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ORCHARD IRRIGATION IN BRITISH COLUMBIA

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EXPERIMENTAL FARMS SERVICE

Looking across Okanagan Lake toward the Penticton and Naramata benches. Most of the tree fruits in the Okanagan Valley are grown on benches such as this. Precipitation is so low that irrigation is required.

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Orchard Irrigation in British Columbia

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In most of the orchard areas in the southern interior of British Columbia, irrigation has been found to be necessary for the production of large crops of fruit of good quality. This is due to the fact that precipitation is inadequate. The total annual precipitation at each of a number of the fruit-growing centres averages approximately as follows:

	Inches
Creston	18.4
Kaslo	26.2
Nelson	28.1
Grand Forks	15.8
Oliver	9.1
Keremeos	9.8
Penticton	11.1
Kelowna	12.0
Vernon	15.6
Salmon Arm	19.1
Kamloops	10.2

Not only is the total annual precipitation of importance, but so also is the distribution of this precipitation throughout the year. In the southern interior of British Columbia, a somewhat higher proportion of it falls in the winter

FIG. 1.—Without irrigation, the semi-arid sections of southern British Columbia are suitable only for grazing, and usually very poor grazing at that.

(Photo by Joy Walker)

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months than in the summer months. The precipitation at Kelowna, for example, occurs usually in each month about as follows:

	Inches
January	1.2
February	0.9
March	0.7
April	0.6
May	0.9
June	1.1
July	0.7
August	0.8
September	1.1
October	1.1
November	1.2
December	1.7

FIG. 2.—With irrigation, the semi-arid areas can be made to blossom like the rose. *(Photo by Joy Walker)*

Tree Requirements for Water

Water is necessary to the plant in many ways. It is the medium through which the minerals in the soil are absorbed by the roots. It transports these minerals to all parts of the plant. It also transports the manufactured foods from the leaves to all parts of the plant. It is a necessary constituent of the protoplasm in every living cell. Without sufficient water, the leaves stop manufacturing foods and the plant stops growing and eventually dies.

The very fine root hairs that are responsible for the intake of nearly all of the water and nutrients from the soil, must be bathed in water continually or they will collapse and die. However, there must also be air dissolved in this water, or the root hairs will not function properly. This means that there must be both water and air present in the soil pores. Thus if the soil is allowed to remain saturated with water for too long a period, it becomes deficient in air and the plants suffer.

Almost all of the water taken in by the roots is eventually given off by the leaves. This process of evaporation from the leaves is called "transpiration". The rate of transpiration is greater in hot, dry, windy weather than in cool, moist, still weather. With any given leaf area, it is greater with some kinds of trees than with other kinds. With any one kind of tree, however, the amount of transpiration varies directly with the amount of leaf area. In other words, the bigger the tree the more water it needs; and the greater the leaf area per acre, the greater the water requirements per acre.

In the "leaf area per acre", we must include that belonging to the cover crop. It is true that by protecting the soil a cover crop will prevent some loss of water by evaporation from the soil surface. However, this loss is far more than offset by the transpiration of moisture from the leaves of the cover crop.

FIG. 3.—A cover crop uses more water from the soil than it saves. Of the cover crops in common use, the grass sods use less water than do alfalfa or sweet clover.

Under the climatic conditions encountered in the Northwestern States and in the southern interior of British Columbia, it has been estimated by investigators that in a mature apple orchard the trees and cover crop require around 12 to 14 inches of water annually for their own use. This of course takes care of the plant requirements only, and not of the wastage entailed in irrigation. As will be noted later in this bulletin, the water wasted is frequently greater than the water used by the plants.

Tree Roots

The location of the roots of the trees is very important in determining where the soil needs to be wetted in irrigating. Investigations of root growth in Okanagan orchards have revealed the following facts: (1) As the tree grows, the roots spread outward much more rapidly than do the limbs. With mature trees, the roots have met in the centres of the panels and have overlapped in almost every case. (2) The concentration of fibrous, absorbing rootlets tends to lessen somewhat with greater distance from the tree. This effect is not so pronounced with older trees. (3) The largest roots are those that spread horizontally from the trunk. They are usually found at depths of 12 to 24 inches in the soil. The greatest concentrations of fibrous tree roots are usually found at depths of 6 to 24 inches. This is therefore the depth at which trees draw on the soil for a large part of their water supply. (4) Under favourable soil conditions, the roots penetrate to depths of 8 feet and even greater. The deepest roots are usually situated directly under the tree, although in old orchards the whole soil mass has been found permeated with roots to a depth of 8 to 10 feet. (5) Where the subsoil is a mixture of clear sand and gravel, the roots seldom penetrate far into it. Neither do they penetrate far into the water-table in a seepage area. A true hardpan, of such a nature as to restrict root growth, is seldom encountered in British Columbia orchards. (6) The cover crop roots are usually concentrated in the upper foot of soil. An exception to this is alfalfa, the roots of which usually grow downward for several feet.

FIG. 4.—In a shallow soil, the roots of apple trees tend to be shallow, with no evidence of a tap root.

As long as temperature, nutrient, and moisture conditions are suitable, roots will grow at any time of the year. As each small root tip progresses through the soil new root hairs are formed just behind it; and a little farther back along the rootlet the oldest root hairs keep dying and the rootlet becomes suberized and brown. Root hairs are very small, and can barely be discerned with the naked eye. They are, however, one of the most important parts of the plant, for it is through them that the plant obtains most of its mineral nutrients and its water supply.

Soil Moisture

Water is present in the soil primarily in three forms: (1) In chemical union with the mineral and organic matter in the soil. This is called "water of hydration." It remains in the soil after drying in an oven at 212°F. (2) As a film around each particle, or as a collar between each pair of particles. This type of water moves through the soil very slowly. When the films become very thin in the process of drying, they are held so tightly by the soil particles that it is difficult for the roots to absorb any of the water. (3) As "interstitial" or "pore" water in the irregular spaces between the soil particles. When these spaces are filled with water, the soil is said to be "saturated." When a saturated soil is allowed to stand with free drainage below, it is acted on by gravity and some of the pore water drains away. This part of the water is therefore called "gravitational" or "free" water. The pore water that remains after drainage is completed is called "capillary" water. The gravitational water is free to move fairly rapidly through the soil, but under ordinary circumstances the capillary water moves only very slowly.

When a soil is watered by rainfall or by sprinkler irrigation, its whole surface is wetted. The free water applied to the surface enters the soil partly through the pull of gravity, and partly through the "capillary" pull of the soil, which acts in a similar manner to the pull of a lamp wick for oil. The water then passes downward through the soil pores, and continues to do so as long as it is applied at the surface. When the rainfall or irrigation stops, the excess water gradually drains away, and leaves the moisture content at what is called the "moisture-holding capacity." This is one of the two most important soil moisture points (the other being the wilting point, as noted below). Whenever excess water drains into the subsoil below, it carries away with it some of the soluble plant nutrients. This process is called "leaching."

When the soil is wetted from a furrow containing water the wetting occurs in a somewhat different manner from that just noted. Free water is usually found only directly below the furrow and for short distances on either side of it. As with sprinkler irrigation this free water drains away gradually after the irrigation is stopped. Almost all of the soil area between the furrows, however, is wetted by the "capillary" or wick-like pull of the soil, which can act sideways as well as up and down. As a result, the soil between the furrows contains very little if any free water when the irrigation is discontinued. Almost all of the leaching effect by the furrow method is therefore directly under the furrows. With a sandy soil, this leaching may still be very serious, resulting in the loss of a large part of the plant nutrients contained in the soil.

No matter how the soil is wetted, it cannot be wetted throughout to a point less than the moisture-holding capacity. If it is desired to wet a soil to a depth of four feet, then sufficient water must be applied to wet it to that depth to the moisture-holding capacity. If only half that much water is applied, what happens is that the soil is wetted to the moisture-holding capacity to a depth of two feet only.

