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SEED-SOIL CONTACT AND THE ROLE OF VAPOR IN GERMINATION

Stewart Wuest

Abstract

Seed-soil contact has been assumed to be the most important factor for rapid transfer of water from soil to seed. Recent research demonstrated that seeds are capable of germinating without soil contact, and that 85 percent or more of the water absorbed by seeds can be directly attributed to vapor. A new appreciation for the capacity of soil atmosphere to supply water vapor to seeds will help in future efforts to improve seeding equipment.

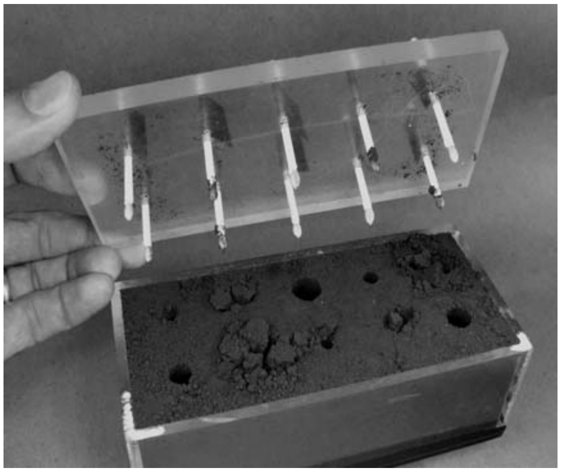
Key words
Germination, seeding equipment, seed-soil contact, water vapor

Placement and germination of seeds has been a concern in agriculture since the beginning. Thousands of years of experience, trial and error, and observation have lead us to the practices and equipment we use today. The current concept of how seeds absorb water from soil was based upon the idea that the seeds are in contact with minute water films on soil particles. From practical experience in touching wet objects, we could imagine that the dry seeds drew liquid water out of moist soil before beginning the process of germination. This led to the assumption that seed-soil contact was very important to rapid germination. Contrary to this logical and long-held assumption, my research has demonstrated that water vapor plays a big role in seed germination in the absence of irrigation or rain.

Theory and practice often co-exist quite happily, even when theory is later found to be incompatible with available knowledge. For example, when it was realized that it would be simpler to consider the earth as revolving around the sun, rather than vice versa, the average person did not need to change their daily routine, and there were no adjustments to make in the length of a day, or in using a calendar. In a similar sense, the revelation that water vapor is more responsible for seed germination than seed-soil contact has little immediate practical impact on our success as farmers. It should, however, help us make logical and effective choices in the future.

Water vapor is abundant in all but the driest soil. In fact, the relative humidity of soil air is above 99 percent at permanent wilting point (-15 bars water potential). It is close to 100 percent when the soil moisture is above -10 bars, the point at which Walla Walla silt loam soil starts to look dry. Even if soil air is below 100 percent relative humidity during the day, relative humidity will rise when temperatures drop at night, probably becoming supersaturated (slightly above 100 percent) for at least short periods. The consequence is that seeds can imbibe water in the form of vapor without physical contact between seed and soil.

To measure the contribution of vapor to water absorption by seeds, I needed a method to keep seeds from touching soil, but without a large gap for vapor to cross. The method adopted was a series of holes in a block of moist soil (Fig. 1). A wheat seed glued to a plastic stick was suspended in each hole. The holes ranged in size from no hole at all to 13-mm diameter (about one-half inch). In positions without a hole, the seed was forced directly into the soil and had maximum seed-soil contact. Since the wheat seed was about 3 mm in diameter, as the hole size increased, there was decreased



contact between the seed and soil. The soil was colored with blue dye, so the amount of seed-soil contact would be apparent after seed removal.

