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REASONS FOR CULTIVATING THE SOIL.

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HOW WATER ENTERS THE SOIL.

Water is the most abundant substance found in living crops. Not only does it form by far the largest proportion of all fresh vegetable substance, but, on account of loss through evaporation from the leaves of growing plants and the necessity of replacing this loss, thirty or forty times more water is needed during the growing period of a crop than is contained in the crop when harvested. Plants require a large amount of water for their life and growth, and it is necessary that the supply should be abundant at all times. If the evaporation from the plant greatly exceeds the amount taken in through the roots, the leaves wilt and the plant suffers.[1]

Therefore one of the most important functions of the soil in its relation to crop production is the maintenance of a proper supply of water. Rain falls, on an average, in the humid portion of the United States for two or three days in succession, and is then followed by an interval of eight or ten days of fair weather. As plants are fixed in their relative positions in the earth, the soil, in order to supply them with water during the fair-weather period, has to offer such a resistance to the percolation of the rain that an adequate supply shall be held back. On account of this resistance, due to the friction which the rain encounters in the minute spaces between the soil grains through which it has to pass, the movement is very slow and only part of the water sinks below the reach of plants before the next rainfall occurs.

The resistance which soils, owing to their difference in texture, offer to the percolation of the rain varies greatly. Light, sandy soils maintain comparatively little moisture, because the spaces between the grains are comparatively large and there is relatively but little resistance to the flow of water, so that the rainfall moves down quite rapidly until there is only 5 or 10 per cent of moisture present in the soil. Strong clay soils, on the other hand, have very minute spaces for the water to move through, and consequently offer a very great

[1] This subject was treated quite fully in an article by Galloway and Woods on "Water as a factor in the growth of plants," in the Yearbook for 1894.

resistance to the percolation of the rain. These soils maintain, as a rule, from 15 to 20 per cent of their weight of water.

Different plants grow best with different amounts of water. For instance, the pasture grasses thrive on a soil which is too moist for Indian corn, or even for the largest and surest yield of wheat. Some classes of tobacco thrive well on soils which are very retentive of moisture, while other classes can only be grown with success on drier soils. We are not concerned in this article with the amount of moisture which different soils maintain or with the amount of moisture required by different kinds of plants. We must recognize, however, that it is not possible nor desirable to maintain the same amount of water in all soils, for if this were done there would not be the opportunity for diversity in agriculture which we have under existing conditions.

While water is maintained for a time in the soil, as already explained, it is liable to be lost to the growing crop by evaporation from the surface of the ground or by being used up by weeds. The end sought in plowing and cultivation is to control the water supply by removing weeds and leaving the surface of the soil covered with a loose, dry mulch to retard evaporation. Many of our crops require no subsequent cultivation after they are put into the ground. Wheat, oats, rye, clover, grass, forest trees, and, in general, such crops as cover and shade the ground are not, as a rule, cultivated during their period of growth. On the other hand, such crops as corn, tobacco, cotton, potatoes, and fruit trees require cultivation during their early growing period, although even with these crops cultivation ceases after they have attained considerable size, and is rarely practiced during the ripening period.

The principal object of plowing is to loosen up the soil, for four purposes: (1) To enable the soil to absorb the rainfall more quickly and more freely than it would in its undisturbed condition; (2) to maintain more of the rainfall near the roots of plants; (3) to admit fresh air to the roots of plants; (4) to enable the roots of the young or quickly growing plants to penetrate the soil more easily.

The principal objects of subsequent cultivation, whether with plow, cultivator, cotton sweep, harrow, hoe, or rake, are (1) to prevent loss of water by weeds and grass, which use up great quantities; (2) to keep the surface covered with a loose, dry mulch in order to prevent, so far as possible, loss of water by evaporation. Water is thus conserved for the use of crops, and the supply is more abundant and more uniform than it would have been without the cultivation.

A soil with a compact surface quickly dries out, and the water supply fluctuates rapidly and excessively, to the detriment of most crops during their growing period. Weeds and grass are generally to be excluded from the crop because they transpire great quantities of water which would otherwise have been at the disposal of the crop. Weeds are, however, occasionally of advantage to the crop, especially during the ripening period, because they help to dry out the soil and thus hasten the maturity of the crop.

Some of our crops, therefore, do not require cultivation, because they shade the ground and prevent evaporation and prevent grass and weeds from springing up and diminishing their supply of water, or because they are deeply rooted and can bring water up from considerable depths. Other crops can not protect their water supply in this way, and it must be artificially controlled by methods of cultivation.