The amount of water held by the soil at the moisture-holding capacity depends to a large extent on the texture of the soil. In other words, a soil made up of fine particles, such as silt or clay, holds more water than one made up of coarse particles such as sand or gravel. Sandy soils usually hold 10 to 20 per cent of water by weight, silt soils 20 to 30 per cent, and clay soils 30 to 40 per cent. These figures, of course, refer only to soils containing low amounts of organic matter. The humus in the soil may increase the moisture-holding capacity by over 100 per cent of its own weight. It should be noted, however, that most of the orchard soils in the interior of British Columbia are comparatively low in humus, so that its effect on the moisture-holding capacity is in most cases actually quite small.

The soil texture also affects the rate at which the soil absorbs water. Irrigation water enters a sandy soil readily, and passes down through it quickly. It enters a clay soil with difficulty, however, and passes through it very slowly. This is especially true if the soil has been packed by heavy implements or by cultivating when it is wet. In a clay soil, the capillary passages are usually too small to be of much practical use in carrying the water through the soil, and it must therefore move downward chiefly through cracks, worm holes and root holes. Organic matter serves a double purpose in the wetting of a clay soil: in the first place, it absorbs water from the surface of the soil or from the furrow very quickly; and in the second place, it helps to open the soil up and thus allow further passage of the water at a more rapid rate.

When water is applied uniformly over the surface of the soil, it travels downward at approximately the same rate at all points; but when it is applied in a furrow, it usually moves downward much more quickly below the furrow than between furrows. Lateral movement is usually most rapid at a depth somewhere between 6 and 18 inches. In a clay soil, the lateral movement between furrows may be almost as rapid as the downward movement beneath the furrow; but in a sandy soil, the downward movement is much the more rapid. In a deep clay soil, the water may spread across a 5- to 6-foot space with no loss of gravitational water into the subsoil beyond the area of the tree roots. In a sandy soil, however, furrows this far apart would induce excessive losses of water into the subsoil.

Once the soil has been wetted to the moisture-holding capacity it starts immediately to lose its water again. Some of it is removed by evaporatioin at the soil surface, some of it by absorption by the plant roots. Under orchard conditions most of the water is utilized by the plant roots. Drying is usually most rapid at the soil surface. Within the tree-root area in the soil, drying is most rapid where the fibrous roots are most concentrated, which is usually within the top two feet. The first water used by the roots is the "capillary" water; then the outer part of the "film" water is used. A point is finally reached where the soil holds the thin films of water so strongly that the plant roots cannot absorb water fast enough. When this point is reached, the plants start to wilt; and if water is not applied again soon, they will die. The moisture content of the soil at this point is called the "wilting point". As already noted, the wilting point and the moisture-holding capacity are the two most important moisture contents of a soil.

On hot summer afternoons, the leaves of some varieties of tree fruits may show signs of flagging a bit, even when there is still plenty of water in the soil. This should not be confused with the true wilting point. In the mornings, the leaves will stand up full and crisp again, and little if any harm will be done.

The wilting point of the soil is much higher with a heavy soil than it is with a light soil. It varies from below 2 per cent by weight with a sand to over 15 per cent by weight with a clay. It is much higher again in a peat or muck soil than it is in a clay soil.

That portion of the water in the soil that is available for plant use is the part held between the moisture-holding capacity and the wilting point. This part is called the "available" water. It varies from below 10 per cent by weight with a sandy soil to around 20 per cent with a clay soil. Humus in the soil can increase the available water content to percentages much higher than this, although (as already noted) its content is too low in most British Columbia orchards to have much effect in this regard.

The moisture content of the soil can also be expressed in terms of inches of water. Thus the "available" moisture varies from around 1½ inches of water per foot of soil with a sand to over 3 inches with a clay. It can thus be seen why the intervals between irrigations can safely be made longer with a heavy soil than with a light soil. Of even greater importance in its effect on the available water content is the depth of the soil. A heavy, deep soil may hold 15 inches of available water to a depth of 5 feet; but two feet of sandy soil underlaid by gravel may hold only about 3 inches of available water.

Irrigation should not be delayed until all of the available moisture in the soil is used up. As already noted the soil in an orchard dries out more rapidly in the top two feet than it does below that depth. When the moisture between the depths of 8 and 24 inches is approaching the wilting point, it is usually time to irrigate again, even though there is still plenty of water available lower down in the soil. It is true that the roots in the lower subsoil may still be able to absorb water more rapidly than it is transpired by the leaves, but the plants will not grow and produce quite so well as when all of their absorbing roots are kept well supplied with water.

There appears to be a prevailing opinion among growers that as the water near the surface of the soil is used up by plant roots, more water rises from the subsoil to take its place. It is true that when there is free water below, as in a water-table, it will rise fairly rapidly by capillary action for a short distance.

This rise is the more rapid in a sandy soil but will eventually go farther in a heavier soil. In most soils however the upward movement is too slow to be of much practical use over distances greater than two feet. When the distance to the water-table is greater than this, tree roots can usually obtain their water more readily by growing down toward the water-table than by the rise of water to them by capillarity.

In most of the orchards in the interior of British Columbia there is no permanent water-table close to the main root area. If there were the soil would not be as suitable for growing fruit trees as it is. Under normal conditions, then, there is a moist subsoil with little or no free water present and with drier soil nearer the surface; and under such conditions the upward movement of moisture into this drier soil is extremely slow. It is too slow, indeed, to be of any practical importance in its effect on the irrigating of tree fruits. This means, then, that for practical purposes all of the water that seeps down below the tree-root area can be considered wasted.

The water lost by seepage is of great importance in its effects on orchard operations. In the first place, it is waste water, and in most districts it cannot be spared. In the second place, it removes plant nutrients from the soil. And finally, it may cause a seepage condition or an alkali condition farther down the slope.

Methods of Applying Water

Irrigation water is applied to the soil by a number of different methods:

Furrow Method.—This is the method that is now most commonly used in the southern interior of British Columbia. The water is carried along in shallow furrows, and wets the soil from them. This method will be discussed in some detail below.

Sprinkler Method.—The water is applied by means of sprinklers. This method, which is already used in many British Columbia orchards, will be discussed below.

Flooding Method.—By this method, levees are erected at periodic distances and the water is allowed to flood the whole area between each pair of levees. It can be used to advantage only where the soil surface is uniform and the slope is gentle. Even then, it uses more water than does the furrow method, and seldom applies it as uniformly. In British Columbia, most of the orchard land is too variable or too steep to use this method.

Basin Method.—This is a modification of the flooding method. Levees are made down the centres of the tree rows in both directions, so that each tree rests in the centre of a basin. Water is carried down each panel in a furrow that runs through the successive basins. The lowest basin is filled to the required depth, the furrow above it is plugged, the next basin is then filled, and so on. This method is suitable only where the land is uniform and has only a slight slope. Under these conditions it gives efficient wetting of the soil. However, it involves considerable expense in the erecting of levees before each irrigation, and in levelling them again after each irrigation.

Porous Hose.—Porous canvas hoses are sometimes used for irrigation. They require that water be delivered under a small pressure. One difficulty with them is their tendency to deliver more water close to the tap than farther down. They are much too expensive for orchard use.

Subsurface Irrigation.—Porous pipes are placed beneath the ground. and water is forced through them under pressure. The method is much too expensive for orchard use.

Fluming

The most popular types of fluming in the past have been those of wood and of galvanized iron. Of these two, wood is cheaper but metal lasts longer and is much the more satisfactory. It is difficult to prevent considerable leakage from wooden flumes, which makes it harder to control the water in the furrows and at the same time causes wastage of water. In addition, wooden flumes cost more for annual upkeep. In spite of their lower initial cost, therefore, wooden flumes are not considered so satisfactory as metal flumes.

