EFFECT OF SOIL-SEED CONTACT ON SEED IMBIBITION

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Imbibition rates by wheat seeds were studied on two soil textures at three moisture levels and at four soil bulk densities in a laboratory with the effect of drying removed. Soil texture and soil moisture within the range used (30, 500, and 1500 kPa) had little effect on rate of imbibition. Imbibition rates decreased as bulk density increased and this relationship became more pronounced with time. Capillary and vapor movement of water near the seed as influenced by compaction, and not soil-seed contact, are apparently the controlling factors in imbibition. The role of water in the vapor phase on imbibition may be greater than previously thought.

INTRODUCTION

Seed drills for zero-tillage will have to be capable of seeding to desired depth into compact, trash-covered soils that do not have conventional plow pans. The market for zero-till seed drills is not expected to mature fast enough to support their exclusive production for some time. Thus, new designs will require a greater range of capability than that of present drills, because they will likely have to operate in both traditional and zero-till seed beds.

Design of a seed drill requires consideration of the various aspects of seed placement that affect germination and emergence. The function of a seed drill furrow opener assembly is to place seed in the soil at a regulated depth in relation to either moisture or soil surface, and also to manipulate the soil in such a manner as to obtain maximum emergence. Many scientists (Stout et al. 1960; Johnson and Buchele 1961; Hadus 1970; Dasberg 1971; Ward and Shaykewich 1972; Feddes 1972; El-Sharkawi and Springuel 1977) have suggested the importance of the degree of soil-seed contact, but its effect has not been measured quantitatively. Collis-George and Hector (1966) found that contact between soil-water and the seed affected the germination of *Medicago tribuloides* at moisture levels above field capacity; however, most seeds germinate at moisture levels well below field capacity. Collis-George and Sands (1959) used two species of *Medicago* and found little difference in germination with different soil moisture tensions and areas of soil-seed contact.

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Wheat has a highly corrugated, hydrophilic seed coat. Collis-George and Melville (1975) suggested that contact between any part of such a seed surface and the source of water is sufficient to ensure a constant moisture potential. This would indicate that a seed requires only enough contact with the soil for moisture to move to the seed, at a rate equal to or exceeding the imbibition rate if the moisture is totally supplied in the liquid phase. The imbibition rate should then decrease proportionately with decreasing liquid movement. This is supported by Ward and Shaykewich's (1972) hypothesis that the hydraulic conductivity of the soil limits imbibition.

Collis-George and Melville (1975) also reported that the rate of imbibition was dependent on the antecedent moisture content of the seed; i.e., the drier the seed, the more rapidly it will imbibe water.

The conditions under which either the seed or the soil control the rate of imbibition have not been defined. As Hadus and Russo (1974) suggested, moisture movement in the micro environment is not fully understood and requires elucidation.

The objectives of this study were to determine: (1) the effect of soil-seed contact on moisture imbibition as influenced by soil texture, soil bulk density, and soil moisture tension when the effect of drying was removed; and (2) the effect of water vapor on moisture imbibition in seeds.

MATERIALS AND METHODS

The rate of imbibition of wheat seeds (*Triticum aestivum* L. 'Canuck') was measured in a 2 × 3 × 4 × 4 factorial experiment that was conducted in a laboratory in two replications. The treatment variables were two soil textures, three soil moisture levels, four bulk densities, and four time periods.

The two soils, Cavendish sandy loam having 19% clay, 74% sand, and 7% silt and Cowley clay having 59% clay, 15% sand, and 26% silt, were ground to pass through a 2-mm sieve. Water was added to the soils or they were dried, as required, to obtain moisture levels equivalent to 30, 500, and 1500 kPa. After preparation, the soils were kept in plastic bags to equilibrate before use.