In tropical countries where rain falls nearly every day, giving an abundant and uniform supply of moisture in the soil, crops require little or no cultivation, and only the larger weeds need be removed from the field. The rainfall is sufficient, both in amount and distribution, for the support of the weeds and an average crop.

PRINCIPLES OF PLOWING.

The common plow is essentially a wedge-shaped instrument, which is forced through the soil to loosen it. The topsoil is forced aside, thrown up, and usually turned over. This action loosens the soil by separating the soil grains. The loose soil occupies more space than the compact soil did, and a cubic foot of the former, therefore, contains more space for water to enter. Each separate space, however, is also larger and has less capillary action and a smaller power of drawing water to the surface. If the soil, by reason of its fine texture or wet condition, is lumpy after the plowing, the spaces in the soil will be of very uneven size, and it frequently happens that the surface of the ground is not left in a suitable condition to draw water up from below. If small seeds are sown on such a rough surface, they are liable to suffer for lack of moisture. It is customary, therefore, and very advisable in such cases, to harrow and roll the seed bed until all the larger lumps are broken down and the surface is left smooth and even, in order to insure a supply of moisture to the seed during the germinating period. However, soil which has thus been rolled will lose more water by evaporation than soil which has been simply harrowed. The evaporation of this moisture is an incident which it is not always possible or desirable to prevent. With some crops the surface may be harrowed after the seed has germinated. This is desirable when it can be done without injury to the crop, as it tends to retard evaporation.

There is one serious defect in the principle of the common plow which, upon some soils and with certain kinds of plowing, is liable to have very serious effects. If a field is plowed for many successive years to a depth of 6 or 8 inches the tendency each time is to compact the subsoil immediately below the plow, thus rendering it more impervious to water; that is, the plow in being dragged along plasters the subsoil just as a mason with his trowel would smooth out a layer of cement to make it as close and impervious to water as possible. This is undoubtedly an advantage to some soils, but, on the other hand, it is very injurious to many.

The injurious effect of this compact layer formed by the plowing is twofold. It makes it more difficult for the rainfall to be absorbed as

rapidly as it falls, and increases the danger of loss of water and injury to the soil by surface washing. Soils plowed at a depth of 3 or 4 inches, which is quite common in many parts of the country, would have a thin layer of loose material on the surface, with a compact subsoil below, into which water would descend rather slowly. With a rapid and excessive fall of rain, the light, loose topsoil is liable to be washed away by the excess of water, which can not descend into the subsoil as rapidly as it falls. This washing of the surface and erosion of fields into gullies occasion the abandonment of thousands of acres of land. The field will not wash so badly if it is not plowed, and, on the other hand, it will hardly wash at all if the cultivation is deeper and the subsoil left in a loose and absorbent condition. The deeper the cultivation, the greater the proportion of rainfall stored away and the less danger of the erosion of the surface soil and the less serious the defect of our common method of plowing. While there is less danger from washing, however, with deep cultivation, there is still a tendency toward the formation of a hardpan at whatever depth the land is plowed. No simple modification of the ordinary plow or of the subsoil plow will overcome this defect. It will require a change in the very principle of the implement. The plow should not cut through the soil, but break it apart so as neither to compact nor puddle it by being dragged along over the subsoil.

While all other farm implements and machinery have been improved, especially within the last fifty years, so that we are able now to harvest more crops than ever before and to handle our crops to better advantage, our common plow has not been essentially improved or modified in any important particular, except as to mechanical construction, since the days of the early Greeks and Romans. It would seem only necessary to call attention to this, the fundamental and simplest principle of agriculture, to have some new method devised of stirring the soil without compacting the subsoil.

The highest art of cultivation which has ever been practiced is that of trenching, so extensively employed in England and so earnestly advocated by the early English writers on agriculture. With a large class of lands there is no implement so effective for loosening and improving the soil conditions as the spade. The spade does not cut the soil from the subsoil as the plow does, but breaks it off, and there is little or no disturbance and no compacting whatever below that point. Everyone is familiar with the difference in the tilth of a garden which has been thoroughly spaded and of a field plowed in the ordinary way. This old method of trenching with a spade can not, of course, be used in the extensive systems of cultivation practiced in this country, and it is now used in England much less than it was years ago, but if this principle could be worked into a practical method of cultivation it would be of great benefit to agriculture.

PRINCIPLES OF SUBSOILING.

