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Effects of seedbed characteristics and surface layer hardening on crop emergence and early plant growth

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Abstract. The emergence and early growth of barley were studied in seedbeds of various properties arranged in plastic boxes. The main objective was to check whether results similar to those obtained in Sweden (Håkansson et al., 2001) could be obtained under somewhat different conditions. In an experiment in Tartu, Estonia, the effects of sowing depth in a sandy loam and a silt loam were studied. Under suitable moisture conditions, sowing at 5 or 10 cm led to lower and later emergence than sowing at 2 cm in both soils. In the silt loam, the effects of surface layer hardening caused by irrigation immediately after sowing was also studied. Since the surface layer started hardening before crop emergence, the number of plants that emerged was considerably reduced. Early loosening of the hardening layer eliminated a large part of the detrimental effect. In an experiment in Saku, Estonia, the effects of moderate compaction of the layer under the seed was studied in a clayey silt and a silty sand. Compaction of this layer improved the early growth of the crop.

Key words: Seedbed preparation; soil compaction; surface layer hardening

INTRODUCTION

Establishment and early growth of a crop largely depends on seedbed quality, soil compactness and subsequent weather conditions and is often unsatisfactory. Seed germination may be poor if the seedbed is too dry at sowing or dries out too quickly. Seedling growth may be impaired by too high mechanical resistance caused by early surface layer hardening. Too deep sowing may delay the emergence and lead to weak plants. Machinery-induced compaction of the soil layer under the seeds may improve seed germination, but may impair subsequent root growth and function. At the same time many studies on structural differences among soils (Horn et al, 1994; Mahboubi and Lal, 1998;) and quality of the seedbed (Arvidsson and Håkansson, 1996) have shown that the compaction decreases the porosity, the proportion of large pores and increases the tensile strength of dry aggregates. Also on clay and loam soils, it decreases the proportion of fine aggregates in the seedbed and gravimetric soil water content in the seedbed.

By tradition, arable fields in Northern Europe are mouldboard ploughed in the autumn. Since spring is relatively dry, satisfactory establishment of spring sown crops usually requires a seedbed of good quality. This is traditionally achieved by several shallow harrowings just before sowing. Unfortunately, this may lead to excessive compaction of the basal soil layers. The requirements on seedbeds for adequate crop establishment under Swedish conditions have been studied for a long time (Håkansson at al., 2001). In an extensive project, the influence of seedbeds with various characteristics on crop emergence were studied using seedbed models built up in plastic boxes (Håkansson & von Polgár, 1984, Håkansson at al., 2001). To check whether the experience retrieved in Sweden was applicable as well under other conditions in the “Balto-Scandic” region, experiments of similar type were carried out in Estonia.

MATERIALS AND METHODS

In 2001 and 2002, laboratory experiments were carried out at the Estonian Agricultural University (EAU), Tartu, and at the Estonian Research Institute of Agriculture (ERIA), Saku. The experiments were carried out with a method similar to that presented by Håkansson & von Polgár (1984) and Håkansson et al. (2001). Soils taken from the A-horizon at various sites were placed in open plastic boxes (area 0.12 m^2, depth 0.20 m) in layers with specified properties; 48 seeds per box (400 seeds m^{-2}) were placed at a predetermined depth. Seeds of barley (*Hordeum distichon* L.) with a germinability of 98% (experiment 1) or 86 % (experiment 2) were used. The number of emerged plants and length of sprouts above the soil surface were registered every day, starting on the first day of emergence.

Experiment 1 (EAU, Tartu, 2001-08-02 - -08-22)

In 12 boxes, moist sandy loam from Eerika near Tartu (*Fragi-Stagnic Albeluvisol,* WRB, humus content 2,3% and soil water content 19%) was applied as a 5-cm deep basal layer. After sowing, the seed was covered by a 2, 5- or 10-cm deep layer of weed and pest free air dry soil (this soil had been previously dried at 105^{o}C). In one set of boxes with these three sowing depths, the soil used for the surface layer was sand from Nåntuna, Sweden, and in three sets it was silt loam from Hedemora, Sweden. In the set of boxes with sand and in one set of boxes with silt loam, each box was irrigated by hand with about 3 mm (300 ml) water daily, starting on the third day after sowing. The objective was to continuously keep the soil optimally moist. In two sets of boxes with silt loam, each box was irrigated by hand immediately after sowing with about 6 mm (600 ml) water and then left to dry without further irrigation. This quickly led to surface layer hardening. In one of the two latter sets, the hardening layer was broken by hand by cutting with a knife three days after sowing, and in the other set, the hardening layer was left unbroken. Fig. 1 shows the arrangement.