The soils were placed in acrylic boxes (6 × 33 × 10 cm deep). Twenty seeds were placed in two rows 3 cm deep in each box. The seeds were positioned 1 cm from the box edge and 2 cm apart to ensure that they did not compete for moisture. Dasberg (1971) has shown that soil moisture travels only 1 cm during imbibition. The soil in the boxes was compressed to obtain four ranges of bulk densities of 800, 950, 1050, and 1150 kg/m^3 for the clay soil, and 1050, 1150, 1250, and 1350 kg/m^3 for the sandy soil. Bulk densities near the seed were confirmed with gamma attenuation apparatus. The boxes were then covered with plastic film to prevent drying. Imbibition was allowed to proceed for 4, 6, 8, or 24 h at a room temperature of 21°C ± 1. After the appropriate time period, the seeds were removed and cleaned with a brush; the moisture content of the bulked seed was determined gravimetrically (dry weight basis). The original moisture content of the seeds was 5.6% and imbibed water is reported as difference in percentage water content.

In a second experiment, conducted in duplicate, Cavendish soil was prepared at moisture levels equivalent to 70 and 1500 kPa. The soil (bulk density 830 kg/m^3) was placed in boxes similar to those used in experiment 1. Twenty holes, 0.7 cm diam and 3 cm deep, were made in the soil of each flat. Single wheat seeds were half embedded in the soil at the bottom of each hole. The holes were plugged with stoppers (Fig. 1), the flats covered with plastic, and imbibition measured after 4, 8, and 24 h.

The data were analyzed by the analysis of variance method. Regression analysis was used to examine the relationship between imbibition and soil bulk density, at various times.

RESULTS

Experiment 1

Moisture gain of seeds placed in the clay soil and sandy loam soil were 15.4% and 14.0%, respectively, at the end of 4 h of imbibition time, but the rates decreased slightly with time, and difference in moisture uptake from the two soils remained virtually constant for the 24-h period (Fig. 2). The imbibition rates increases as soil moisture tension decreases as illustrated in Fig. 3. Figure 4 shows the regression of soil moisture gain by wheat seeds on increasing bulk density, at various times. The negative regression coefficients show that imbibition was inversely related to bulk density, and that this relationship became more pronounced with time. None of the first-order interactions was significant.

Experiment 2

The imbibition rates of seeds half embedded in plugged holes were similar for the two moisture levels (Fig. 5) and closely paralleled those of seeds at the 1500-kPa moisture tensions of experiment 1 shown in Fig. 3.

At the soil moisture tension of 1500 kPa, moisture gain for buried seeds (Fig. 3) during the first 4 h was 13.8% compared to only 11.0% for seeds that were half embedded in soil (Fig. 5). After 8 h, however, moisture gain for both was about 20%. Apparently, the seeds buried in moist soil used the readily available water first and then depended on transported water for imbibition. The area available to supply moisture in the vapor phase in the holes was large compared to that available for the buried seeds. Thus, water in the vapor form may have compensated for any initial loss in liquid flow to the imbibing seeds that were half buried.

DISCUSSION

Owen (1952) reported that wheat seeds must contain 46% water for germination to take place. Our results (Fig. 3) showed that the time required for seeds to imbibe sufficient water to attain this level from a relatively moist soil at 30 kPa and a

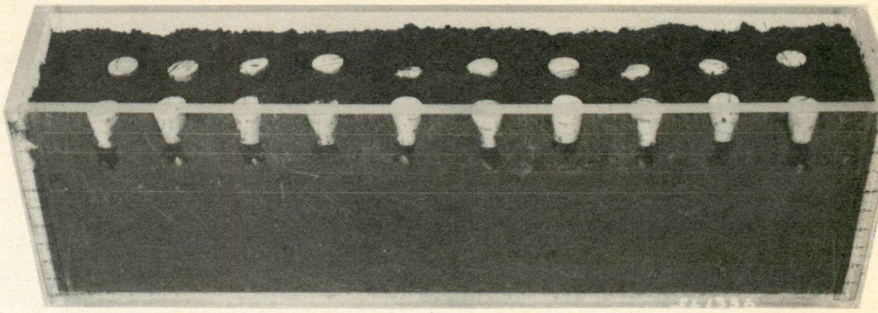

Figure 1. Wheat kernels partially embedded in soil at the bottom of holes, with holes stoppered. In the actual experiment, the holes were placed away from the edge of acrylic box.

