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C. M. Sanford

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DRY-FARMING

By C. M. SANFORD,

Normal School, Plattsville, Wis.

By dry-farming we mean the profitable production of crops, without irrigation, on lands that have a yearly rainfall of less than twenty inches. The chief purpose of dry-farming is the reclamation for the use of man of the vast, unirrigable, semiarid areas of the world, which hitherto have been thought hopelessly barren.

The importance of dry-farming is apparent when we consider our extensive areas of arid and semi-arid lands. According to Professor Henry of the United States Weather Bureau, nearly one-half the United States receives an annual rainfall of twenty inches or less. These areas of slight rainfall include eighteen states. Mr. Widtsoe gives the dry-farming territory as more than one billion one hundred and ninety-one million acres. Surely these figures should provoke a lively interest in our subject.

A consideration of dry-farming must first include a review of our knowledge of soils. Soil is rock so pulverized and altered by weathering that it forms a foothold and nourishment for plants. It is composed of fine particles of clay, coarser particles called silt, and still larger grains called sand. These are not arranged with any regularity but are jumbled together in clusters. A sand grain will have many smaller soil grains clinging to it by the cementing power of clay. These in turn will be united into still more complex soil grains through the cementing power of lime. It is only when soil particles are united in this manner into large clusters that it has the desired tilth. This is why ploughing the ground when it is too wet is injurious, for it breaks up these complex soil grains.

The most important factor in giving soil its desired tilth is the presence of clay; therefore soils are classified according to the amount of clay that they contain. Unfortunately the soil of semiarid regions contains little or no clay: in other words it is a sandy loam. It is only after rock disintegration has become complete that we get clay, and moist conditions are necessary for complete rock decomposition. All crystalline rocks, volcanic rocks and shale when decomposed under moist conditions will produce abundant clay, but these same rocks when decomposed under arid conditions form sand almost exclusively. Fortunately the sand of arid sections, unlike the sand of humid regions, produces profitable crops whenever water is applied. The reason is that this sand under humid conditions would have produced clay, hence it possesses some of the properties of clay. Prospective dry-farmers need have little fear, then, if their soil is somewhat sandy.

A further difference between the soil of humid and arid regions is the absence of humus in the latter. The scarcity of plant life in deserts makes the reason apparent. Here again there is a redeeming feature since the humus in arid sections contains nearly four times more nitrogen than in sections where rainfall is abundant.

It frequently happens that the soil in semiarid or arid regions is much more productive than that of humid regions. The reason is that in the latter as the rainfall constantly drains through the soil into the standing ground water it subjects the soil to a perpetual soil wash. This water, as it leaches through the decayed vegetable matter on the surface, becomes charged with carbon dioxide and hence acquires great solvent power. It is then able, in the downward movement, to take up in solution many soil constituents and carry them away.

In arid areas, on the other hand, the rainfall moves downward only a few feet, very rarely reaching the standing ground water. After this rather short descent downward, it is brought back to the surface through the agency of plants and the capillarity of the soil. Since little of this water sinks far enough to unite with the ground water, there is practically no removal of the richer constituents from the soil. It is only natural then that the dry soils of the West should retain a much greater fertility than the water washed soils of the East.

In no other respect does the soil of humid and arid areas so differ as in the nature of the subsoil; for indeed arid districts may be said to have no true subsoil. In regions of abundant rainfall a great distinction usually exists between the subsoil and the soil. The soil is rich in humus and is modified by various cultural operations. The subsoil is an accumulation of fine clay, lime, and other soil ingredients, which through the action of heavy rainfalls, have leached from the overlying soils. It is so compact that roots find it very difficult to enter it, and in fact so little air can penetrate it that it remains unweathered and raw.

In arid regions, the slight rainfall in the form of a film of moisture about each soil grain, slowly moving downward, is unable to carry the clay and other soil particles. As a result the finer soil particles remain in the soil, instead of collecting beneath it as an impervious subsoil. A marked characteristic of the soil of arid districts is that the soil and subsoil are about equally porous. This permits the air to move freely to a great depth and so weather the soil as to render it suitable for plant nutrition. The roots can also penetrate deeply. The most important advantage is that it constitutes an ideal storage for water away from sunshine and winds.