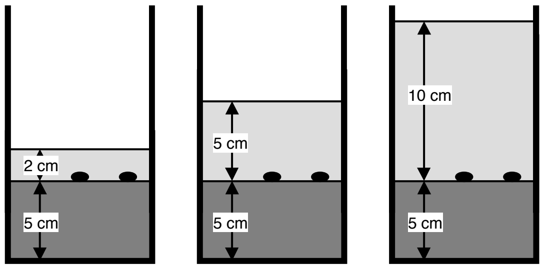

Fig. 1. Schematic diagram of the arrangement in Experiment 1. In the set of boxes with sand and in one set of boxes with silt loam, the soil was kept continuously moist. In two sets of boxes with silt loam, irrigation immediately after sowing led to surface layer hardening. In one of the latter sets, the hardening layer was broken three days after sowing and in one set it was left unbroken.

Experiment 2 (ERIA, Saku, 2002-03-14 – -04-10)

An Estonian silty sand from Kuusiku (*Mollihumi-Calcaric Cambisol,* WRB, humus content 2,5%, soil water content 18%) and an Estonian clayey silt from Kuusiku (*Eutri-Endogleyic Cambisol,* WRB, humus content 2,7%, soil water content 25%) was applied as a 6-cm deep basal layer, using three boxes for each soil. This layer was either non-compacted, slightly compacted or moderately compacted by hand. After sowing, the seed was covered by a 2-cm deep layer of the same soil and with the same water content as the basal layer. Fig. 2 shows the arrangement. Immediately after sowing, each box was irrigated with about 6mm (600 ml) water, and to keep the soil continuously moist the irrigation was repeated five times during the growth period with about 3mm (300 ml) water each time. Soil water content was measured repeatedly by a DELTA-T DEVICES moisture meter HH2, whose measuring element was Theta Probe type ML 2x, and at the same time a gravimetric method was used.

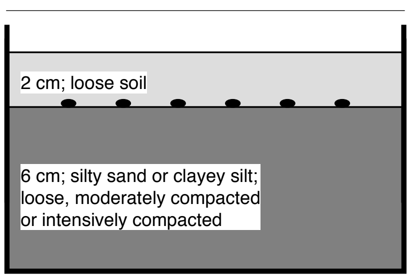

Fig. 2. Schematic diagram of the arrangement in Experiment 3.

RESULTS AND DISCUSSION

Figure 3 shows final emergence of barley in the sandy soil in Experiment 1. The boxes were irrigated daily to make moisture conditions suitable and mechanical resistance low. Deep sowing (10 cm) reduced emergence considerably compared to shallow sowing because of shortage of energy in the seedlings. The shallower the sowing the more rapidly the emergence, and consequently, the more energy was left in the seedlings at the time of emergence, which is an advantage for subsequent growth.

Crop emergence was much lower in boxes with silt loam irrigated immediately after sowing and then left to dry, since the surface layer in these boxes started hardening quickly (Figure 4).

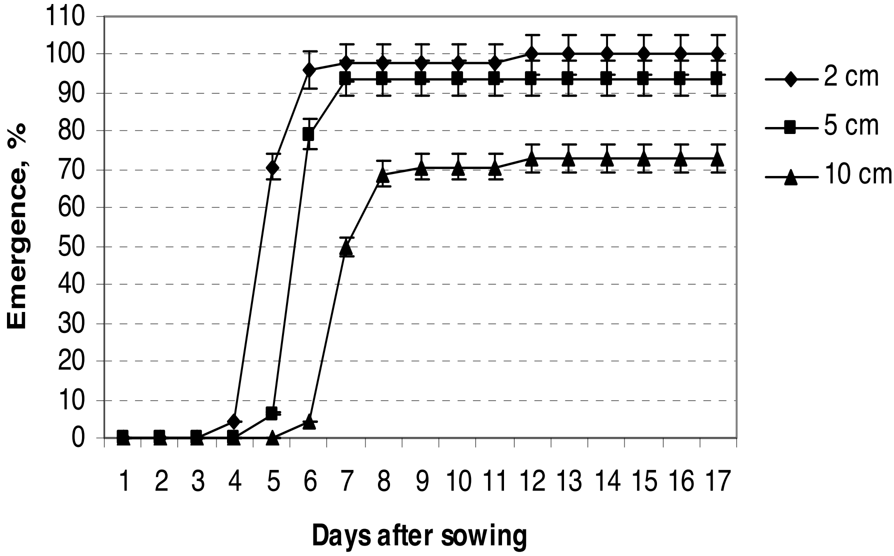

Fig. 3. Emergence of barley sown at 2, 5 or 10 cm depths (cf. Fig. 1) in sandy loam with daily irrigation (Bars denote *0.95 confidence intervals*).

Three days after irrigation, the hardening surface layer in one set of boxes was loosened manually and this improved crop emergence considerably. However, the emergence approached 100% only at 2-cm sowing depth. Table 1 shows data on the time of emergence.