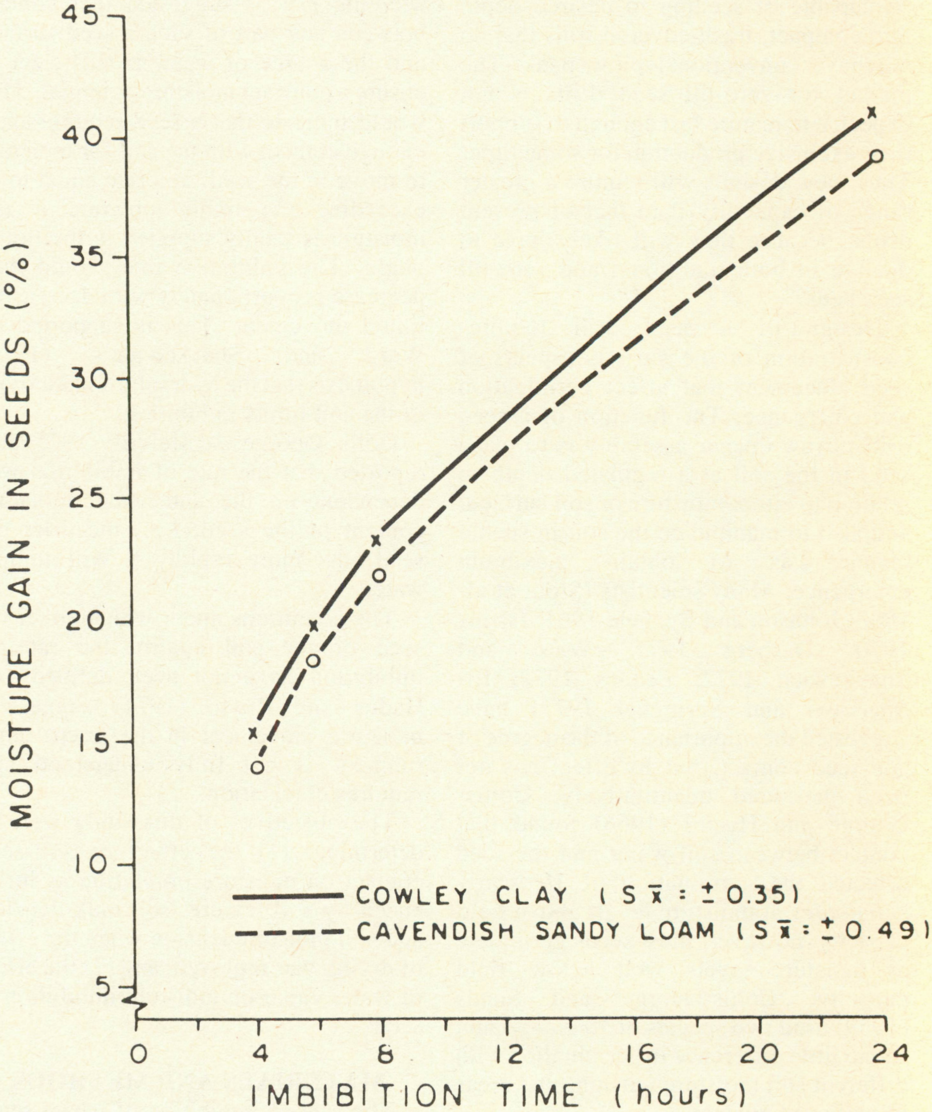

Figure 2. Effect of time on moisture imbibition of wheat seeds in two soil types (means of three soil moisture tensions, four soil bulk densities, and two replicates).

relatively dry soil at 1500 kPa differed by only 8 h. Under field conditions, where imbibition rates may be slower because of lower temperatures, germination rates could also be affected. Although the effect of soil temperature on imbibition rate was not part of our study, it should be investigated. If a positive effect is found, design engineers should consider the possibility of exploiting direction and shape of furrow beds for intercepting solar energy.

Although imbibition to the level required for germination in the clay soil was achieved 2 h earlier than in the sandy soil (Fig. 2), it appears that soil texture per se would play a relatively insignificant role in seed germination under field conditions.