During the past few years, cement fluming has become popular in certain districts. When properly made, it has been giving just as good satisfaction as metal fluming. When poorly made, however, it has disintegrated and cracked, especially at the ends and in the collars. On the whole, cement fluming shows good promise for orchard use.

Transporting the water in head ditches instead of flumes is not at all satisfactory in orchards. There is too much loss of water by seepage, even in the heavier soils, and the water is too hard to control in the furrows.

In order to promote good control of the water in each furrow, it is advisable to have an opening in the flume for each furrow instead of one opening for two or more furrows. Each opening should be controlled by a gate, so constructed that leakage is reduced to a minimum. It is also advisable that the water be screened at the delivery point, in order to prevent plugging of the flume gates with debris. Plans for a screening box can be provided by District Agriculturists.

Furrow Construction

Grade.—The ideal grade of furrow is one that is on a gentle slope, barely steep enough to allow the water to flow easily to the lower end without the necessity of starting a big flow at the top and without any soil washing. A grade of 4 to 6 inches per 100 feet is usually satisfactory. In most orchards, it is of course difficult to attain this ideal. Where there is a steep slope, the best that can be done is to run the furrows at an angle along the face of the slope. This may mean running them diagonally across the tree rows. They should never be run straight down a steep slope, as this may cause a serious loss of soil by surface erosion.

Length.—Given a gentle slope, the furrows should be short enough that the water will reach the lower end within two hours. If the water takes too long to move down the furrows, the soil near the flume will be wetted long ahead of that lower down, and there will be excessive wastage of water into the subsoil below. Another reason for short furrows is the greater degree of control that can be exercised over the water. Short furrows also induce less soil erosion. The two-hour rule usually restricts the length of furrow to not more than 200 feet in a sandy soil, and not more than 400 feet in a heavier soil.

Distance Apart.—The furrows should not be so far apart that the soil beneath them has been wetted deep enough for too long a time before the moisture has spread across between them. Once the soil beneath the furrows has been wetted to the required depth, the water then seeps down into the subsoil and is lost. It is better, therefore, to have the furrows close enough together that the water spreads across between them before it penetrates the soil too deep below them.

The best way to determine how far apart the furrows should be placed is with a shovel. The following procedure is suggested: Run the water down a furrow for six hours. Close the water off, and dig a trench across the furrow to find how far down and how far out the water has spread. Fill the trench in, run the water for a further period, and dig another trench above the first one. Repeat this until the water has gone down far enough. In a deep soil, this will likely be four or five feet. In a shallow soil underlaid by gravel, it will be the top of the gravel, or at least not far into it. Note the total distance of lateral spread of the water. For best results, the furrows should be somewhat closer together than this. Since there is frequently a great deal of variation in the soil in any one orchard, tests like this should be made at several locations in the orchard. This procedure can also be used to help in determining how long to apply the water at each irrigation.

As already explained, in a sandy soil the downward movement of the water is much more rapid than the lateral movement, whereas in a clay soil the two are more nearly equal. This means that in a sandy soil the furrows must be made closer together than in a heavy soil. They must also be closer together in a shallow soil than in a deep soil, since in the shallow soil the losses of water into the subsoil will occur so much sooner. In a light, shallow soil they should be not more than 3½ feet apart, while in a deep heavy soil they can safely be spaced up to 5 or 6 feet apart.

FIG. 5.—In a sandy soil, the furrows need to be close together. In this orchard, there were 4 furrows in 15 feet. These furrows are somewhat deeper than necessary.

In planting a cover crop, it is desirable to keep the surface soil properly wetted until the young seedlings become established. For this purpose the usual spacing of the furrows may not be adequate. Some growers meet the situation by making twice as many furrows, then eliminating every other one once the cover crop is well established.

In a mature orchard, the roots of each tree meet and interlace with those of the surrounding trees. They are therefore able to make use of the moisture and nutrients in all of the soil areas; that is, they can if this soil is kept properly wetted. If any part of it is allowed to dry out too much during the season, the absorbing roots in that part are all killed off. Where the soil is not kept wetted, then, it can be looked upon as just so much waste soil. In order to keep the soil wetted, it is necessary to avoid any unduly wide spaces between the furrows. This holds true along the tree row and in the centre of the panel as well as elsewhere. Where the furrows are spaced only 3 or 4 feet apart, it is of course difficult to keep them to this distance along the tree row, especially where the trees are large; and in such a case one must be content not to utilize all of the soil. In a mature orchard, however, there is no excuse for allowing the furrows to be farther apart in the centre of the panel than elsewhere in the panel.

In a young orchard, it is usually not considered necessary to make furrows in the centre of each panel, except for the cover crop. A difficulty frequently encountered with young trees in an old orchard is that the furrows on either side of the tree row are too far apart to keep the restricted root areas properly wetted. In such a case, the furrows should be drawn in with a shovel or hoe to within 18 inches or so from the young tree.

Depth.—Advantages are claimed for both shallow and deep furrows. With shallow furrows, there is less loss of water by seepage into the subsoil, less caving in of the sides of the furrows, less earth thrown up and hence less mounding between furrows, less loss of soil by erosion, and less cutting of tree roots. With deep furrows, there is less loss of water by evaporation, less growth of the cover crop in the furrow, and less lopping of the cover crop into the furrow. Where the slope is fairly flat and uneven, deep furrows may be necessary to carry the water. As a general rule, however, shallow furrows are preferable. In a shallow, sandy soil the furrows should never be made deep.

Furrowers.—Various types of furrowers are used. The two most popular types are the shovel type and the double disk. Small ploughs are occasionally used, as also are various types of homemade furrowers.

In a well cultivated soil, containing no grass sods or gravel, it is easy to make good furrows; but in a soddy or gravelly soil it is much more difficult. The shovel type works quite well in a thoroughly-cultivated soil, but not so well as the double disk or plough in sod or gravel. In a heavy sod, the disk furrower needs to be well weighted down, and if possible kept at a constant depth with guide wheels or skids. A stiff, heavy tooth of the desired shape of the furrow is sometimes used with good effect in a grass sod. However, no implement will make a good job of furrowing in a heavy sod unless the sod has been well cultivated first. In any type of soil, it helps to leave the furrows cleaner and smoother if a heavy rounded drag is pulled behind the furrower in each furrow.

Most furrowers make only two furrows at once. When the land is thoroughly cultivated and well levelled off, a ditching machine that makes three or more furrows at once can sometimes be made to work satisfactorily. On uneven land, however, such a machine will make uneven furrows, that require a lot of hand cleaning. For general use, a two-furrow ditcher is the most satisfactory.

When To Make Furrows.—A procedure that is commonly used in orchards cultivated only once a year is to cultivate in the late fall, then make the furrows as late in the spring as possible before irrigation starts. By the time the furrows are made, the soil has had a chance to settle and become reasonably firm; and at the same time, growth of weeds in the bottom of the furrows is delayed as long as possible.

On side hills, it is not desirable either to cultivate or to re-make the furrows any oftener than necessary, because of the adverse effect on soil erosion. It has been found quite feasible in experimental work to leave the orchard without cultivation for several years, and simply to clean out the furrows with a ditcher once or twice a year. With a good slope, one cleaning a year (in the spring) has been found sufficient.

Furrow Irrigation

Length of Season.—When to start irrigating in the orchard depends primarily on the moisture content of the soil; in other words, it is advisable to start irrigating early enough in the season so that the soil will not become too dry by the time the first irrigation is completed. This time will vary with the weather, the size of the trees, and the kind of soil. A shallow, sandy soil needs irrigating earlier than a deep heavy soil. Under the weather conditions usually encountered in the southern interior of British Columbia, it is considered advisable to start irrigating a shallow sandy soil early in May and a deep heavy soil early in June.

