SOIL TYPE AND SOIL CONDITION EFFECTS UPON VALUE OF WATER APPLIED FOR CROP PRODUCTION

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Plant growth is limited over much of the earth's surface by either too much or too little water in the soil. Much of the water research in agriculture has been aimed at controlling the amounts of water present in the soil during given times of the year. In order to accomplish this, a better and more full understanding of soil-water relations is necessary. The understanding of these relations leads us to look at several conditions which affect the amounts of available water in the soil and its value in crop production. Among these are permeability of the soil, texture of the soil, structure of the soil, depth of the soil, and fertility of the soil - either native or added.

Permeability of the soil to water is essential if the root zone of the plant is to be supplied with water necessary for crop production. Permeability has been shown by Bodman (1) to follow a pattern of decrease upon wetting, then increase with additions of water, and followed by a slow decrease with further water additions. The overall decrease in water permeability of the soil was attributed to salt removal by the water and the subsequent dispersion, and rearrangement of the soil particles. Further work by Christiansen (2) and Greacen and Huon (3) showed that the increase in permeability at stage two was partly the result of removal of air entrapped upon wetting by water passing through the soil. This resulted in freeing pore space for the movement of water which had been blocked with air and gave increased permeability. The decrease in permeability was caused partly by increase in volume of the soil aggregates which is accompanied by a decrease in size of large pores. Also, Allison has shown that microorganism growth can restrict permeability by clogging pores of the soil. Other factors will affect permeability but it will suffice for us to say that permeability of the soil profile must be unrestricted if an adequate supply of water is to enter the root zone to be effective in crop production.

Among these other factors, affecting both permeability and amounts of available moisture retained by the soil, will be both texture and structure of the soil. Coarse textured, very sandy, soils usually are rapid in permeability to water having rates of water movement, called hydraulic conductivity, ranging from 5 to 10 inches per hour. Fine textured soils (heavy clays) range in hydraulic conductivities from .05 to 1/2 inch per hour. Similar hydraulic conductivities can

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be associated with very porous well granulated soils and soils with plate like or platy and columnar structures (particle arrangement) respectively.

The amounts of water available to plants as related to texture are shown in Table 1. From this index, it is possible to get some information that is useful to the irrigator in our area. The amounts of water per foot of soil should indicate the need for frequent light irrigations while the inverse is true for the fine textured soils.

In Table 2, the work of Heinonen shows some broad relationships of structure to the amount of available water for plant growth retained by the soil. In the soil groups a to c it was found that the increase in available water was the result of increased clay and silt content. For soil groups d to f the relationship was an increase in available water with a decrease in bulk density. Heinonen associated the decrease in bulk density with an increase in more open granular structure which resulted in greater quantities of available water being held by these soils. Such results have been reported by other research workers and lead to the conclusion that soil management practices such as good crop rotations have a definite effect upon water management practices for subsequent crop production. This effect is a result primarily of the effect of granular structure in the soil.

TABLE 1. A Rating of Available Moisture for Plant Growth by Soil Texture

Rating	Inches of Water/ Foot of Soil	Texture
Very low	$<$ .6	Very coarse (coarse sands)
Low	.6 - 1.2	Coarse (loamy fine sand, sandy loam)
Medium	1.2 - 1.8	Medium (loam, fine sandy loam)
High	$>$ 1.8	Fine (clay loam, clay, silt loam)

TABLE 2. Water Retained in the Surface Layer (5-15 cm) of Soils Under Pasture[1/]

Group	Bulk Density	Available Water
	g/cm^3	percent by volume
a	1.26	14.9
b	1.20	19.6
c	1.09	22.4
d	1.07	18.0
e	1.01	16.5
f	.73	23.3

1/ Part of average data of Heinonen, 1954, for 129 Finish soils from Marshall, Relations Between Water and Soil, 1959 (4).