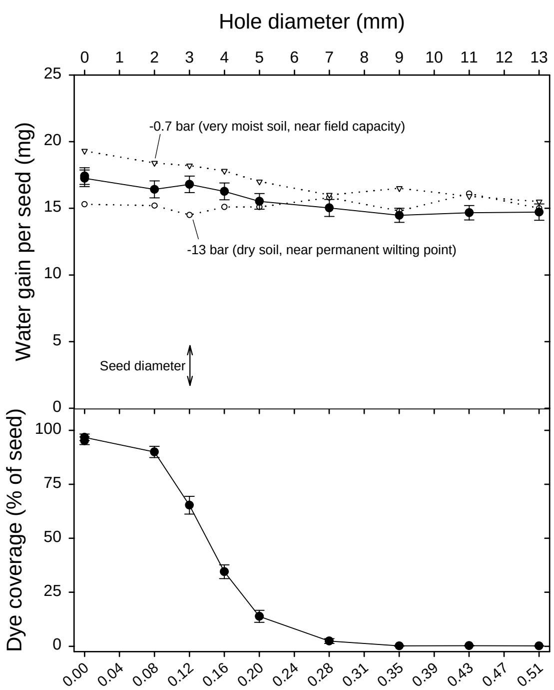


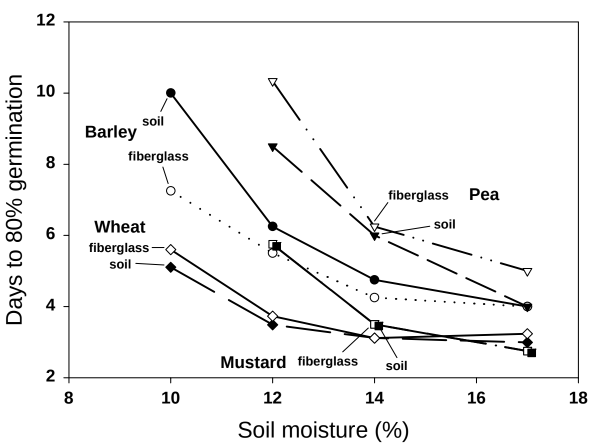
Figure 2 compares hole diameter to the amount of water taken up by wheat seeds after being suspended in the soil block for 24 hours, compared to the amount of dye covering the seeds. There was relatively little increase in water absorption by seeds as seed-soil contact and dye coverage increased from none to 100 percent. This indicates that the flow of liquid water through seed-soil contact is not the major source of water. The data were generated over a wide range of soil moistures. Some of the very moist and very dry data are shown separately in Figure 2. It is evident that soil moisture did not have a large influence on the amount of water absorbed.

Researchers question whether seeds absorb water only as liquid when soil contact exists, but as vapor when it does not. This is not likely unless the soil is very wet. Scientists have calculated how much contact a seed might have with soil (Collis-George and Hector, 1966). Only about 10 percent of a seed's surface theoretically would be touching liquid water films in a soil near field capacity, meaning 90 percent would still be exposed to soil atmosphere. In addition, as soon as a dry seed came in contact with liquid water, water would be absorbed by the seed, resulting in thinner water films and less seed contact. I believe our assumption that seeds often make effective contact with soil water films is erroneous.

In the past, scientists have tried to correlate liquid water movement in soil to the rate at which a seed absorbs water, and they have encountered a problem. Seed germinates within days whether the soil is quite moist (near field capacity) or almost dry (about -10 bars water potential). We know that as soil gets dry, water movement in the soil slows exponentially. (That is, if water can move 2 mm per day in a particular soil at –0.1 bar water potential, water will only move 0.02 mm per day when the soil dries to –1 bar, and only 0.002 mm per day when the soil dries to –10 bars.) Not only would moisture move much, much more slowly as the soil dries and the water films thin, but seeds would have to draw water from a much greater distance to germinate.

