This Week's Citation Classic®

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Gardner W R. Dynamic aspects of water availability to plants.
Soil Sci. **89**:63-73, 1960.
[US Salinity Laboratory, Riverside, CA]

Solutions of the equation for the flow of water to plant roots show that the water potential gradients in the vicinity of roots of actively transpiring plants are small until the soil water content approaches the wilting range and that they depend upon the soil properties. [The SCI® indicates that this paper has been cited in over 210 publications since 1960.]

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At the time I joined the staff of the US Salinity Laboratory, there was a heated debate about the availability of soil water for plant growth. Richards and Wadleigh, in a classic chapter, argued that "plant growth is simply related to soil moisture stress."[1] F.J. Veihmeyer and coworkers[2] at Davis defended vigorously the opposite view that all soil water in the range between the field capacity and the permanent wilting point was equally available to plants.

I had devised a method for measuring the unsaturated water permeability of soil for the entire plant growth range. This soil property varies about six orders of magnitude in the range, depending upon soil water content and soil texture. These were the first such data obtained over virtually the entire range of soil water contents, and they made it possible to examine theoretically a number of interesting soil water flow problems. In view of the controversy over soil water availability, the urge to calculate the flow to plant roots was irresistible. This represented one of the first attempts to describe this flow system quantitatively, and a large number of assumptions had to be made about the plant and its root system.

When I submitted this paper for publication, the response was what has turned out to be my favorite review. It reads in part: "This paper has proved to be a difficult one to criticize.... This impression corresponds to the feeling one might have when he finds that the path he has been following suddenly crosses a swamp, and it is necessary to skip from one tussock to the next, never putting the full weight on either foot until safely across.... In spite of this problem, the author evidently arrives at his destination with dry feet...."

I believe this paper has been so frequently cited because the approach is essentially the same that all computer models of plant water uptake now follow. While this was probably a useful start, I think it has eventually led us to a dead end. We can hope that some young scientist is even now preparing the paper that will supersede this approach and become another *Citation Classic*. For me, this paper was the first in a not-yet-concluded series of studies of soil-plant-water relations,[3,4] and set the course of my scientific career. It possibly contributed to my election to the National Academy in 1983.

1. **Richards L A & Wadleigh C H.** Soil water and plant growth. (Shaw B T, ed.) *Soil physical conditions and plant growth*. New York: Academic Press, 1952. p. 74-251.
2. **Veihmeyer F J.** Soil moisture. (Stocker O, ed.) *Water relations of plants*. Berlin: Springer-Verlag, 1956. p. 64-123.
3. **Herkelrath W N, Miller E E & Gardner W R.** Water uptake by plants: I. Divided root experiments. *Soil Sci. Soc. Amer. J.* **41**:1033-8, 1977.
4. ----------. Water uptake by plants: II. The root contact model. *Soil Sci. Soc. Amer. J.* **41**:1039-43, 1977.