The type of soil also affects the time when it is safe to *stop* irrigating for the year. With a deep heavy soil it is usually considered satisfactory if the last irrigation is finished toward the end of August. There should then be no need for a late fall irrigation. With a shallow sandy soil it is usually better to continue irrigating until the middle of September, unless heavy rains are encountered. By irrigating this late, it will only be in an exceptionally dry year that a late fall irrigation is needed. If irrigating is discontinued before the end of August, a sandy soil is much more likely to need a late fall application. Owing to the necessity of opening up the furrows again after the crop is off, it is usually considered desirable to avoid a late fall irrigation wherever possible.

The question is frequently asked as to whether stone fruits need irrigating after the crop has been picked. With all of the earlier stone fruits, including cherries, apricots, and all peaches except possibly the latest varieties in deep soil, they do. If the trees are allowed to dry out after picking, they will be far more subject to winter injury, there will be danger of a heavy drop of blossoms and young fruits the following spring, and the general health of the trees will be impaired. In general, then, stone fruits should be irrigated during the same period as apples and pears.

How Often To Irrigate.—Profitable orcharding requires that the soil be not allowed to become too dry nor to remain too wet. The question is, what is meant by "too dry" and "too wet"?

As the plant roots absorb the moisture in the soil, a point is finally reached where the plants wilt; hence this point is called the "wilting point". As this condition is approached in the soil, the plants begin to suffer in various ways, and production is adversely affected. In fact, some investigators have found harmful effects long before the wilting point is reached. Care should be taken, therefore, to avoid letting the soil moisture become so low as to cause the trees to wilt.

Various methods have been used for determining when the soil moisture is approaching the wilting point. Some of these involve the use of intricate instruments, and so are not suitable for growers' use. Some growers judge the moisture status by the appearance of the cover crop. In very shallow soils, this may in some cases prove fairly satisfactory; but as a general rule it is not reliable. The tree roots are usually deeper in the soil than the cover crop roots; and if the cover crop does have deep roots—as with alfalfa—the trees will suffer as soon as it does.

The most satisfactory routine method yet devised for telling when the soil is getting too dry is as follows: Dig a hole near a tree (say 6 to 10 feet away from the trunk), to a depth of about 15 or 18 inches. Scrape some soil from the side of the lower part of the hole, squeeze it tightly in the hand, and let the fingers fall apart again. If the soil holds together in a tight, wet ball there is no hurry to irrigate; but if it tends to fall apart and crumble, it is high time to irrigate. Such tests should be made at various points through the orchard. As is noted below, permanent "observation holes" have proved convenient as a source of soil for these tests.

It is not quite so easy to specify what is meant by "too wet". Plants can thrive in soil that is saturated with water, so long as sufficient air is dissolved in this water. With a sandy soil that has good drainage, there is never any danger from an excess of water, no matter how often the soil is irrigated. With a clay soil, however, or a soil that is subject to seepage, there is a real danger of inducing a deficiency of air in the soil. The only sure way of avoiding this danger is to let the soil dry out somewhat between irrigations. As the water in the soil is used up, air is drawn in to take its place. A mistake commonly made is to irrigate a silt or clay soil too heavily and too frequently early in the season.

During hot, dry weather the soil dries out much more quickly than in cold, wet weather. It is therefore reasonable to suppose that the irrigations should be more frequent in July and August than earlier and later. In some cases, growers are able to change their schedules to suit the weather; but in other cases this can not be conveniently done. In most cases, the safest procedure appears to be to establish a schedule for each type of soil in the orchard and to maintain this schedule throughout the irrigation season. The question arises as to whether the interval between irrigations should be long enough to avoid difficulties from too much water early in the season, or short enough to avoid difficulties from too little water in July and August. Experience has shown that as a general rule the latter danger is the greater. In other words, the best time to establish an irrigation schedule is during the hottest part of the season.

In any one orchard, there is frequently a great variation in the texture and depth of the soil. The question may arise as to whether a grower should attempt to establish a different schedule for every variation encountered. As a general rule, such a procedure is impracticable. However, it is sometimes possible—and advisable—to irrigate the sandy parts of the orchard more frequently than the silt or clay parts.

Irrigation investigations in the Okanagan have shown that no hard and fast rules can be drawn up for irrigating each soil type. Every grower must make his own tests to determine his own best schedule. During the heat of the summer, he should test his soil by the squeezing method before each irrigation. If he does this for a year or two, he should then have sufficient information to be able to establish a satisfactory schedule.

During 1944 and 1945, irrigation investigations were conducted in the Summerland district, and it was found that in mature orchards the shallow sandy soils required irrigating every 10 to 14 days, whereas the deep heavy soils lasted well over a month. This only held true, however, where the soil was well wetted at each irrigation. Where it was not well wetted—as frequently happened at the lower ends of the furrows—the trees sometimes wilted before the next irrigation came around. As can be inferred from this investigation, no schedule will work satisfactorily unless the soil is properly wetted at each irrigation. In previous experiments, some gravelly soils were found to require irrigating every seven days. Such soils could probably be handled better by the sprinkler method than by the furrow method of irrigation.

The schedule of water delivery to the growers in each district should be so arranged as to fit in with the requirements of those soils needing the most frequent irrigation. In most districts, each grower should receive his water either continuously or at least for one period every two weeks. In some districts, one period every week or ten days is desirable. This will take care of the shallow, sandy soils. The question then arises as to whether those growers with deep, heavy soils should operate on the same schedule. As already noted, they may not need to irrigate—and perhaps should not irrigate—more frequently than once a month. The grower can readily obviate this difficulty by irrigating a part of his place each time. For example, if he gets his water every week but only needs to irrigate once a month, then he need irrigate only one-quarter of his orchard each time. In such a case, it is far better to do this than to attempt to irrigate the whole orchard every week.

How Long To Irrigate Each Time.—As already noted, the soil cannot be wetted by irrigation to a moisture content lower than the moisture-holding capacity. It is therefore necessary to irrigate long enough to wet the soil to this degree. Since a heavy soil will hold more water than a light soil, and since water moves much more slowly through a heavy soil, it takes much longer to wet a heavy soil to the moisture holding capacity. It also takes longer to wet a deep soil than it does a shallow soil of the same kind.

In most irrigated orchards, the subsoil around the lower tree roots is kept continually moist by the small amounts of water lost below the furrows. These lower roots usually use very little water, and for practical purposes can be ignored. The main problem is to apply water long enough to wet the soil down to where it has remained comparatively wet between irrigations.

During an irrigation, the last part of the soil to be freshly wetted is usually the lower part of the dried out area midway between the furrows. Occasionally, it is near the surface of the soil between the furrows. The top three or four inches of soil can usually be ignored.

To determine when the soil has been properly wetted, a suitable method is to dig cross trenches periodically, as was suggested under "Distance Apart of Furrows". In fact, these two problems can in this way be solved together. If the furrows are placed close enough together, the losses of water by seepage below them will not have been great when the soil has been properly wetted between them. The newly applied water usually meets the subsoil water at a depth of four or five feet in a deep soil. The length of time required to accomplish this should be noted. Where the soil is underlaid by a mixture of clean sand and gravel, it is seldom necessary to irrigate for more than a foot into this mixture. The best time to conduct this test is during the hottest part of the season.