The foregoing factors or conditions can be related to depth of the soil as seen in Figures 1 to 4. Figure 1 shows a soil of sandy loam texture with a depth of 8 to 10 inches over sand. The soil is permeable with a low water holding capacity. Adequately watered and heavily fertilized this soil produced the cotton plant we see in Figure 2. The yield on this crop was one-fourth bale of lint cotton per acre. In Figure 3, the depth of the same soil is seen to be 18 to 24 inches. Other practices with respect to water and fertilizing were the same as stated for the soil and cotton in Figure 1 and 2. This soil produced the cotton plants shown in Figure 4. The yield on this crop was 1.9 bales of lint cotton per acre. It can be noted in Figures 3 and 4 that no roots penetrated the sand beneath the surface soil. The abrupt change in pore space has created a barrier to air, water, and root penetration. This has resulted in restricted root volume and reduced yield of the crop. Similar patterns of crop response have been noted for crops of alfalfa and forage sorghum on this same field. Such findings throughout the world have resulted in a statement that, except for a few shallow rooted crops, the depth of surface soil should be more than 20 inches with no restrictive layers or abrupt breaks in texture if a near normal crop is to be produced. Most of our cultivated crops, when no restrictions are present, will have a root system that extends to 4 to 6 feet in depth.

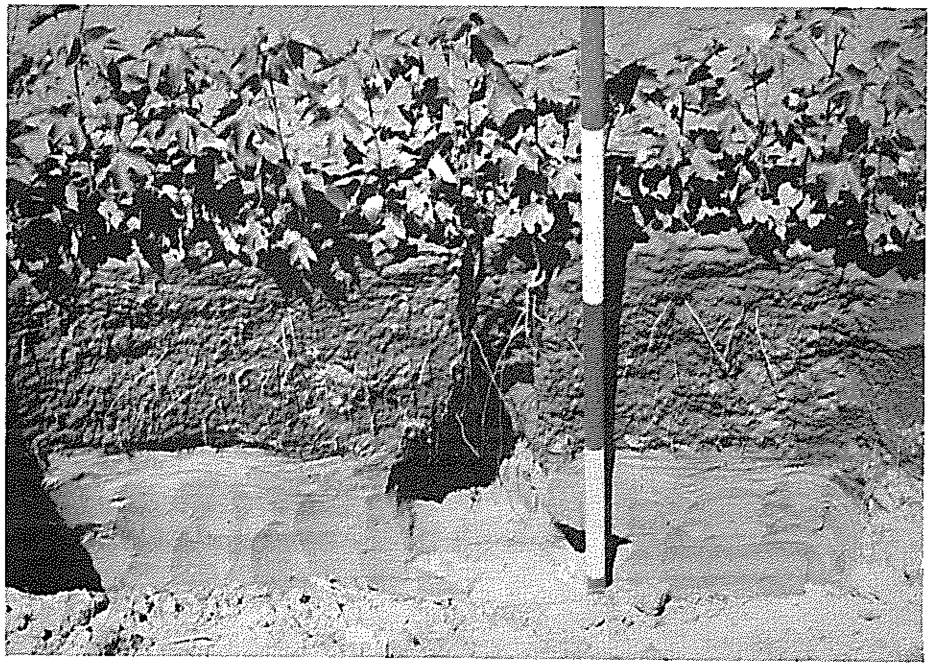

FIGURE 1. Shallow (8 x 10 inches) shallow loam soil over sand.

FIGURE 2. Cotton produced with adequate water and heavy fertilization on shallow sandy loam soil.

