II.—THE SOIL AS A WATER RESERVOIR

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Dr Gadd has spoken to you of the general mechanism of transpiration in the plant, and of the way in which this may be checked. In so doing he has indicated how it is sometimes possible to prevent the worst features of drought. It does not inevitably follow that even with these precautions deaths and dieback will be completely prevented, because the balance between transpiration and soil moisture supplies may still be unfavourable. My province is to describe to you briefly how water is distributed in the soil, and to consider what can be done to conserve it in the soil during drought periods.

The soil may be roughly likened to a sponge. You may soak a sponge in water and then remove it, when a certain amount of water will just drip off by gravitational force. Eventually the sponge will cease to drip, and will contain in its pores, water which will only be released when the forces acting against it are great enough to overcome those that are holding it in close association. As a matter of common experience we can squeeze water out of the sponge. Finally, we are left with an apparently dry sponge, but if we placed it in an oven, it would be possible to dry it out still further. In some such manner we can visualize the soil-water held by the porous soil structure. When saturated, a mass of soil will drip and lose gravitational

water; thereafter, capillary water is held by the soil pores of various sizes, and if water is still lost by evaporation, we arrive at a stage of apparently dry soil which, however, if baked in an oven, still loses hygroscopic water.

The conditions under which plants thrive lie between the two extremes just mentioned. A water-logged soil is of no use except in special cases. At ordinary ranges of soil-moisture the plant can exert sufficient pull on the moisture to gain adequate supplies, but the last remaining traces are so firmly held that they are not available to living vegetation.

Though it is convenient to classify soil-water thus, there are no sharply defined divisions between these three states. The essential picture I wish to draw is that of water held by certain forces, some of which the plant or direct evaporation can easily overcome, and some of which offer greater resistance, so that as the quantity of water diminishes, the forces required to make that water move are correspondingly increased. The provision of an adequate supply becomes a question of how large the immediate supplies are, how hard the root pull is, and how easily and rapidly water can move from one portion of the soil to another to replace supplies utilised by the plant.

In periods of drought we are mainly concerned with movement from lower to higher levels, and it is, I imagine, a common, and one may say natural impression that, blessed as we are normally with a relatively high rainfall, there should be adequate supplies in the sub-soil to draw on when the drought pinches. In this respect I must warn you definitely that experimental evidence provides very little support for such cheerful optimism. Once moisture has receded into the sub-soil it rarely comes back again sufficiently quickly to be a factor in plant growth. In times past, a great deal has been made of the capillary theory of water distribution and supply. It has been supposed that this capillary force will rapidly draw up water from the water table over large distances, whereas actually, the capillary forces are effective only for a few feet above the water table.[1] The best authenticated estimate of the distance is no greater than six feet.[2]

However unpalatable it may sound, on the average Ceylon tea estate with its irregular contours, this fact disposes completely of that attractive speculation about capillary water. The result is that the plant has either to go in search of water at depths where loss has been less severe, or has to depend upon the very slow efforts a soil makes to distribute its water content evenly within its mass. The normal procedure on our soils is for the top layer to dry out, and for this dry layer to extend downwards until the resistance to evaporation that this dry layer provides, minimises further loss. Unfortunately, the roots of tea are ordinarily restricted to this extending dry layer, and the tale of consequent disaster is plainly written this year in the districts of Balangoda and Uva.

What then can be done, particularly by cultivation processes, to minimise inevitable losses? Is it advisable to cultivate in a drought with a view to forming a soil mulch? The answer is definitely no. The aforetime much-desired mulch is valueless as a means of stopping loss of capillary-raised water, since the latter is non-existent at our distances from the water table. If it could be produced satisfactorily, it would form a non-heat conducting layer to protect lower layers from evaporation of such residual supplies as are present, but except in a minority of light soils nothing worthy of the name of mulch is producible. As you will see tomorrow, our soils are definitely clay soils containing in some cases 40 to 50 per cent. of fine clay particles, difficult to cultivate and bring into a state of fine tilth. The only effect of forking these soils in dry weather is to increase considerably the surface exposed to evaporation.

On the other hand, if a non-conducting mulch can be otherwise procured, some advantage will be gained. Such a mulch is provided by Grevillea droppings, and where these form a good carpet, the soil temperature is noticeably lowered and the surface soil protected. With the cognate question of competition between tea and shade trees I will deal later.

Passing from cultivation in the drought period to cultivation in general, the lesson emphasised by the last few months is that of deep cultivation. In the main, our soils cake and form a cap readily.