Some semiarid districts, for example parts of the Dakotas, have a distinct subsoil. Instead of the heavy clay subsoil of humid districts we find

here a layer of hardpan. This is the clay, lime, and other soil ingredients leached from the overlying soil. This layer of hardpan is very undesirable from the standpoint of dry-farming as we shall see later. A further hindrance is gravel seams, for in breaking up the continuity of the soil mass, they prevent the upward movement of water stored in the soil depth. From the above it is seen that the prospective dry-farmer should avoid land having streaks of gravel or layers of hardpan; and that he should insist upon a soil of uniform structure to a depth of at least eight feet.

To appreciate the problems of dry-farming one should understand the root systems of plants, especially those that grow under arid conditions. The chief purpose of roots is to secure the water and mineral foods that are indispensable to plant growth. So true is this that the crop yield is usually proportionate to the development of the root system. Since roots are beneath the ground their extent and importance are usually overlooked. According to Schumacher the roots of a field of clover weigh as much as the clover of the year's crop, and the roots of an oat field equal 43 per cent of the weight of the oats and straw. Nobbe, a German investigator, found that the total length of all the roots of one wheat plant was 268 feet. King of Wisconsin found that a single corn plant produced 1452 feet of roots. Investigations have further shown that the roots of all plants extend much deeper than was formerly supposed. For example the roots of the small grains, oats, barley and wheat, penetrate to a depth of from four to ten feet. Only in irrigated districts do we find the root systems of plants very imperfectly developed. This is because the water is so lavishly supplied that the plants acquire the habit of feeding very near the surface. Upon this principle we are able to account for the fact that if a person begins watering his garden in the spring he must continue to do so throughout the season. Since roots are constantly in search of food and water they will likely best develop in arid regions, for it is here that they must go long distances to secure the needed water supply. The desirability of the loose, permeable subsoil is now apparent.

The dry-farmer, in addition to his knowledge of soils and the root systems of plants, must thoroughly acquaint himself with the annual rainfall over the area that he is to cultivate. All plants require a definite amount of water. This moisture is almost entirely taken from the soil. By growing plants in large pots containing weighed quantities of soil, it has been possible to determine the number of pounds of water necessary for the production of every pound of dry material.

During the eighties King by careful experiments found that in Wisconsin it required 385 pounds of water to produce one pound of oats, 464

pounds of water to produce one pound of barley, 271 pounds of water to produce one pound of corn and 576 pounds of water to produce a pound of clover. In regions where dry farming is likely to be practiced this amount would need to be greatly increased, since in these districts the atmosphere is very dry causing the evaporation to be great. In 1900 experiments were carried on in Utah under Widtsoe and Merrill with the following results: to mature one pound of wheat it required 1048 pounds of water, one pound of corn 589 pounds of water, and one pound of peas 1118 pounds of water. These figures show that far more moisture is required under the arid conditions of Utah, than under the humid conditions in Wisconsin. According to the above figures it requires 45,000 pounds of water to produce sixty pounds or one bushel of wheat. Furthermore, to produce a bushel of wheat it is necessary to produce a corresponding quantity of straw, which would require another 45,000 pounds or 90,000 pounds of water to produce both straw and wheat for one bushel.

Rainfall as we know is measured in inches, and an inch of rainfall on an acre of land weighs about 227,000 pounds. If all of this moisture could be so stored in the soil as to be available for plant production it is easy to see that a rainfall of one inch would produce two and one-half bushels of wheat per acre, and ten inches in rainfall would produce twenty-five bushels. It must be remembered however that by no known system of tillage can all the rainfall be conserved for plant production.

Over most of the semiarid regions the rainfall comes in the winter leaving the growing season rainless. The chief problem then in dry-farming is the storing in the soil of the rain that falls in any season until it is needed for plant growth. Already we have learned that soil is formed of particles ranging from the coarsest sand to the finest clay, and that these unite to form complex soil grains. These clusters of soil grains, while touching at many points, leave pore-space between them which often constitutes as high as 50 per cent of the total soil bulk. The importance of this pore-space cannot be overestimated as it permits the storage of moisture. After a rain these soil pores are filled with water but they cannot long so remain for the pull of gravity soon forces the water downward. In humid regions this water, which is known as gravitational water, sinks until it finally unites with the ground water and is thus lost to the soil. In semi-arid regions, on the other hand, as it moves downward it forms a film of moisture about each soil grain. This film is known as capillary water. It is the water that clings to a pebble that has been submerged in water, for there is an attraction between water and nearly all substances. The importance of this capillary water is not at first appreciated. But according to Professor J. A. Widtsoe in his excellent book on dry-farming, from which I have drawn freely, in one cubic inch of ordinary soil the total surface exposed by the soil grains is about twenty-five square feet, all of which

may be covered with this film. So important is the capillary water that according to King it often constitutes as high as 17 per cent of sandy loams.