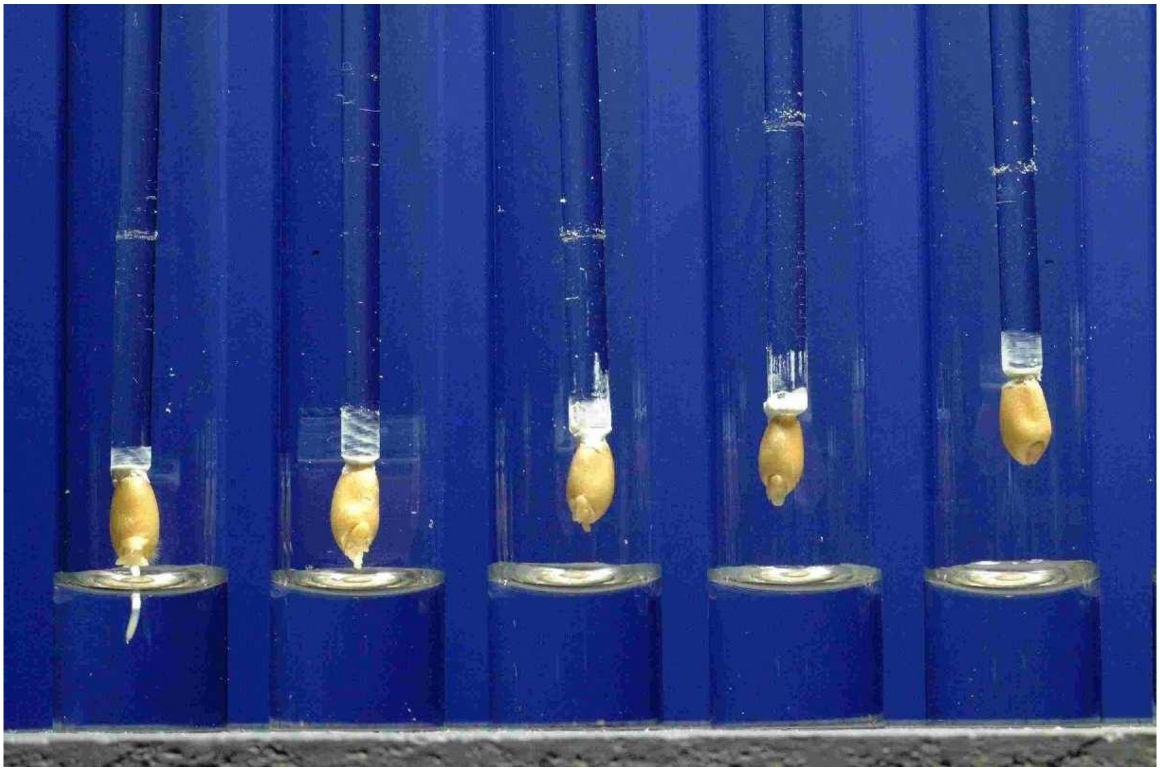
Again, what we observe under laboratory and field conditions is that seed will germinate at nearly the same rate when planted in a wide range of soil moistures. Our explanation is that water vapor remains at nearly 100 percent over a wide range of soil moistures, from field capacity to fairly dry. This also explains why such a wide variety of drills, with and without packer wheels, in tilled or untilled soil, all are capable of producing good stands. Some farmers seed with drills they know are producing "poor" seed-soil contact, and then follow seeding with a light harrow to cover the seed with a loose layer of soil. Large, uniform fields of emerging wheat would be a rare sight if germination were highly dependent on good seed-soil contact.

Barley, pea, mustard, and wheat have all been tested for their ability to germinate rapidly with vapor alone. Figure 3 shows



the results of a test where several seeds were placed in petri dishes filled with moist soil. Half the soil surface was covered by fiberglass cloth to prevent seed-soil contact. Seed laid on the fiberglass cloth germinated nearly as fast as seed with good seed-soil contact. (Exactly the same time in the case of mustard, and in this test, faster in the case of barley.) It is also possible to germinate seed in a dry, sealed beaker, if sufficient water vapor is made available (Fig. 4).

The distance that water vapor travels from the liquid source to the seed is critical, as shown in Figure 5. Wheat suspended very close to the water surface in the sealed test tubes germinated in about 3 days. The seed on the right, suspended about one-half inch from the water surface, required about 9 days to germinate. It is surprising to most people that seed can germinate without any contact with liquid water. It is also surprising that a closed vessel with water in the bottom does not have uniform 100 percent relative humidity in the air space above the water surface. These non-intuitive relationships may be why scientists have underestimated the role of vapor in seed germination.



We have yet to precisely measure seed-soil contact, or how to separate liquid flow from vapor flow when both might be contributing to the water absorbed by a seed.

Knowing that vapor is sufficient to quickly germinate seed should help guide future improvements in seeding equipment. Placement at a desirable depth near moist soil is still important, but pressing the seed into firm soil is only helpful if it helps maintain high relative humidity near the seed. Seed should germinate just as quickly in loose moist soil as in firm moist soil, if it has adequate protection from the drying effects of wind and sun.

Acknowledgements

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