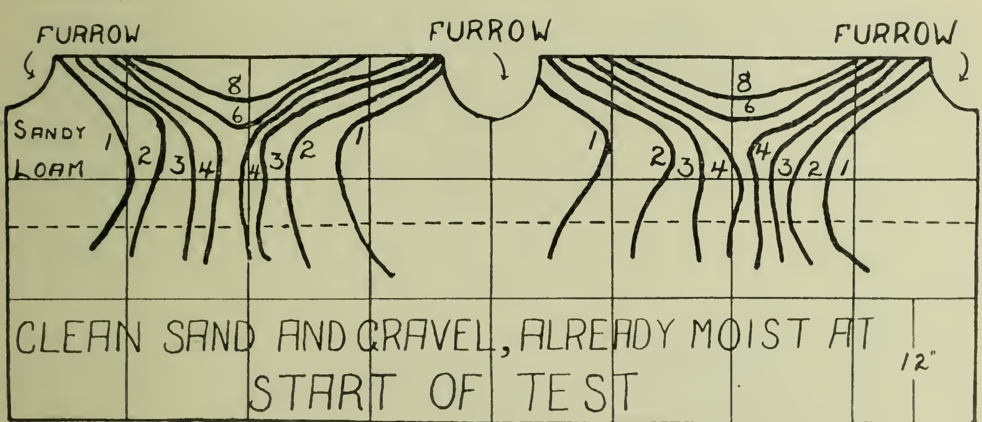

Fig. 6.—Spread of water from furrows in a shallow sandy loam, underlain by clean sand and gravel. Below a depth of 16 inches, the subsoil was still moist at the start of the test. The furrows were four feet apart. The curved lines represent the spread of freshly-applied water, and the figures represent the number of hours of irrigation.

Another way of telling when to stop irrigating is to use "observation holes". These and their use are explained more fully below.

It was suggested above that in many cases it is desirable to establish a uniform irrigation schedule for the whole season. If this is done, the soil will not be dried out so much before each irrigation early in the season as it will during the hot weather. It will therefore not require so much time to wet all of the soil early in the season Some growers have met this difficulty by asking their water bailiff for a somewhat lesser flow of water during May and June. If this is done, the length of time required should be investigated during May and June as well as during July and August. The flow of water can then be adjusted in accordance with the seasonal requirements.

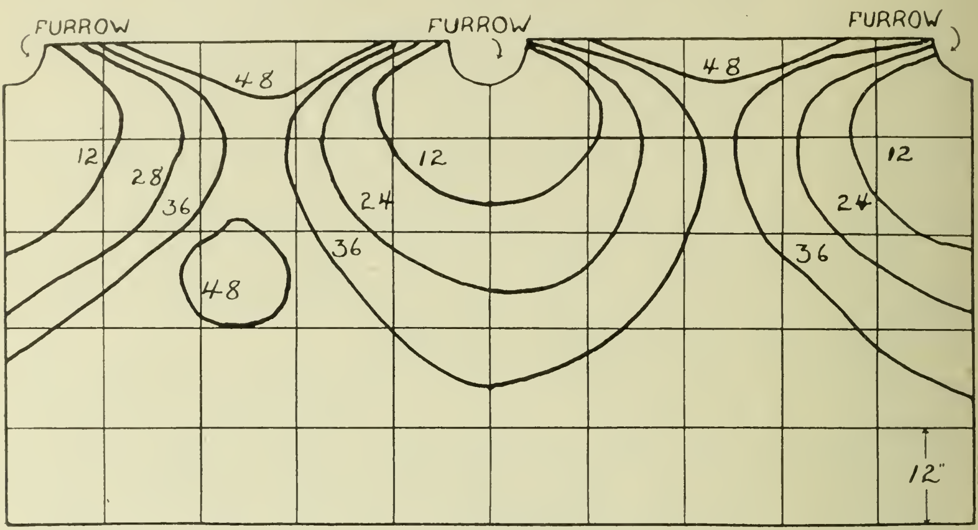

FIG. 7.—Spread of water from furrows in a deep silt loam soil. Below a depth of 36 inches, the subsoil was increasingly moist with greater depth when the test was started. Because of this, the rate of downward movement was more rapid after 24 hours than if the subsoil had all been dry. The furrows were five feet apart. The curved lines represent the spread of freshly-applied water, and the figures represent the number of hours of irrigation.

In deciding on a suitable length of time to run the water in each furrow, it is necessary to give consideration not only to soil moisture requirements but also to labour requirements. For example, it is more convenient to change the water at periods of 8, 12, 18, 24, 36 or 48 hours than at odd periods such as 10½, 16 or 31 hours. If it is found that the soil is well wetted in 10 hours, the water can more conveniently be changed every 12 hours; and 31 hours can similarly be extended to 36 hours. Most growers consider it inconvenient to change the water during the night, and even with sandy soils they do not use less than an eight-hour run. The time required to wet the soil properly varies from 6 hours or less with a shallow sand to 72 hours or more with a deep clay.

Tests conducted in a number of orchards have revealed gravelly spots where water is being lost below the furrows after a run of only 4 to 6 hours. A grower with a soil like this is up against a difficult proposition. Changing the water every 4 to 6 hours is most inconvenient. On the other hand, running it for 8 to 12 hours will not only double the amount of water used, but will also leach a high percentage of the nutrients out of the soil, and will induce seepage conditions lower down on the slope. Where water can be obtained under pressure, sprinkling would appear to be a more suitable method under such conditions.

In some orchards, there is a much wider space between the furrows in the tree row than between the tree rows. The question arises as to whether irrigation should be continued until this space is all wetted. If this is done, too much water will be applied all across the panel except in the tree row. If it is not done, a dry space will be left along the tree row and the soil there will not be utilized. This latter is usually the lesser evil. In other words, in deciding on when to stop irrigating, the wide furrow space along the tree row can be ignored. The best way of meeting this problem is to keep the furrow spaces as uniform as possible.

It was suggested above that the top three inches or so of soil between the furrows can usually be left dry without doing much harm. An exception is where a cover crop is being started. In such a case, the soil near the surface should be kept moist until the young plants are well established.

Growers with a heavy clay sometimes encounter the difficulty of a very slow rate of water absorption by the soil. This may be caused by any one of a number of factors: (1) The soil may be so heavy that the rate of absorption is naturally very slow anyway. In such a case the water moves down through cracks, worm holes and root holes rather than through the minute soil pores. (2) The soil may have been compacted by the use of heavy disks and other equipment, or by disking while it is too wet. (3) The organic-matter content of the surface soil may have become depleted. This condition may have been caused by excessive cultivation or by too much shade, both of which affect the growth of cover crops adversely. (4) There may be a small amount of black alkali in the soil. This causes a clay soil to become "puddled" and tight. For black alkali, gypsum should be applied at the rate of three tons per acre. For soil compaction, cultivate as little as possible. To open up the soil and increase its permeability to water, grow alfalfa or sweet clover for several years. Alfalfa roots penetrate the soil much better than do sweet clover roots.

Water Wastage.—Irrigation water is wasted in a number of ways. Although some of these ways have already been mentioned, it will be worth while here to summarize them:

(1) *Leaky flumes.*—Some growers lose far more water from their flumes than they realize. This is one source of water loss, however, that can usually be easily prevented. There can likewise be large losses from the use of head furrows instead of flumes.

(2) *Seepage.*—Water is lost into the subsoil in large quantities. The two main causes are furrows that are too long and irrigating too long. The losses are much greater in shallow sandy soils than in deeper or heavier soils. Seepage is serious not only because of the loss of water, but also because of the leaching away of the nutrients and the inducement of seepage conditions farther down the slope.

Pocket gopher holes likewise cause wastage of water; in fact, they are a general nuisance. Every effort should be made to keep these animals under control.