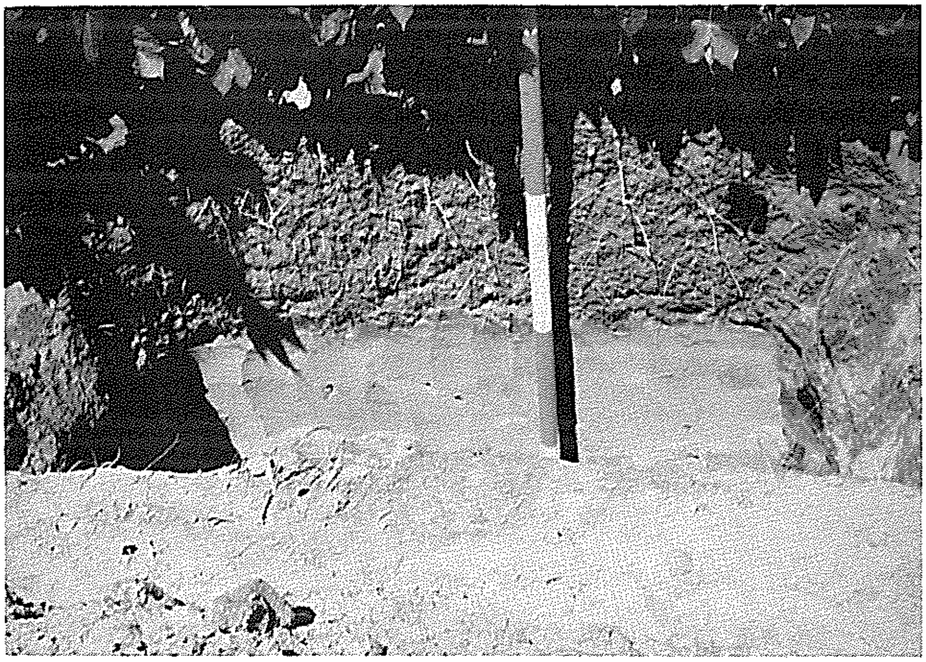

FIGURE 3. Medium depth (18 x 24 inches) sandy loam soil over sand.

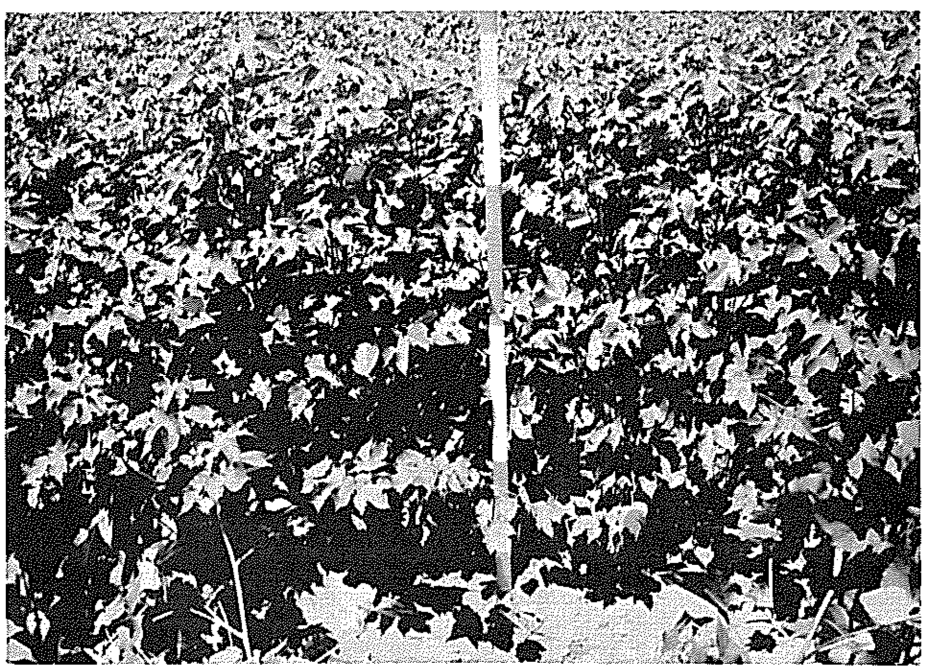

FIGURE 4. Cotton produced with adequate water and heavy fertilization on medium depth sandy loam soil.

On soils having good depth, permeability, medium to fine texture, and good structure several experiments have been conducted to obtain some information about crop response to fertilizers and water.

