entire new growth or only a portion of it. Under the bark of the young limbs gum pockets form and burst out, causing large, unsightly eruptions on the twigs, as shown in figure 18.

Larger gum pockets frequently form at the nodes, producing large swellings. If a tree is badly affected no fruit is formed; if moderately affected an abundance of fruit sets, but the larger portion of this turns to a lemon-yellow color before half grown, becomes stained by the

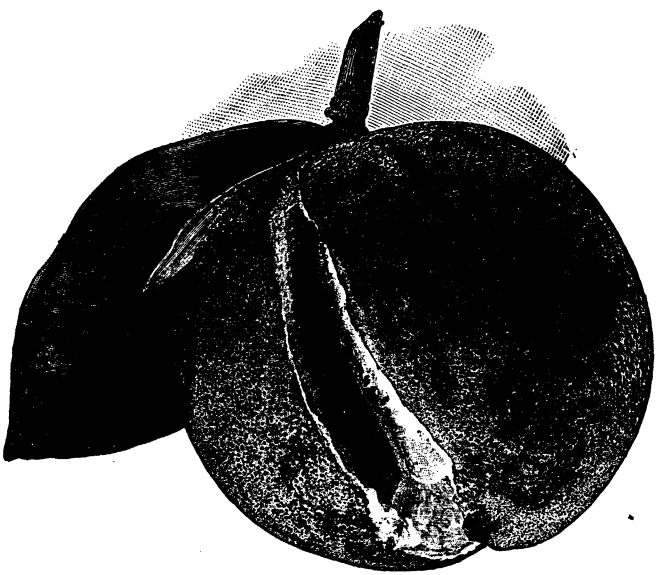

FIG. 19.—Orange fruit showing effects of die-back.

characteristic reddish exudations like that occurring on the branches, and prematurely falls. Fruit which hangs on the tree till nearly ripe is large and coarse and is frequently stained. It usually splits and falls before thoroughly ripe. The fruit on a slightly affected tree is very large and coarse, with very thick, rough rind. Much of it is rendered unsalable by the reddish die-back stain. It is very prone to split and fall before mature. A split fruit of this character, showing also the die-back stain, is illustrated in figure 19.

Frenching, or variegation of the foliage, frequently accompanies die-back and seems to be a symptom of the disease. The very dark green coloration which some growers believe to be an indication of a healthy grove, may, on the contrary, denote a condition verging on die-back. A lighter green would probably indicate better general health.

DIE-BACK A DISEASE OF INDIGESTION.

Die-back appears to be a form of indigestion, due to an overfed condition of the plant. It occurs apparently wherever excessive quantities of nitrogenous manures from organic sources are applied or become available to the plant. Trees near closets or barns or in barnyards almost invariably have die-back. When chickens roost on a tree for any length of time, so that the droppings fall on the soil beneath, the disease usually results. Many cases are known to the writer where it has apparently been caused by excessive applications of cotton-seed meal, blood and bone, barn manure, etc. Indeed, all organic manures in excessive quantities appear to give rise to it. If organic fertilizers are used they must therefore be applied with considerable caution to avoid an excess. No safe rule can be given as to the amount of manure that can be used with safety; this depends upon the size and condition of the tree, previous treatment, and soil conditions.

Whether the chemical manures, nitrate of soda and sulphate of ammonia, will produce the disease if used in excessive quantities, is questionable. We have not been able to learn of any instance where this has occurred. Several cases are known where nitrate of soda was used of sufficient strength to cause the leaves to fall without producing any sign of this disease. Frequently the method of cultivation has considerable to do in causing die-back, excessive cultivation appearing to aggravate it very greatly.

MAL-DI-GOMMA.

The much-dreaded disease of foot rot, or mal-di-gomma, is probably not produced primarily by improper methods of fertilization, but seems to be considerably affected by the use of fertilizers and methods of cultivation. Groves in which cow-penning[1] has been practiced to a considerable extent are frequently affected with foot rot. This is so generally the case as to admit little doubt that this practice has considerable to do in inducing the disease. The extensive application of organic manures appears also to aggravate the malady to some extent, and their use in infected groves should be discouraged.

INSECT DISEASES.

With regard to the effect of fertilization upon insects which infest the orange, it may be said that the question is little understood. A general impression exists among the growers of the State that groves fertilized with blood and bone or barn manure are more liable to be badly infested with injurious insects than those fertilized exclusively with chemical manures. This appears to be especially true in the case of the six-spotted mite (*Tetranychus 6-maculatus*) and the purple scale

[1] A term used to designate the practice of penning cattle in orange groves over night, using a movable pen, the position of which is changed every few days.

(*Mytilaspis citricola*); judging from observations on many groves which have been fertilized with chemical manures only, it certainly seems that this belief is well founded. There is some evidence that the muriate of potash aids to some extent in preventing the ravages of the rust mite. Dr. Smith, of the New Jersey Agricultural Experiment Station, has found nitrate of soda and kainit to be very active insecticidal fertilizers. These have not been used to any extent in fertilizing orange groves in Florida, and no data have been obtained as to their effect on orange insects. It is probable that they would prove more effective than sulphate of ammonia or sulphate and muriate of potash, and they should be thoroughly tested to determine their value as fertilizers for the orange.

SUMMARY.

Summarizing, it may be said:

(1) By a proper combination of the various elements used in fertilization one can undoubtedly largely govern the quality and flavor of the fruit.

(2) To obtain a fruit with thin rind, use nitrogen from inorganic sources in moderate quantities, with considerable potash and lime.

(3) To sweeten the fruit, use sulphate of ammonia in considerable abundance, decreasing the amount of potash.

(4) To render the fruit more acid, increase the amount of potash and use nitrogen from organic sources.

(5) If it is desired to increase the size of the fruit, as is sometimes the case, apply a comparatively heavy dressing of nitrogen in some organic form and slightly decrease the other elements. In the case of the tangerine and mandarin, where a larger size is usually desired, a heavy dressing of nitrogen fertilizers would favor this end, and is not objectionable unless carried to excess.

(6) Fertilization has an important bearing on diseases.

(7) Die-back, a serious malady, is in all probability the result of overfeeding with nitrogenous manures from organic sources. These manures if used at all should be applied with great caution.

(8) Foot rot, although not primarily due to improper methods of fertilization, is no doubt considerably influenced by this cause.

(9) Insect diseases are also apparently influenced by the use of fertilizers, organic manures rendering the trees more liable to injury from this source than chemical fertilizers.