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INVITED RESEARCH OPINION

# Vapour is the principal source of water imbibed by seeds in unsaturated soils

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## Abstract

The assumption that seeds imbibe most of the water required for germination as liquid through seed-to-soil contact has been a dominant theme in germination research and seeding technology. Under most conditions, seeds are also exposed to water vapour during imbibition, but the relative contributions of liquid and vapour are difficult to assess. In water uptake models that include vapour, procedures used to estimate potential vapour imbibition have under-appreciated the effect of distance on diffusion rate. At the same time, the amount of seed-to-soil contact and the liquid bridge from soil water to the seed tend to be greatly overestimated, considering the soil water contents often found in the field. Most researchers have recorded an approximately equal time to germination at soil water contents ranging from field capacity to nearly permanent wilting point, and little response to bulk density, soil type or seed–soil contact. While hydraulic conductivity decreases by several orders of magnitude as soil water content, bulk density and seed-contact decrease, relative humidity remains near 100%. There are several experiments demonstrating timely germination in water vapour alone. The combined evidence contradicts the assumption that seed–soil contact is important for imbibition of water by seeds. Water vapour should be considered the primary source of water for seeds in unsaturated soils.

**Keywords: germination, hydraulic conductivity, imbibition, seed-soil contact, water vapour**

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## Introduction

The importance of seed-to-soil contact has been emphasized for a long time in the water relations of seeds. Agriculturalists and others concerned with germination and growth of seeds often assume that the predominant source of imbibed water is contact with liquid water films on soil particles. However, it is difficult to measure transfer of liquid water from soil to seed, and especially difficult to separate this from the absorption of water as vapour. While seeds can be placed in liquid water and the rate of imbibition measured, it is deceptively difficult to create a laboratory set-up where water vapour is supplied at an unlimited rate. It is impossible to place seeds in an environment where soil, water and air exist, but without water vapour. As a result, we have a poor understanding of the relative contributions of liquid and vapour to seed imbibition.

Here, some common misconceptions are noted that appear to have hampered imbibition research, and evidence is presented that water vapour plays a major role in seed germination and probably other plant and soil phenomena. This discussion considers conditions where soil is not near saturation. Soil is usually seeded when dry enough to support the weight of humans or tractors, and to be worked without excessive plasticity, puddling and compaction, and yet often the soil is still moist enough to produce rapid germination and growth without additional rain or irrigation.

The seed environment in the field is extremely complex, varying over time and even with time of day. Depth of seeding, weather and soil conditions, species and condition of the seed all determine whether and how quickly germination and emergence occur. But this does not prevent the drawing of conclusions regarding the relative roles of liquid and vapour transport in imbibition of water by seeds in unsaturated soil.