Table 3 reports work from Yuma, Arizona on alfalfa response to fertilizer and water. Here the data are reported to show the effect that increasing fertility of the soil has upon water use. Wet soils correspond to a suction less than 175 cm at a depth of 12 inches, medium treatment was a suction less than 600 cm at a depth of 18 inches, and dry treatment was a suction less than 800 cm at a depth of 36 inches. This experiment shows increased efficiency in water use by keeping the soil moist and by increasing the fertility level of the soil. These data on moisture treatments are comparable to those of E. G. Hanson at New Mexico State University.

Further effects of fertility on water use by crops can be seen in Table 4. These data show that although crops differ in the amounts of water required to produce a given amount of dry matter per acre they all respond to proper management. One evidence of the response is noted here in the reduction of inches of water required to produce a ton of dry matter when all factors are the same except proper fertilization. The fertilizer applied was 120-60-0, 60-30-0, 200-50-0, and 160-80-0 for barley, wheat, common sweet sudan, and sumac respectively. These rates of available nitrogen and phosphate were the most effective in increasing yield of the respective crops. The yields for the crops were 48 and 92 bushels of barley per acre, check and fertilized respectively; 26 and 47 bushels of wheat per acre, check and fertilized respectively; 39 and 56 tons of sudangrass silage per acre, check and fertilized respectively; and 34 and 48 tons of sumac silage per acre, check and fertilized respectively. These data show that increasing soil fertility increases the efficiency in use of a given quantity of water. The efficiency may double which can mean that proper use of fertilizers may result in nearly double the yield of crop for the same amount of water.

In summary it can be said that for most efficient use of water we need a soil which is deep, with good structure and uniform texture, with good permeability and drainage, with good aeration, with a large fraction of available moisture held at low suction, and having a high fertility level. In such a soil as we see in Figure 5, a plant can produce deep, dense roots which can effectively remove both water and nutrient sufficient to give increased value to the water used. If these conditions are present except for depth as we can see in Figure 6, then the value of water is reduced and agriculture is in trouble.

TABLE 3. The Amount of Water Required to Produce One Ton of Alfalfa Hay for Various Moisture and Fertility Treatments at Yuma, Arizona1/

Pounds P_2O_5/A	Inches of Water/Ton of Hay: Wet	Medium	Dry
100	10.67	11.60	12.81
200	8.79	9.11	10.49
400	7.45	8.20	8.80
600	6.82	7.45	8.86

1/ Data of Stanberry, Converse, and Haise in Marshall's Relations Between Water and Soil, 1959 (4).

TABLE 4. Effects of Fertility upon Water Used in Crop Production1/

	Inches of Water per Ton of Dry Matter			
	Barley	Wheat	Common Sweet Sudangrass	Sumac
No fertilizer	13.0	13.4	7.0	3.9
Fertilized	6.2	6.7	4.2	2.5
Irrigation plus rainfall for growing season	28.45		38.5	

1/ Data of Williams, 1962 and 1963 (5).

SUMMARY

To obtain best value of water use in crop production a soil should be deep, have more than 20 inches of good surface soil; should have good structure; be well drained and aerated; and have high fertility.

Reduced depth of surface usually results in reduced yield with higher amounts of water required for this yield.