Cultivation ensures that the surface layer is in a suitable condition to receive, with a minimum of run-off, any rain that occurs. But there is a further effect; the roots of tea do no more vertical exploration than is required to meet their needs, and the bulk of the adventitious feeding roots are concentrated in the cultivated and manured layer. A policy of shallow forking, particularly a mere scraping in of manures, encourages a shallow feeding root surface which is easily affected by drought. The same conclusion has recently been arrived at in an exhaustive root survey of coffee.

One of the most striking sights our drought tour provided was that of manured and forked tea suffering badly, whilst adjoining tea, giving an equal or greater yield per acre, which had received no cultivation or manure since planting, escaped almost entirely. There was in this case a difference in age of the two plantations; one was five years old, the other fifteen. Whether age, or cultivation, or, as seems likely both were responsible for differences in root range, the argument for deep cultivation, when cultivation is resorted to, seems irresistible. Nobody I hope will infer that because of the localisation of roots by manuring and cultivation, these processes are to be dropped. It would be ludicrous to forego maintenance of crop for forty-nine years for the sake of possible immunity from deaths of tea bushes in the fiftieth.

An additional help in conserving moisture is suitable drainage. Many districts where drains are needed to discharge surplus water at one time of the year, would be only too glad to trap scattered moderate falls later on when drought threatens. Reverse slope drains offer advantages in both seasons. They are superior to silt-pits because of their greater capacity and because their percolation path is within the range of the feeding roots. A silt-pit at the bottom of an existing drain distributes its contents less evenly and less advantageously. The situations in which any attempt to waylay water would be detrimental are not nearly so extensive as may be imagined, and this compromise between lock-and-spill and open drains deserves a more extended trial both on this and other grounds.

On the question of competition between tea and shade trees a long view must be taken. We must credit their virtues over long periods against possible disadvantages occasionally. We have seen areas of tea under shade where drought casualties have been severe. These have generally been in hollows. Close by, with equally dense shade no such effect was visible. More curious still, on exposed and rocky slopes and towards the tops of ridges, particularly facing the prevailing wind, drought effects have been very little in evidence.

From the industry's point of view, it is satisfactory that severe droughts are infrequent, but from the point of view of scientific investigation it is a handicap. The most I can do is to invite you to relate your own experiences in the discussion period that will follow, meantime suggesting possible causes for this remarkable state of affairs.

Some exceedingly interesting work done in South of France [3] and at Poona, India, [4] has shown that there are important secondary sources of soil-moisture besides rain and dew. Experiments at these two centres have demonstrated that water can be absorbed from air on soil or rocky surfaces when the temperature of the air is much higher than the dew point, *i.e.*, under conditions which preclude dew formation. During a period of three months' dry weather at Montpelier, the average deposit of water in the top layers of soil reached a daily figure equivalent to a quarter-of-an-inch of precipitation. Assuming that this quantity was evenly distributed over a depth of nine inches, it would account for a difference of about 2·25 per cent. in moisture content.

All this may sound very surprising, but it is not only an experimental fact, but one of which practical use is made in vine and olive culture. In certain countries, olives are protected by building little walls of dry stone round them, and it is common knowledge that rocky slopes in vineyards suffer drought less than the average. In this country every one must have noticed the tenacious hold which lichens have on bare stone and boulder well removed from any absorbent soil, and yet they survive the keenest drought. On these lines we have a possible explanation of the behaviour of exposed and rocky

ridges which, as was previously mentioned, seemed at first sight to be behaving in an anomalous way.

We may sum up the soil aspect of this discussion on drought in tea in these words:—

Under our conditions of soil texture and ground contour, we have little to hope for from the tapping of sub-soil reserves, or from the protective influence of a soil mulch. We must depend largely on root exploration aided by deep cultivation, and stimulated by the competitive activities of suitable associated shade trees. We shall have to leave in the balance the question as to whether in specially severe circumstances the latter effect is overshadowed by the demands of the shade trees themselves. Cultivation in the dry period is to be avoided as leading to increased direct evaporation and root injury at a specially critical time, but there is everything to be said for having a reasonable tilth formed before the dry period sets in and persisting through that period. Whatever secondary sources of moisture are available can only be deposited in a well-aerated soil. Their effect is evanescent, and the moisture will have no time to diffuse any distance before the drying effect of the sun reasserts itself. Consequently, such secondary absorption water must be deposited in close contact with the roots for immediate use. There is no universal and unfailing panacea for averting drought, but attention to these points will minimise its effects, and, according to the severity of its incidence, may sometimes provide complete immunity.

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