At the present time little is known definitely about the practical value of subsoiling. In certain localities it has or has not been found to be beneficial to crops. There is a wide difference of opinion upon this fundamental point. Fifteen or twenty years ago it was very generally advocated throughout the East by all of the agricultural journals. It was tried in a great variety of soils and under many conditions, and there is no doubt that in perhaps a majority of cases it showed no beneficial effects. This might have been expected, for no one method of cultivation can be equally valuable under the various conditions of soils, climate, and crops such as prevail over such a great extent of country. At present the subject is being prominently agitated in some of the Western States, particularly in the semiarid regions, and very favorable results are being reported through the local agricultural papers.

A few general principles only may be laid down for guidance in this matter. Subsoiling is rarely necessary in light, porous, sandy soils or in a climate where there are frequent light showers. It is not beneficial in heavy, wet soils, unless they are previously thoroughly underdrained. It is likely to be injurious if in the operation much of the subsoil is brought to the surface and incorporated in the surface soil, especially if the subsoil itself is in an unhealthy condition as regards drainage and contains poisonous matters which would be deleterious to plant growth. Poisonous matters frequently occur in subsoils as a result of improper aeration and the growth of certain minute organisms.

Subsoiling when properly done consists merely of breaking up the subsoil without bringing it to the surface or in any way incorporating it with the upper layer of the soil. In this respect it differs from deep plowing. The ideal subsoil plow consists merely of a tongue fashioned much like a common pick and hardly larger in its dimensions—slightly smaller at the point than in the rear, but as small in all its parts as is consistent with perfect rigidity and with the nature of the soil through which it is to be drawn. This usually follows an ordinary plow. It should be run at as great a depth as possible, the endeavor being to get it at least 16 or 18 inches below the surface. It is often advisable by this means to break up a hardpan formed, perhaps, by long-continued plowing at a uniform depth or existing as a natural formation below the surface.

Subsoiling is likely to be beneficial, under the prevailing climatic conditions east of the Mississippi River, in any soils of medium or of heavy texture, provided the land has fairly good drainage. In the semiarid region of the West it is likely to be very beneficial upon many classes of soils, especially where the rainfall occurs in heavy and infrequent showers and where it is necessary to increase the capacity of the soils to absorb water readily and rapidly.

Subsoiling, to be efficient, should be done a sufficient length of time before the crops are planted to insure to the soil a thorough soaking with rain; otherwise it may injure rather than improve the soil conditions for the first year. Subsoiling by stirring the land to an unusual depth favors the drying out of the soil, so that if it is not supplemented by a soaking rain before the seed is put in, the ground is drier than if the work had not been done. This fact has been shown to a notable extent in central and western Kansas during the present season and has been commented upon in Bulletins Nos. 1, 2, and 3 of this division.

There are few places in the West where this practice has been carried on long enough and under conditions necessary for beneficial effect. One such place, however, is at Geneva, Nebr., where subsoiling has been intelligently carried on for a number of years under nursery stock. The records of soil moisture which have been made at that place by this division through the present season show that on the average, through the months of June, July, and August, there was 10 per cent of moisture in the soil to a depth of 12 inches where ordinary methods of cultivation had been used, and 15 per cent where the land had been previously subsoiled. No crops were growing on the soils from which the records were kept in either case. This difference of 5 per cent in the amount of water, or 50 per cent increase over that in the uncultivated soil, is a very large amount and would doubtless have a very important effect upon the crop yield. This is confirmed by the actual yields on the two soils, as reported by Younger & Co., on whose farm the observations were made.

Further work will be done along these lines by this division, to establish these general principles. In the meantime great care and judgment should be exercised in deciding upon whether it is advisable to adopt this practice in every case.

CULTIVATION.

Cultivation as here used means the actual stirring of the surface after the crop is planted, either with a plow, cotton sweep, cultivator, harrow, hoe, or other implement. The object of cultivation is twofold—to destroy weeds and thus prevent the great drain which they make upon the soil moisture, and to loosen and pulverize the surface, leaving it as a fine mulch, the object of which is to prevent evaporation. The first of these objects needs no further comment here. As regards the second object of cultivation, the result to be attained is to have the surface covered with a fine, dry mulch before the dry spell sets in, so as to conserve the water in the soil during dry periods.

Cultivation is usually most effective in the early stages of the growth of crops, especially during the growth of the vegetative parts of the plant. It is usual to stir the surface after each rain. If another rain follows within a short time, this cultivation may do little or no good; but if a dry season follows, the cultivation may save the crop by its having diminished the evaporation. While cultivation does

not add water to the soil, as some claim, it prevents excessive loss, and thus maintains more water in the soil, which means about the same thing.