The lack of a positive response in imbibition to increasing bulk density appears to contradict the observation that packing improves germination. Apparently, it is not the intrinsic effect of bulk density per se but the resulting changes in porosity and their effect on water-holding capacity and water movement that have the major influence on germination. Our observation of a slight negative effect on imbibition from increased bulk density indicates that water transport in the vapor phase may have decreased. Collis-George and Melville's (1978) investigation of water vapor imbibition by wheat seeds showed that increasing length and tortuosity of the vapor path reduced imbibition. They also suggest that the soil may mechanically restrain the swelling seed and so reduce imbibition. This could explain part of the decrease in imbibition rate that we obtained when bulk density increased.

We suggest that the benefit of soil compaction on imbibition is not from greater soil-seed contact, but from changes in soil porosity that affect soil water transport to the seed and reduce moisture loss in the vapor phase. Johnson and Henry (1964) and Bowen (1966) found that press wheels that exert 1 psi (6900 Pa) or less pressure reduced the drying rate of soils by consolidating the soil surface.

SUMMARY AND CONCLUSIONS

1. Soil texture had little effect on the rate of soil moisture imbibition by wheat seeds.

2. Soil moisture tension within the ranges used (30, 500, and 1500 kPa) had little effect on soil moisture imbibition by wheat seeds.

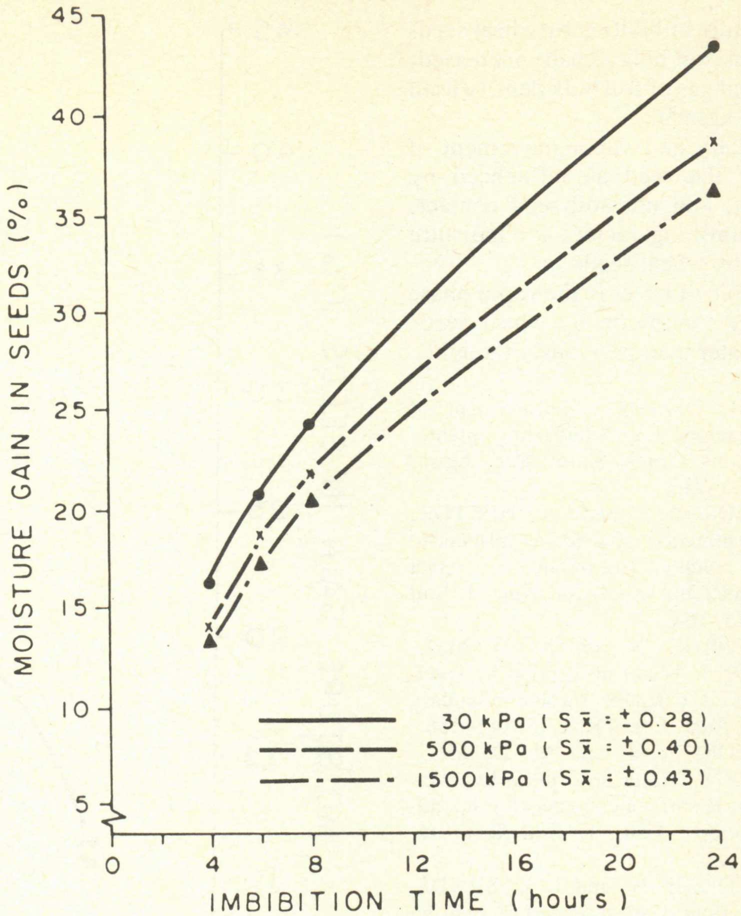

Figure 3. Effect of time on moisture imbibition of wheat seeds at three soil moisture tensions (means of two soil types, four soil bulk densities, and two replicates).

