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SOIL PROPERTIES AND ROOT DISTRIBUTION DETERMINE WATER AVAILABILITY TO CROPS

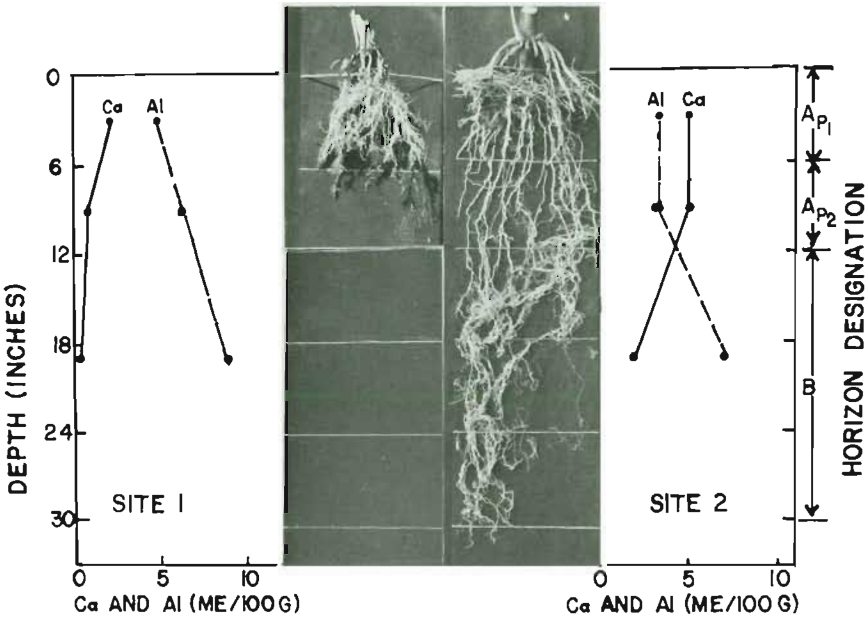

Fig. 1. Root distribution for corn growing on a Haiku clay.

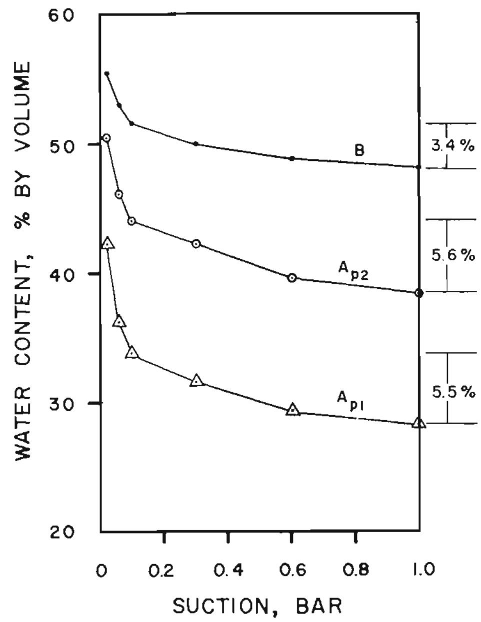

Fig. 2. Water-retention curves for a Haiku clay.

An important concept of soil fertility is that the soil is a reservoir for nutrients and water. Physical properties largely determine the soil's inherent capacity to store water. Physical, chemical, and biological factors determine whether or not the reservoir will be tapped by crops. Since seasonal drought is typical of much of the tropical zone, it is important that water be utilized from soil horizons below the immediate surface during seasons of water deficit.

Figure 1 illustrates how soil profile characteristics can modify root development, thus restricting or enhancing water utilization from subsoils during times of moisture deficit. Corn plants from two sites are represented in Figure 1. Plants at site 1 wilted unless rains came frequently, while nearby at site 2, plants remained turgid even if there was no rain for several days.

Crop behavior corresponded to root distribution; and root distribution, in turn, was related to soil chemical and physical properties. Roots at site 1 scarcely penetrated below 15 cm (6 inches) even though the soil was friable to a depth of 30 cm (12 inches). Thus, it appeared that the factors that prevented root development below 15 cm were chemical rather than physical in nature. At site 2, a mass of fibrous roots was located in the 30- to 45-cm (12 to 18 inches) depth increment. These roots marked the bottom of the A_p horizon. Root growth into the B horizon (below 45 cm) at site 2 was possible because the dense subsoil had been broken by deep chiseling during earlier pineapple culture. Thus the soil was modified both physically and chemically.

The chemical factor that accounted for the abrupt curtailment of roots at site 1 seems to have been calcium deficiency aggravated by active aluminum in the soil. Calcium is not translocated downward in root systems at a rate sufficient for root extension into calcium-deficient soil, especially if aluminum is present in toxic concentrations. An examination of the soil data graphed in Figure 1 shows that low calcium in the soil of site 1 was associated with high aluminum levels. Thus, the ratio Ca:Al was 0.2 to 0.1 in the subsoil at site 1, but was 1.0 to 0.3 in the subsoil at site 2.

Even if the chemical environment had permitted root proliferation, most pores in the unshattered B horizon were so small (<0.05 mm) that roots could not have entered.

The amount of plant-available water in the total soil volume occupied by roots can be estimated from the water-release curves of Figure 2. For example, as suction increased from 0.1 to 1 bar, water released was only 5.5 percent by volume. The 15-cm depth of soil occupied by roots, when drained to field capacity, would contain $15 \times 0.055 = 0.82$ cm of water — a quantity that would not last 2 days with normal evapotranspiration. This explains why plants at site 1 wilted much more quickly than those at site 2.

Highly weathered and strongly aggregated Hawaii soils, such as this Ultisol, have unique mineralogical properties that give them physical properties similar to those of sand. However, these soils can retain as much as 40 to 50 percent water by volume when they have drained to field capacity, although little of this water can be utilized by crops because most of it is held in very small pores within aggregates.

Good water management for highly weathered, strongly aggregated soils may include one or more of the following practices:

(1) Choice of a crop (such as pineapple) that is tolerant of moisture stress.
(2) Choice of a crop (such as sugarcane) that is relatively insensitive to aluminum toxicity.
(3) Deep tillage to shatter impervious subsoils.
(4) Judicious introduction of lime or fertilizers containing calcium into the subsoil.
(5) Fertilization to provide vigorous plants with vigorous roots.
(6) Frequent but not excessive irrigation.

Richard E. Green and Robert L. Fox—No. 14, 1978