While in humid regions the farmer is concerned primarily with conserving in the soil the elements of plant nutrition, in semiarid districts the chief concern is the conservation of moisture for plant growth. As the average soil has a capacity for water of about two and one-half inches per foot it follows that twenty-two and one-half inches of water can be stored in ten feet of soil. As this exceeds the rainfall of dry-farming areas the problem is to store up the rainfall of successive years until we have enough for a successful crop. To accomplish this the dry-farmer must as far as possible prevent the direct evaporation of water from the soil, for in arid regions it is by evaporation that most of the water is lost. Unfortunately in dry-farming territory the rate of evaporation is very great, often ranging from six to thirty times the precipitation. This is usually due to high temperature, abundant winds and low relative humidity.

There are two ways of decreasing the rate of evaporation. It is a known fact that water containing any mineral in solution, salt for example, will not evaporate as rapidly as will clear water. This being true the dry-farmer can so richly fertilize his lands that the soil water becoming burdened with mineral plant foods in solution will evaporate very slowly. The farmer under humid conditions has one reason for keeping his land rich, namely that it may afford ample plant nutrition; the farmer under arid conditions has an additional reason—to decrease evaporation and thus conserve soil moisture.

The second method of decreasing the rate of evaporation is to form a protective mulch, or thin layer of dry soil over the surface. The loss by evaporation occurs almost wholly at the surface. This surface evaporation may continue however, until the soil moisture is depleted to a depth of ten feet or more, for the water passes by capillary movement from the soil depth to the surface. A protective mulch decreases the rate of evaporation for the following reason: As soil water diminishes, its capillary movement is retarded. This drying of soil may continue until the capillary movement wholly ceases. That very dry soil and water even repel each other may be seen by driving along a road immediately after a slight rain. The wheels show that the dust is wetted only on the surface. Accordingly, a surface layer of very dry soil prevents the deeper soil water from reaching the surface, since it destroys the capillary movement of soil water. That there would be almost no evaporation from the surface of this dry mulch is apparent. Naturally a chief concern in dry-farming should be the forming and preserving of such a protective mulch.

The dry-farmer must use exceptionally good judgment and be persistent in the cultivation of his soils. Deep fall ploughing will permit the winter's precipitation to sink quickly into the soil depth. The seed should not be sown until enough moisture has been collected to insure a successful

crop, for it is only the dry-farmer who has his deep soil well stored with moisture that can go into the summer with any assurance. The most successful method of collecting the rainfall of successive years for a single crop is by clean fallowing, or resting the ground a season with proper cultivation. Ground clean fallowed and covered with a carefully prepared protective mulch is in the best possible condition to receive and retain moisture. King has shown that soil, clean fallowed, was able to carry over per square foot over nine pounds more moisture than adjoining land that was cropped. In clean fallowing weeds cannot be tolerated for the reason that it requires as much moisture to produce weeds as it does to produce a profitable crop.

Early spring cultivation is necessary if the stored soil water is to be retained. Since the rate of evaporation is greatest when the soil is wet, much of the needed moisture will escape if the farmer permits the early spring days to slip by before he begins spring cultivation. During the summer the most important time to cultivate is immediately after each rain. These summer rains quickly establish connection with the store of moisture in the soil, and are hence often a disadvantage rather than an advantage, as they quickly draw from the deeper soil the stored up moisture.

The writer in this short article has attempted only a very general discussion of dry-farming. The aim has been to give the general reader a clear statement of the more fundamental principles involved, which may be summed up as follows:—

If dry-farming is to succeed the farm must be located in a section having a rainfall of ten inches or more, and with the least possible wind movement. The soil should not contain layers of hardpan nor streaks of loose gravel, but must be uniform in texture to a depth of eight feet. This is necessary to promote the development of root systems and permit the storage of moisture away from sunshine and wind.

After the land has been cleared it should lie fallow for one year, in fact it should never be sown until sufficient moisture has been stored in the deep soil to insure a crop. Deep fall ploughing will permit the accumulation of the winter's precipitation. Early spring cultivation is necessary if the stored up soil moisture is to be retained. Throughout the entire growing season no pains should be spared in forming and preserving a protective mulch or a dry soil covering.

The dry-farmer should keep in mind that his is a system of agricultural practice that requires the constant application of skill and intelligence. But he may be assured that whenever correct methods are applied the results will be satisfactory.