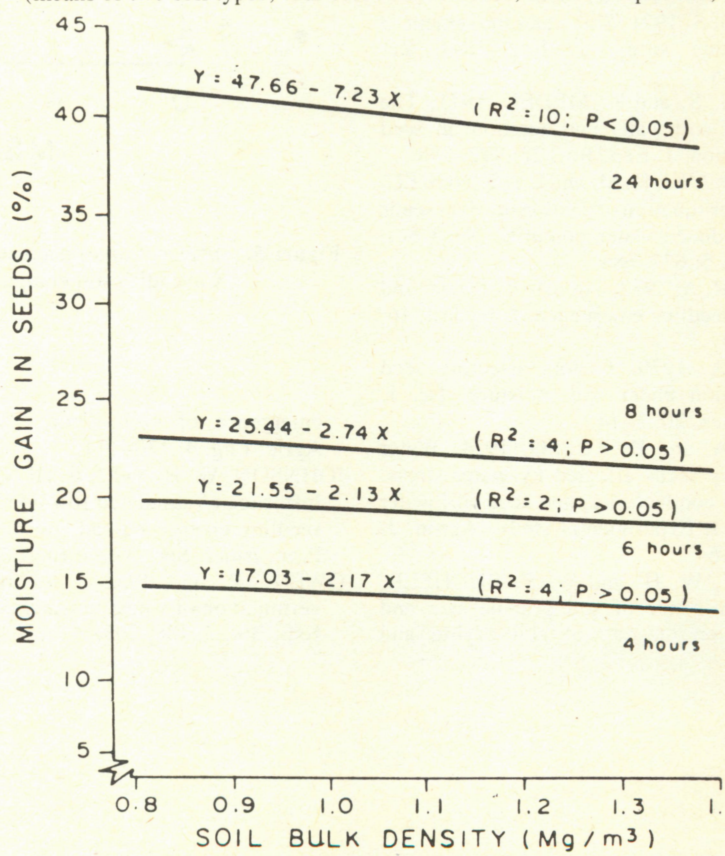

Figure 4. Effect of soil bulk density on moisture imbibition for various time periods (means of two soil types, three moisture tensions, and two replicates).

3. Moisture imbibition by wheat seeds decreased as soil bulk density increased, within the ranges of soil bulk density used (800–1350 kg/m^3).

4. Capillary and vapor movement of water near the seed as influenced by compaction, and not soil-seed contact, are the controlling factors for moisture imbibition by wheat seeds.