The kind of treatment adapted to the cultivation of different soils depends upon local conditions, climate, and the kind of crop. The object sought is the same in all cases, but the means of attaining it must be adapted to the local circumstances. As a rule, cultivation should be shallow, for two reasons, namely, to avoid disturbing the roots of the growing plants, and to avoid losing any more of the soil moisture than possible. A single cultivation after each rain is not necessarily enough, especially if a dry season is expected. The surface must be kept loose and dry, and this may require more than one cultivation, even if there has been no subsequent rain.

Few of our agricultural crops require cultivation after they have attained their vegetative growth, and a crop is frequently injured when cultivation is continued too long, because the soil is thus kept too wet, and the plants are not inclined to ripen as early as they should or to mature as large a yield of fruit or grain. Most of our grain crops will mature more seed if the ground is moderately dry during their ripening period.

UNDERDRAINAGE.

A soil containing too much water during the whole or a considerable part of the season should be underdrained to draw off the excessive amount of moisture. Most of our agricultural crops do better in a soil containing from 30 to 60 per cent of the amount of water which the soil would contain if saturated. With less water, crops suffer; with more, they suffer from lack of air around their roots. Wheat may be grown very successfully, and will attain a perfectly normal development in water culture with its roots entirely immersed in a nutritive solution, provided the water is supplied with air at frequent intervals, but it will not grow in a stagnant, saturated soil, not because there is too much water, but because there is too little air. A soil, therefore, which contains too much water contains too little air, and part of the water should be drawn off through ditches or tile drains.

Centuries ago the Romans used to overcome this trouble by planting the crop on very high ridges or beds, often 8 or 10 feet high and fully as wide. In this way alleys were provided at frequent intervals to carry off the surface water, and the greatest extent of surface was presented for the drying out of the soil, while the roots were kept at a considerable distance from the saturated subsoil. Storer states that some of these ridges are still to be found in localities in Europe. They are used to-day in a modified form in the cultivation of the sea-island cotton off the coast of South Carolina, but are being gradually given up as the practice of underdrainage is introduced, which is cheaper in the end and more effective.

Tile drainage is usually most effective in stiff clay soils and in low bottom lands, but it is occasionally beneficial in medium grades of

loam or even in light sandy soils. It is practiced to a considerable extent in the light sandy soil of the truck area of the Atlantic Seaboard, where the question of a few days in the time of ripening of the crop is an important factor.

IRRIGATION.

If the climatic conditions are such that it is impossible, with the most improved methods of plowing, subsoiling, and subsequent cultivation, to maintain a sufficient amount of moisture in the soil for the use of crops, it is then necessary to resort to irrigation or the artificial application of water to the soil. It is not the purpose here to enter into a discussion of the best methods of irrigation, but simply to discuss briefly the general principles of irrigation as practiced in maintaining proper conditions in the soil.

Our ideas of irrigation should not be confined to the arid regions. To be sure, irrigation is much more important there than elsewhere, for without artificial application of water crops could not be produced in many localities. In the humid portion of the United States, even in localities in Florida where they have from 60 to 70 inches of annual rainfall, irrigation is used successfully as a means of insuring the crop against drought due to the uneven distribution of the rainfall. It has been pointed out in several publications of this division that where the supply of water in different soils reaches a certain point, which differs according to the texture of the soil, crops suffer for lack of it. In the truck soils of the Atlantic Coast this minimum is approximately 4 per cent, while in the heavy limestone grass lands of Kentucky the pasture begins to dry up when the soils contain as much as 15 per cent of water.

Under our present modes of cultivation the farmer can do little for the crop during the time of actual drought. Ordinary cultivation is of comparatively little benefit during a prolonged dry season. Its most effective work is before the dry spell sets in. No matter what the value of the crop, and no matter how much this value is concentrated on small areas of land, there is practically but little to be done to save the crop. Irrigation should be used as an insurance against the loss of crops. A small pond fed by a windmill would often save a garden or a small area of a valuable crop from destruction or great injury during a dry season. A small portable farm engine, which would be available at other times for cutting feed, thrashing grain, and other farm purposes, could be used to drive an irrigating pump during the dry seasons. This would be particularly valuable for tobacco, truck, and other crops which are grown under a very intensive system of cultivation.

The object of all cultivation, in its broadest aspect, is to maintain, under existing climatic conditions, a uniform and adequate supply of water and air in soils adapted to different classes of plants. This is the object alike of plowing, subsoiling, cultivation, underdrainage, and irrigation; they are all processes to be used in maintaining suitable moisture conditions for the growth of crops.