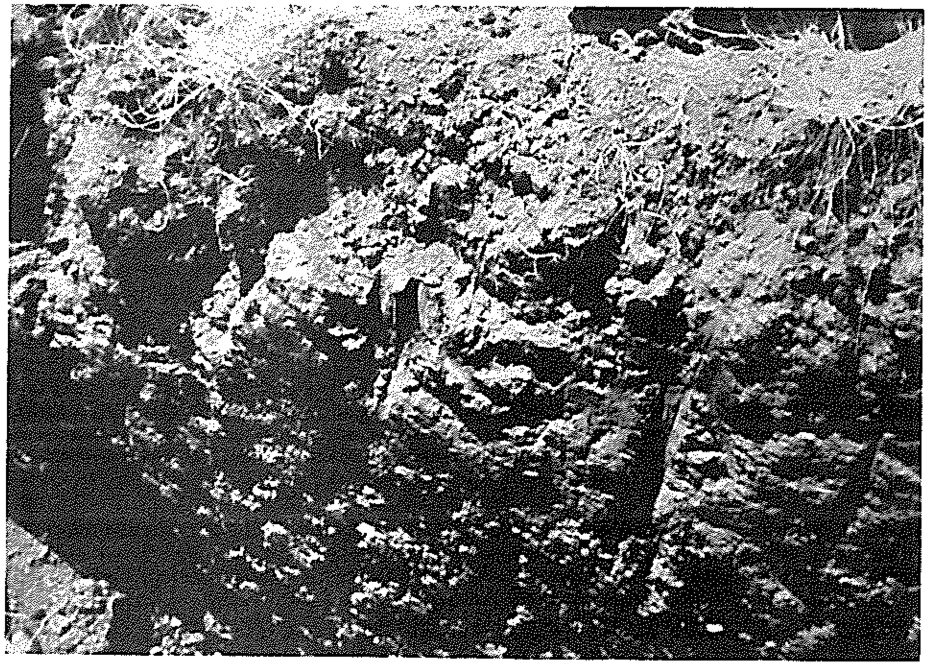

FIGURE 5. Deep, uniform soils such as these are best for deep dense root penetration for effective moisture and nutrient removal by plants.

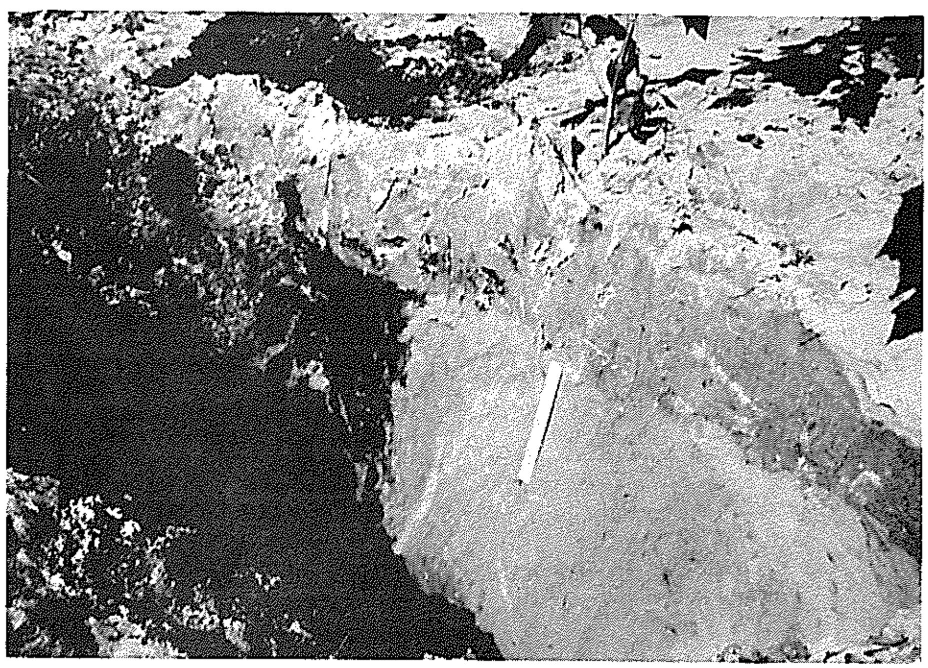

FIGURE 6. Lack of depth in soil prevents efficient use of nutrient and water by plants by restricting root growth.

Poor structure results in poor drainage and aeration with reduction in yields and increased water requirement for this yield.

Increasing fertility level of the soil usually results in decreased water use per given amount of crop produced. This reduction may be as much as one-half. This would mean that proper use of fertilizers can result in twice the yield for the same amount of water.

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