(3) *Tailings.*—Where the ground is almost flat, it is sometimes possible to dam up the lower end of each furrow and thus prevent the loss of water in tailings. This requires great care in the regulating of the water at the flume. The slope is such in most orchards, however, that damming does not help much. It is usually preferable to allow some water to run off the lower end of each furrow. If this is not done, it is difficult to wet the lower end properly. Thus some wastage is unavoidable. By care in the adjustment of the flume gates, however, the wastage can be minimized. It is usually advisable to inspect the ends of the furrows two or three times during the day, and to adjust the flume gates accordingly.

What to do with the tailings water is frequently a problem. Most growers carry it off in a bottom furrow at right angles to the others. In some cases, it can be used again in a lower part of the orchard. Every precaution should be taken to keep it off the roads.

Water Requirements.—As already noted, there are a number of factors that affect the amount of water required by an acre of trees. Of these factors, variations in texture or depth of soil have much less effect than have weather conditions and total leaf area per acre. A tree does not absorb any more water from a shallow sand than it does from a deep silt or clay; and were the tree requirements the only factor of importance, we should not have to apply any more water to the shallow sand. Actually, however, we do have to apply more. The reason is that there is so much more wastage of water in the shallow, sandy soils than there is in the deep, heavy soils. To some extent, the wastage can be avoided, by proper care in irrigation; but even with proper care, there will still be a much greater loss of water from the shallow, sandy soils when the furrow method of irrigation is used. The loss can of course be minimized by the use of sprinkler irrigation.

With so many factors affecting the requirements for water, it is difficult to tell a grower just how much water his orchard needs. The best that can be done is to quote some of the figures that have been obtained in irrigation experiments in the Okanagan Valley. In a shallow, sandy soil at the Dominion Experimental Substation at East Kelowna, medium-sized apple trees were found to require from 23 inches to 38 inches, the amount varying between these limits over a period of years. In a gravelly soil nearby, the extremes were 27 inches and 40 inches. In these two tests, care was taken to reduce water wastage to a minimum. At the Experimental Station at Summerland, the range with large apple trees in a loam soil of medium depth was from 24 to 31 inches.

The question may be asked, how does actual usage in the southern interior of British Columbia compare with the experimental results? Through the courtesy of officials of 19 of the Irrigation Districts, figures on water usage have been obtained up to 1943. Of the 19 districts, two districts have been using 18 inches or less in their orchard areas, three around 26 inches, nine 30 to 36 inches, one 42 inches, and four around 48 to 50 inches. In parts of at least two districts, the growers are supplied with well over 60 inches of water annually.

For the most part, these differences among districts can be attributed to soil differences. In other words, there is a general tendency for those districts containing a high proportion of light, shallow soils to use far more water than those with deep, heavy soils. It is, of course, possible that the excessive amounts of water used in some areas could be reduced by improved methods of irrigation.

The water supplies have now been improved in most districts to the point where actual shortages are seldom reported. In the two districts reporting the smallest water usage, there did not appear to be any dissatisfaction over an insufficiency of water. In both districts, most of the soil is deep and heavy.

Water Shortage.—Although it is true that most districts are now well supplied with water, some are not so fortunate. Serious shortages of water do occasionally occur toward the latter part of the season. Not only that, but there is always a chance of a breakdown in the water delivery services in any district at any time during the season. An emergency may therefore be encountered at any time, during which the orchards are likely to suffer from a lack of water.

The suggestions that may be offered for dealing with such a situation fall into two categories: first, lessening the requirements for water; and second, efficiency in the use of water. Both of these are important, and should receive equal attention by the grower.

The requirements for water can be lessened in several ways. As already noted, most of the water absorbed by the tree roots is evaporated or "transpired" through the leaves. In order to save water, therefore, it is a help to lessen the leaf area. This can be accomplished by summer pruning. Summer pruning is not ordinarily recommended (except for suckers and water sprouts), as it fails to give the stimulus to tree vigour that is provided by winter pruning. In an extreme emergency, however, it is well worth while. With mature trees, the following pruning can be done to advantage: (1) Remove suckers and water sprouts. (2) Remove all badly shaded limbs around the bottom. (3) If limbs are too thick in the top or are crowded together, open them up by removing limbs one inch or larger in diameter.

The question arises as to whether a heavy thinning of the fruit will relieve a water shortage. Since the leaves get most of the water, thinning the fruit will help very little. Removing 500 boxes of fruit per acre will save only about 1/10 acre inch of water. Thinning severely for this purpose is therefore not worth while.

As already noted, the cover crop uses up far more water than it saves. This is especially true of the broad-leaved types, such as alfalfa, sweet clover, and weeds. Midsummer cultivation is not ordinarilly recommended, as it induces erosion, invigorates the trees at the wrong time of year, and is an unnecessary expense. In a water shortage emergency, however, it may be advisable to cultivate. If the emergency continues, more than one cultivation may be necessary. It should be noted that the main benefit from cultivation is the elimination of the cover crop, rather than the maintenance of a dust mulch on the surface.

Efficiency in the use of water and prevention of wastage are closely linked together. The main causes of water wastage have already been discussed. If an insufficient supply of water is being received, every effort should be made to reduce wastage to a minimum. This involves stopping up the flume leaks, irrigating no longer than necessary to wet the soil, regulating the flow in each furrow so as to reduce the tailings to a minimum, etc.

When the water supply is not sufficient to keep all of the soil well wetted all of the time, the question arises as to just how the supply available can best be utilized. A common practice has been to flush each furrow to the bottom, then change the water. If the soil is shallow and sandy, the upper part of the furrow may receive sufficient water by this method, but the lower part will receive practically none. It is more than likely in most cases that a flushing out will merely wet the soil close to the furrow, and little of the water will ever reach the tree roots. A practice followed by some growers has been to irrigate every second furrow, trying to give them a fairly decent wetting each time. The tree roots should get a much higher proportion of the available water by this procedure. The soil adjacent to the unwetted furrows may not be utilized, but if the water shortage is severe this cannot be helped.

Observation Holes.—The periodic examination of the soil for its moisture content can be facilitated by the use of permanent observation holes[2]. These holes should be placed two-thirds to three-quarters of the way down the furrows, several of them being scattered around the orchard in the different soil types. Each hole should be placed midway between two furrows, and preferably within 6 to 8 feet of a tree in order to be out of the way of equipment. If there is an especially wide space between the two furrows on either side of the tree row, this space should not be used for locating the hole. The hole can be dug with a shovel or with a post-hole auger, down to a depth of four feet or more. If the soil is shallow and underlaid by a mixture of wash sand and gravel, less than four feet may prove satisfactory. A 12 $\times$ 12 inch cribbing (outside measurement), made of 1 x 6 inch rough lumber, should be fitted into the soil around the top of the hole, and covered snugly with a 12 $\times$ 12 inch lid. The location should be well staked so it will not be disturbed by orchard machinery.

So long as the observation hole is kept tightly covered, the moisture in the soil exposed around its sides is representative of that in the soil farther away from the holes. These holes are therefore very useful for determining the

2 The use of permanent observation holes was first suggested about 20 years ago by Dr. H. R. McLarty, Officer in Charge of the Dominion Laboratory of Plant Pathology at Summerland, B.C.

moisture status of the soil, both between irrigations and during irrigation. They are also useful in determining the depth of the feeding roots.

During the course of an irrigation, each observation hole can be examined periodically to determine when sufficient water has been applied. The advent of fresh moisture along the sides of a hole can be seen readily by the change of colour of the soil. As the water spreads out from the furrows, it usually meets across the space at a depth of 6 to 18 inches. After meeting, the wetting front spreads downwards fairly quickly, and upwards more slowly. When the newly wetted area merges into that already wet lower in the hole, it is time to stop the irrigation.

