Relation on Soil, Water, and Plants

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A. Moisture Retention by Soil:

The wetted soil particle has considerable attraction for it. Water is distributed over the surface of the particles and filled with pore systems. In relatively dry soils the moisture is distributed in films around the soil particles. The more closely attached to the soil particles the attraction more firmly. When a soil is moistened, the film of water around the particles becomes increasingly thickly until finally the cohesion of the water in the films are less than the gravitational force, and some water moves downward through the pore spaces. When the water films enlarges, the water is held less tightly and it becomes freer to move than before.

Fig. 1: Vertical column of soil as water reservoir

In one of a vertical column of immersed in a water reservoir as illustrated in figure 1 and evaporation is prevented from the other end, an equilibrium moisture distribution will be actually established throughout the column. If the soil moisture throughout in moisture-retaining characteristics, a study of the soil will show that the moisture content decreases with increasing distance from the free water table. The rise of water up the soil column and the final distribution of water in the column indicate that there exists an attraction between soil amount of energy would be expended. It is apparent that would be required to remove any of the moisture from the column. This work might be provided by suction, centrifugal force, heat, or other means.

B. Soil Moisture Curve and Moisture Expressions:

The method of determining soil moisture to bring soil samples into laboratory and to determine the percentage moisture content. This results the soil, but it does not give the availability of this water to plants. Recently, the procedure such as tensionmeters or gypsum blocks which give directly the tension on soil moisture, indicate the approximate availability of soil moisture but do not measure the quantities of water involved. And so, both methods are used concurrently to draw a moisture curve to solve the problem, such as shown in figure 2.
Fig 2: Moisture characteristics curves for two common soil of the western United States showing the range and unavailable Moisture (Redrawn from S.A. Taylor, Farm and Home, 1951)

After the moisture can be employed for field measurements, the values obtained, either tension or percentage figures, can located on the curve to give a complete picture of the moisture status of the soil.

The following sample are given for calculating soil moisture percentage

\[ P_w = \frac{W_m}{W_s} \times 100 \]

\( P_w \): per cent moisture in soil on dry weight basis
\( W_m \): weight of water
\( W_s \): weight of soil on a water free basis
\( W_w \): weight of wet soil
\( W_s = W_w - W_m \)

\[ P_v = \frac{d_w d_b}{d_w} = P_v \]

\( d_w \): density of water
\( d_b \): bulk density of soil

\( P_v \): moisture of soil in terms of percentage of total soil volume

C. Soil and water Relation:

After a heavy irrigation, we, analyzing the soil, may get the following points:
Fig 3 Relation between P.W.P., field capacity, range of readily available moisture, drainage vapor pressure, and moisture content of soil.

1. Immediately following or during irrigation, the soil is raised to a point below saturation, corresponding to point A in the Figure 3. At point A, the soil pores are about 80% filled, and the soil contains the maximum amount of water that it will retain if there is an aquiclude (or confining layer) below. Otherwise, the soil infiltrates or percolates into the drier soil layer.

The vapor pressure of free water is expressed at point (a), in the right hand figure, but that the left hand figure cannot be measurable.

Owing to the gravitational, the water of A point will move downward unless there is an impeded drainage.

2. As loosely held moisture drains from the soil, a point is soon reached beyond which free drainage is slow, but the moisture conductivity remains measurably greater than zero, as shown on the curve. According to Briggs, the gravitational water is from A to B. The amount of water in the soil in the vicinity of B is known as field capacity. If there are no plants present and evaporation is negligible, the moisture stress content would be slowly reduced, as shown by the B-E part of the curve. The vapor pressure is still 99.8% that of free water, as represented by point(b). If there is a growing crop on the soil, the field capacity will be reached somewhat sooner because of transpiration.

3. The plants will continue to reduce the water in the soil until the permanent wilt point at last, C, is reached along some such curve as B-D. At the P.W.P, the
vapor pressure of the soil moisture percentage is still about 98% that of free water, as represented by point (c). The energy required to remove a unit mass of water increases quickly and but little additional moisture is removed by plants, as shown by the curve CD. At the same time from P, W, P, point downward, the vapor pressure decreases rapidly with small water losses as shown (dc) on the right hand curve.

D. Soil, Water and Plants Relations:

There is no general agreement on how water enters into a plant and passes through the root system. Plants seem to absorb water principally through the terminal portions of root system. Root hairs move through small soil capillaries, contacting and absorbing water. Root hairs are small and under good conditions they will grow rapidly. Dittmer reported that, on an average, in excess of 100,000,000 root hairs were formed daily on a winter rye plant during periods of rapid growth.

The following categories are commonly used to classify the forces involved in the entry of water into plants: 1. osmotic, 2. imbibitional, 3. metabolic and 4. transpirational pull.

This may be regarded as intensity factors in the entry of water. The total amount of water entering a plant during any given time is dependent on the net water moving forces and the total area of effective root surfaces.