5. The role of water in the vapor phase on moisture imbibition by wheat seeds may be greater than previously thought.

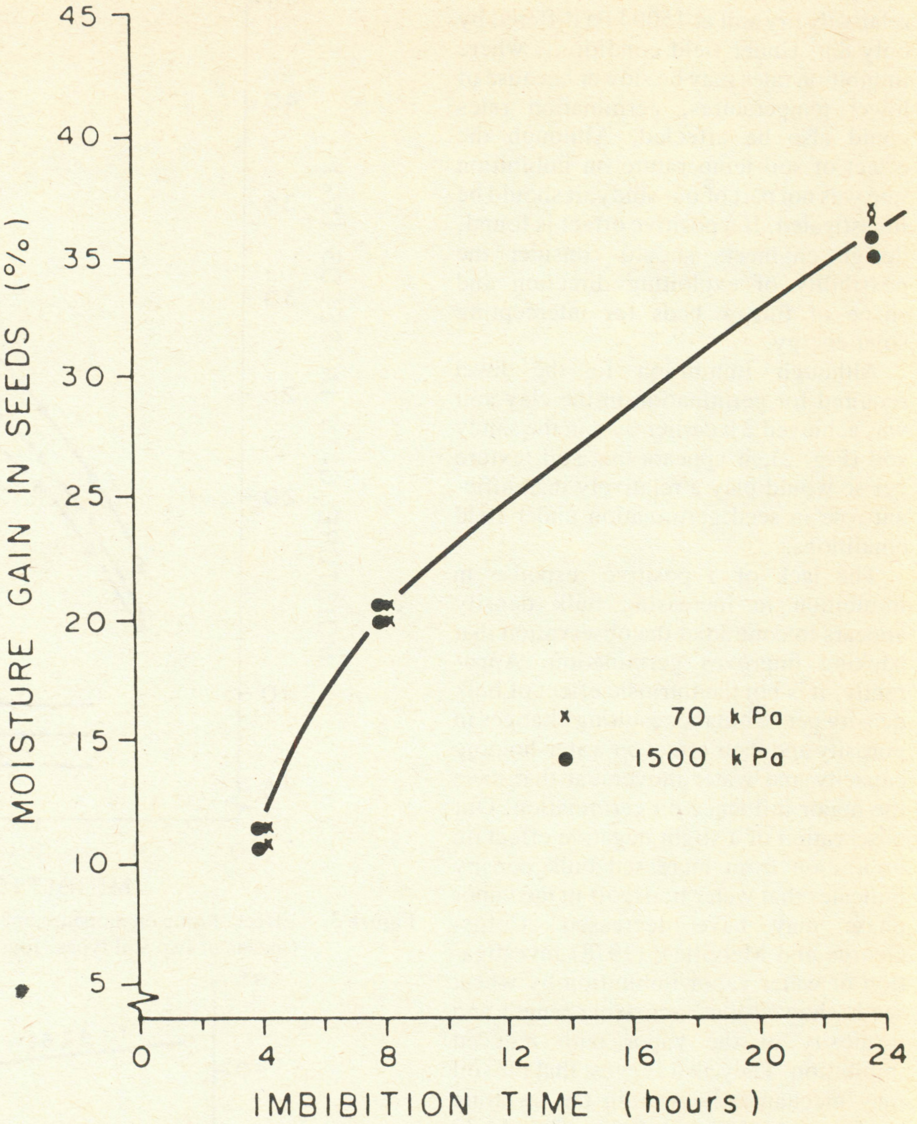

Figure 5. Effect of time on moisture imbibition of wheat seeds half embedded in 3-cm holes in Cavendish soil compacted to a soil bulk density of 830 kg/m^3.

BOWEN, H. D. 1966. Measurement of edaphic factors for determining planter specifications. Trans. Amer. Soc. Agric. Eng. 9: 725–735.

COLLIS-GEORGE, N. and J. B. HECTOR. 1966. Germination of seeds as influenced by matric potential and by area of contact between seed and soil water. Aust. J. Soil Res. 4: 145–164.

COLLIS-GEORGE, N. and M. D. MELVILLE. 1975. Water absorption by swelling seeds, I constant surface boundary condition. Aust. J. Soil Res. 13: 141–158.

COLLIS-GEORGE, N. and M. D. MELVILLE. 1978. Water absorption by swelling seeds, II surface condensation boundary condition. Aust. J. Soil Res. 16: 291–310.

COLLIS-GEORGE, N. and J. E. SANDS. 1959. The control of seed germination by moisture as a soil physical property. Aust. J. Agric. Res. 10: 628–636.

DASBERG, S. 1971. Soil water movement to germinating seeds. J. Exp. Bot. 22: 999–1008.

DASBERG, S. and K. MEDEL. 1971. The effect of soil water and aeration on seed germination. J. Exp. Bot. 22: 992–998.

EL-SHARKAWI, H. M. and I. SPRINGUEL. 1977. Germination of some crop plant seeds under reduced water potential. Seed Sci. Technol. 5: 677–688.

FEDDES, R. A. 1972. The effect of water and heat on seedling emergence. J. Hydrol. 16: 341–359.

HADUS, A. 1970. Factors affecting seed germination under soil moisture. Isr. J. Agric. Res. 20: 3–14.

HADUS, A. and D. RUSSO. 1974. Water uptake by seeds affected by water stress, capillary conductivity, and seed-soil water contact. I: Experimental study. Agron. J. 66: 643–647.

JOHNSON, W. H. and W. F. BUCHELE. 1961. Influence of soil granule size and compaction on rate of soil drying and emergence of corn. Proc. Amer. Soc. Agric. Eng. 4: 170–174.

JOHNSON, W. H. and J. E. HENRY. 1964. Influence of simulated row compaction on seedling emergence and soil drying rates. Proc. Amer. Soc. Agric. Eng. 252–255.

OWEN, P. C. 1952. The relation of germination of wheat to water potential. J. Exp. Bot. 3: 188–203.

STOUT, B. A., F. W. SNYDER, and W. F. BUCHELE. 1960. The effect of soil compaction on moisture absorption by sugar beet seeds. Q. Bull. Mich. Agric. Exp. Sta. 42: 548–557.

WARD, J. and C. F. SHAYKEWICH. 1972. Water absorption by wheat seeds as influenced by hydraulic properties of soil. Can. J. Soil Sci. 52: 99–105.