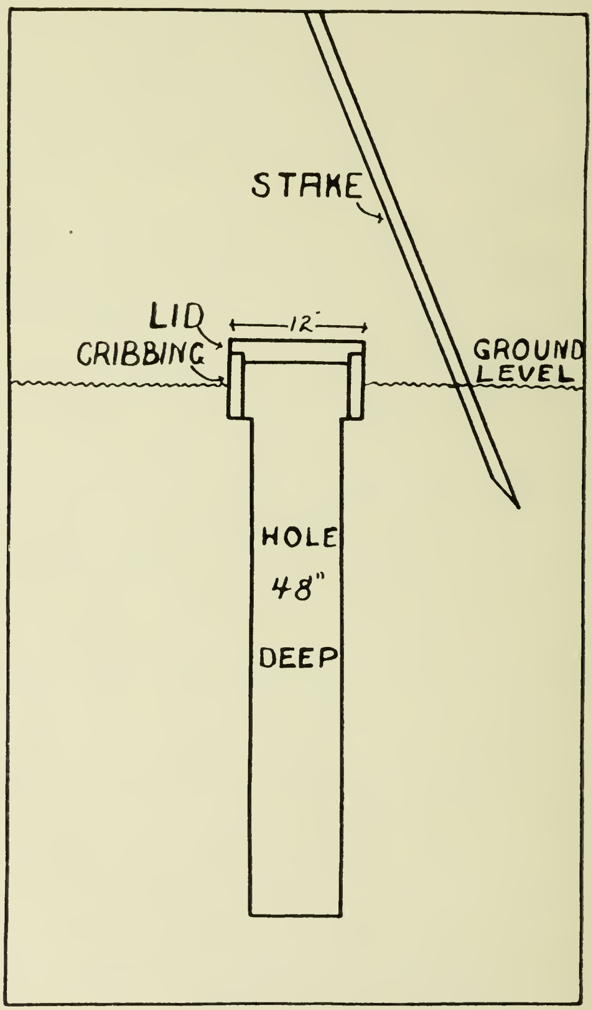

Fig. 8.—Diagram of an observation hole used for watching moisture changes in the soil. Note the wooden cribbing around the top. In a shallow soil the hole need not be so deep as this.

Between irrigations, the holes can be examined periodically (say every week), to determine to what extent the soil is drying. A sample of soil can be taken from the side of the hole, at a depth of 1 to 2 feet, and squeezed tightly in the hand. If the soil remains in a tight, sticky ball when the hand is opened, irrigation can safely be delayed for some time; but if it crumbles or falls apart, it is time to start irrigating. As already noted, the best time to use these examinations as a basis for establishing a uniform schedule for the season is during the hot weather.

A large number of growers have already made good use of observation holes. After they have been used systematically for a year or two, the desired information has usually been obtained and their use can be discontinued.

Sprinkler Irrigation

Most of the orchards in the interior of British Columbia are irrigated by the furrow method. Some growers, however, have been using the sprinkler method for several years, and more growers are planning on installing sprinkler systems. The question as to which is the better method is one that is to the fore at the present time.

A considerable fund of experience in the use of low sprinklers in orchards has been accumulated in British Columbia. In the Creston district, the majority of growers use the sprinkler method; and in an increasing number of orchards in the Okanagan Valley, sprinklers are now being used. Some growers have been enthusiastic users of sprinklers for 10 to 15 years.

Little actual experimental work has been done with sprinklers in British Columbia orchards. Several reports of experimental work, however, have been issued from various States in the U.S.A. It appears from a study of these reports that the last word on sprinkler irrigation has not yet been written. Both furrow irrigation and sprinkler irrigation, however, are conceded to have points in their favour. Based on both experiment and experience, these points may be summarized as follows:

In favour of furrow irrigation:

(1) It is much cheaper to deliver water to growers in flumes or ditches than in pipes under pressure. Few Irrigation Districts in British Columbia can now deliver water to their growers under pressure. Also, it is cheaper to distribute the water through the orchard in flumes than in pipes.

(2) There is a danger of wetting the leaves of the trees by the sprinkler method. This danger is of course much greater with overhead sprinklers than with undertree sprinklers. The wetting of the leaves has been claimed to cause damage in two ways—first, by washing some of the protective spray off the leaves and fruit; and second, by maintaining more humid conditions and thus giving encouragement to certain diseases and insect pests.

(3) Flume gates do not become plugged with trash in the water as readily as do sprinkler nozzles. In both cases, of course, the difficulty can be largely obviated by adequate screening of the water.

(4) Water in furrows is not blown aside by the wind, as is the spray from sprinklers.

(5) There is less evaporation of water from the surface of the soil, and no loss from spray evaporation.

In favour of sprinkler irrigation:

(1) Once the distribution system is established, the sprinkler method requires less labour to operate. This is due largely to the fact that it is not necessary to make and maintain furrows.

(2) The absence of furrows makes spraying, hauling, and other orchard operations easier to perform. Furthermore, the orchard area is not cut up with fluming.

(3) There is no wastage of water over the ends of the furrows. Loss of water into the subsoil is (under good management) much less than by the

furrow method. Largely because of these two factors, less water is required by the sprinkler method.

(4) Because of less loss of water into the subsoil, there is less danger of seepage difficulties in the orchards farther down the slope.

(5) There is much less soil erosion by the sprinkler method.

(6) It is easier to control or cure alkali in the soil. In the case of black alkali, gypsum (applied as a cure) can be washed down into the soil more quickly and uniformly; and in the case of white alkali the harmful mineral salts can be washed down into the subsoil more easily.

(7) It is easier to start and maintain cover crops by the sprinkler method.

Nothing has been said in the above about uniformity of coverage. Tests made at Kelowna and Summerland indicate that it is impossible to obtain absolutely uniform wetting of the soil by either method. Tests of sprinkler "efficiency" show that most of the sprinkler heads now in common use are highly inefficient, insofar as uniformity of coverage is concerned. With the butterfly types, for example, a much higher proportion of the water falls near the sprinkler than farther out. In order to obtain the most efficient coverage with this type of sprinkler, therefore, the wetted areas need to be overlapped. Good results have been obtained with an overlap of around 75 per cent. This means that sprinklers with a throw of 20 feet (making a 40-foot diameter) would be spaced 25 feet apart, and sprinklers with a throw of 30 feet would be spaced $37\frac{1}{2}$ feet apart. To put it the other way around, if the trees are 25 $\times$ 25 feet apart on the square, and a sprinkler is placed in the middle of each square, the sprinkler should be adjusted at the tap to throw a distance of around 20 feet.

Fig. 9.—The butterfly type of sprinkler has been the type most commonly used in British Columbia orchards. It is now being replaced by more efficient types.

Efficiency tests have been conducted not only on the butterfly types of sprinkler, but also on various other types that are in use in the U.S.A. Some of these show very good promise. Most of the more promising ones apply the water with a low trajectory and wet the soil reasonably uniformly. Further tests are being made of some of these sprinklers under orchard conditions.

The rate at which the nozzles deliver the water is important. For the most part, a slow rate of delivery (say 2 to 3 gallons per minute) is desirable for orchard use. This is especially true with heavy clay and with shallow sand. With heavy soils, too rapid an application of water results in surface runoff and erosion. This is far more likely to occur on a bare soil than on one with a heavy cover crop. The cover crop helps by breaking up the water drops, by adding organic matter and thus assisting in water penetration, by opening up the soil with its roots, and by preventing the surface flow of unabsorbed water. In shallow sandy soils the difficulty with a nozzle that delivers water rapidly is that the soil is wet too soon and the irrigator needs to change his sprinklers too frequently during both day and night. It is considered preferable to use sprinklers slow enough that they will not require moving more often than every 6 or 8 hours, even though this may mean purchasing a few more of them in order to handle the flow of water.

FIG. 10.—This is a revolving arm type of sprinkler that shows good promise for orchard use. It has a low trajectory and is adjustable in several respects.