The principal force involved in water absorption is the osmotic pressure. It occurs when the concentration outside the cell is larger than the inside. A small plant root in intimate contact with the soil forms a coordinated system with continual movement of moisture in or out of the plant toward the point of the greatest produced by different concentration. If the osmotic pressure of the root cells smaller than the moisture stresses in the soil water moves inward, otherwise, it moves outward. Under somewhat unusual conditions, moisture stress in the soil may become sufficiently great to draw moisture out of plant roots.

Because of the imbibitional properties, it is known that hydrophilic colloids in plants play an important role in the absorption of water. Though there is some evidence to indicate that movement of water in plants may take place as a result of metabolic activity, it is of minor importance in comparison to the osmotic effects.

Kramer has found that the rate of water entry into the roots closely follows changes in the rate of transpiration. The total suction force exists in plant root for soil water varies somewhat for different plants and different soil and different climatic conditions. It is assumed that the plants permanently wilt at about 15 atmospheres of the soil moisture pressure. It is because the plants are no longer able to draw any appreciable quantities of water from the soil. But before death resulted, suction forces have been recorded as 60 atmospheres for some plants.
Fig. 4. Absorption and transpiration rates in Sunflowers. (Redrawn from Kramer, Am. J. Botany. 1937)

Wilting often occurs at much higher moisture level (and lower stress) than P. W. P. Any part of the plant may wilt when the transpiration rate exceeds the rate at which the water can be replaced. During periods of low humidity, high temperatures, and high wind velocity, the desiccating power of the air is high, and many plants with large leaf surface, such as corn and sugar beets, may show wilting even though the soil is comparatively moist. The daily variations in transpiration and absorption of water are illustrated in Figure 4 taken transpiration, we may find that during a hot summer day, water loss by transpiration exceeded water entry with the reverse relation taking place at night.

E. Water Availability in Soil:

Soil water must not be pure, it always dissolves various materials from soil, such as the plant cell sap possesses a definite osmotic pressure due to dissolved ions.

Magistad and Reitemeier reported that the osmotic pressure of moisture in normal productive soil under field conditions are usually between 1 and 2 atmospheres may be found. In some cases, especially in sandy soils, heavy applications of fertilizers have greatly increased the osmotic pressure of the soil solutions.

F. Range of Available Moisture:

Field capacity is the maximum amount of water that a well-drained soil can retain and the P. W. P. represents about the lowest limit to which moisture is reduced by growing crops, so, the range of available water in a soil is bounded by these two limits. Then, the total storage capacity for available water can be got by subtracting the wilting percentage from the field capacity.
G. Optimum Moisture Level:

The storage range from field capacity to wilting percentage of relatively available water has been widely discussed. Veimeyer and Hendrichson reported that water over the entire range from field capacity to near the wilting point is equally available. There are some reports on the studies that the growth and quality of apples and pears, grapes, peaches, prunes, walnuts and cotton were not affected by the moisture content of the soil unless it felt to wilting point and remained there for some days. It has been also reported that the seeds of many species of plants germinate equally well over the entire range of moisture from wilting percentage to field capacity, but the celery seed was an exception, it germinated only in the higher range of soil moisture.

Many studies have shown that water is not equally available over the entire range down to the wilting percentage. Magness reported that in Maryland the growth rate of apples was reduced when the driest part of the root zone approached the wilting percentage, even though much of the root zone was considerably more moist. Lewis also reported that in Oregon the rate of pears growth was retarded when the soil moisture was reduced to 70% of the available moisture.

The optimum level of moisture for plants growth is greatly applied on irrigation agriculture. That is because it is basic in determining the best time for irrigation. Although the problem of optimum soil moisture for plant growth is not completely solved, many of the plants of apparent disagreement are of little significance in irrigation agriculture.

H. Water Requirements of Crop Plants:

The "transpiration ratio" has been expressed on relative water requirement of different crops. It may be defined as the number of pounds of water required to produce each pound of dry matter exclusive of roots, and often termed the "water requirement of crops or the water cost of dry matter."

Through many tests, the values obtained varied from 200 to 1000. Such data have only a very limited value, however, because the water requirements of plants fluctuate widely with changes in such factors as intensity of light, air humidity, and velocity, temperature, available supply of moisture, and the supply of available plant nutrients.

In the field management of crops, other characteristic may be more important than the over-all ratio of water required to produce dry matter. There is a test on transpiration in alfalfa compared with sugar beets. Yet in the field, alfalfa can give a moderate production with limited irrigation, however, under the same conditions, the sugar beets fail completely. Similar tests could be made in terms of the survival of corn and sorghum under drought conditions. This results that it is important to know something of the total amount of water needed, the stage of plant growth at which adverse moisture conditions are most critical, and the ability of crops to adjust to adverse conditions associated with high moisture stress.
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