A number of orchards in the southern Okanagan that have been irrigated with low sprinklers for 10 or more years have been examined for diseases. The trees grown included apples, pears, cherries, apricots, and peaches. In all orchards, the butterfly type of sprinkler was used, and in some cases the leaves and fruit were wetted during the irrigation to a height of eight feet or more. In spite of this, no more disease was found in the sprinkled orchards than in furrow-irrigated orchards. In fact, the trees were remarkably free from disease. A possible explanation is that the sprinklers were usually not used for longer than 12 hours in any one place. In spite of these observations, it is felt that a sprinkler with a low trajectory is to be preferred. Wetting the lower part of the tree might make it necessary to spray for scab or other diseases in some districts where such spraying is not now necessary.

The usual type of distribution system for sprinkler use in orchards has consisted of the following: (1) Water delivered by the Irrigation District, or obtained from a high flume, under pressure. A pressure of 20 pounds per square inch (with the sprinklers running) is usually sufficient for orchard use. This can be obtained with a head of 50 to 60 feet, if a large enough pipe is used to minimize friction losses. (2) A main pipe running either through the middle or along one side of the orchard. (3) Smaller lateral pipes running at right angles to the main pipe. These pipes have been spaced at varying distances. The greater the distance apart, the less is the total initial cost (including rubber hoses) but the longer and heavier is the hose that must be dragged around. A popular spacing of the lateral pipes is around 100 to 120 feet. All pipes are placed underground. (4) Risers at frequent distances along each lateral. A riser at every second tree row is very convenient. There should be a tap on every riser. (5) Sufficient garden hoses to handle the sprinklers. Each hose needs to be at least half as long as the laterals are spaced apart. If water is received continuously, two or three hoses are needed per acre. Proportionately more are needed when the water is received intermittently. (6) As many sprinklers as there are hoses, plus a few spares in case of plugging or breakage. (7) A stand for each sprinkler. A suitable height for the sprinkler head is usually 12 to 18 inches. Overhead sprinklers (above the trees) are definitely not suitable.

A few growers have combined their sprinkling systems with their stationary spray systems. A difficulty encountered has been that the pipes for delivering the spray need to be small enough to ensure rapid movement of the liquid and thus prevent settling out, and this pipe may be too small for delivery of the irrigation water. This difficulty has been obviated in one of two ways: first, the irrigation water has been delivered under high pressure; or second, two sets of main pipes have been used, and only the one set of lateral pipes. With a small main pipe for the spray, a large main pipe for the water, and a suitable system of valves, both irrigation and spraying can proceed at the same time in different parts of the orchard.

Considerable interest has recently been shown in the use of portable metal laterals. These are made of aluminum or other light material. Handy couplings are attached at the ends of each section, so the sections can be placed end to end quite easily. The chief advantage of the portable laterals is their cheapness. They take the place of both permanent laterals and rubber hoses.

Sufficient experimental work has not yet been done in British Columbia to justify definite recommendations on when to irrigate and how long to irrigate by the sprinkler method. There appears to be no reason for recommending different intervals between irrigations than those that have been found suitable by the furrow method. The best way to determine how long to run the sprinklers at one time is to use a shovel: run the sprinklers for say 6 hours, stop them and dig with a shovel to find out how far down the water has penetrated; run them for a further period, and repeat the process until sufficient water has been applied. Since most sprinklers apply the water somewhat unevenly, tests with the shovel should be made at various distances from the nozzles.

Sprinkler systems have not yet been investigated sufficiently in British Columbia to justify a recommendation for their general use in orchards. In certain cases, however, their possible disadvantages appear to be more than offset by the known disadvantages of the furrow method. In such cases, growers should give the sprinkler method their serious consideration. Examples of such cases are as follows: (1) Steep hillsides, where soil erosion may be serious by the furrow method. (2) Shallow soils, where water wastage into the subsoil may be serious by the furrow method. (3) Rolling land, where the mechanics of furrow irrigation are difficult. Too much levelling of the ground surface prior to planting is not advisable, as the infertile subsoil is thereby exposed. (4) Saline soils (white alkali), where sprinkling can wash the excess mineral salts out of the soil. (5) Districts where there is an insufficient supply of water for the furrow method.

Soil Erosion

Soil erosion occurs as a result of two agencies, namely wind and water. Of these, water is the cause of almost all of the erosion in the irrigated sections of British Columbia. The relationship between erosion and irrigation is therefore of the greatest importance. Mention of erosion has already been made several times in this bulletin.

The surface soil is the best soil. It contains the highest contents of organic matter, nitrogen, phosphate, and potash. It is not only the richest part of the soil in nutrients, but it is also in the best physical condition. It absorbs water more readily than does an exposed subsoil, and it erodes downhill less readily. Loss of this surface soil is therefore a very serious matter. This is especially true when the soil is shallow.

Although the irrigated orchard areas in British Columbia have only been under cultivation a comparatively short time, some of them have already been subjected to severe soil erosion. In most orchards the erosion has not yet caused serious damage; but in some orchards the original surface soil has been almost entirely removed after only 40 years or less of irrigation. This bodes ill for the future of the orchard lands. Every grower should do everything he can to save his soil for the use of future generations.

Experimental and observational data indicate that certain factors are important in their effects on water erosion of the surface soil. These factors are as follows:

(1) *Texture of soil.*—Fine sand and coarse silt soils usually erode the most easily, and clay and gravelly soils the least easily.

(2) *Organic-matter content.*—The higher the organic-matter content, the less easily does the soil erode.

(3) *Vegetative cover.*—A bare soil erodes much more readily than does one that has a vegetative cover. A cover crop helps to hold the soil partly because of the organic matter it supplies, but largely because of its mass of fibrous roots that permeate the soil. Of the various types of cover crop tested, the grass sods (such as couch grass, brome grass, Kentucky bluegrass and redtop) allow the least amount of erosion. Grass sods are now being recommended for hillside apple orchards in the Okanagan Valley.

(4) *Cultivation.*—Because it loosens up the soil, cultivation increases the amount of erosion. If cultivation is considered necessary once a year, it causes the least amount of erosion when done in the late fall. Cultivation in midsummer can be especially harmful from this viewpoint. In tests made at the Dominion Experimental Substation at East Kelowna, the erosion occurring during the first irrigation after a midsummer cultivation was greater than that occurring during all the rest of the irrigation season. Where it is necessary to open up the furrows during the irrigation season, this should, if possible, be done without cultivating.

(5) *Slope.*—The steeper the slope, the greater the erosion. So far as possible, cultivation should be done on the contour and furrows should be made with only a slight slope. This is not always possible where the orchard is on a steep slope; but in such a case the furrows should at least be run on the diagonal instead of straight downhill. On steeper slopes, it often pays to let weeds and grass grow in the furrows, in order to minimize the amount of erosion.

(6) *Method of Irrigation.*—More erosion is caused by irrigating immediately after a cultivation than by letting the ground stand for awhile first. The same holds true with making the furrows. More erosion is also caused by a heavy

FIG. 11.—This type of furrow erosion is frequently encountered. It bodes ill for the future of the soil.

FIG. 12.—Almost all of the surface soil has been eroded away on this hillside.

FIG. 13.—A serious case of soil erosion in an orchard. Such a condition reduces the value of the land markedly.

FIG. 14.—This is an example of what can happen when the furrow tailings accumulate.

head of water in the furrow than by a small head. If it is very difficult to get the water through to the far end of the furrow, the furrows should be shorter. Care should be taken in the disposal of the tailings. It frequently happens that the tailings accumulate and cut ditches or gullies along roadways or down sidehills.

Less erosion is caused by the sprinkling method of irrigation than by the furrow method. As already noted, it is urged that serious consideration be given to use of the sprinkler method wherever erosion is severe.

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