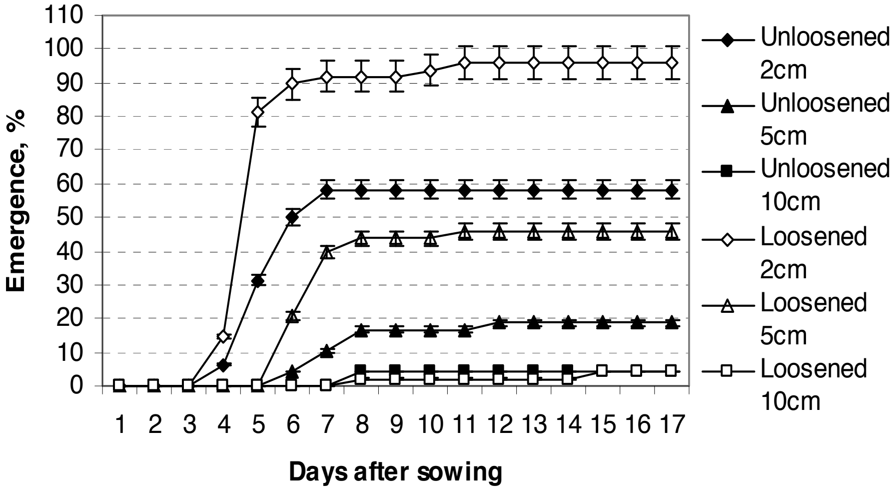

Fig. 4. Final emergence of barley sown at three depths in boxes where irrigation was conducted immediately after sowing in order to cause surface layer hardening, and where the hardening surface layer was either loosened manually three days after sowing or left unloosened (Bars denote *0.95 confidence intervals*).

Table 1. Emergence of plants sown at three depths and with three treatments as regards irrigation and loosening of the surface layer

Treatment	Sowing depth, cm	First day of emergence	Last day of emergence	Final number of plants emerged
Unloosened[a]	2	4	7	28
Unloosened	5	6	12	9
Unloosened	10	8	8	2
Loosened[b]	2	4	11	46
Loosened	5	6	11	22
Loosened	10	8	15	2
Irrigated daily[c]	2	4	12	48
Irrigated daily	5	5	7	45
Irrigated daily	10	6	12	35

[a]Irrigated immediately after sowing, then left to dry and form a hard surface layer; no loosening.
[b]Irrigated immediately after sowing; the surface layer loosened manually three days after sowing.
[c]Irrigated daily, starting three days after sowing.

Figure 5 shows the length of plants above the soil surface as a function of time. Plants in boxes with loosened soil grew faster than plants in boxes with unloosened soil. The elongation rate in boxes where the seed was covered by 2 cm of unloosened soil decreased considerably after some days, probably because of lack of water. With a 5- cm deep layer, the elongation rate started to decrease a couple of days later. The reason for this decrease is probably a relatively rapid loss of water by evaporation, due to high capillary conductivity in the unloosened surface layer. As reported by Stenberg et al. (1994) this occurs, particularly in silty soils, when a rainfall leads to a collapse of the structure of the entire surface layer.

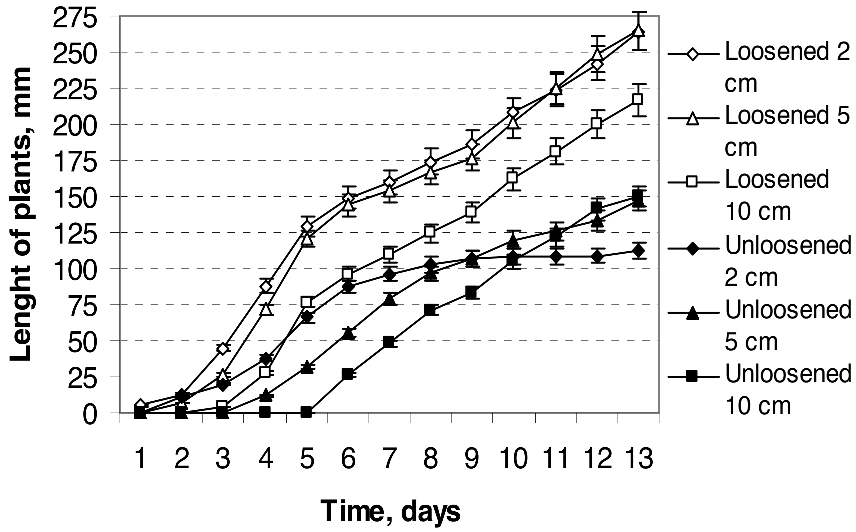

Fig. 5. Length of barley plants in Experiment 1 as a function of time. Day 1 is the day when the first plants emerged in any of the treatments. The seed was covered by a 2, 5 or 10-cm deep layer of silt loam. The boxes were irrigated to form a hardening surface layer, and this was either loosened manually three days after sowing or left unloosened (Bars denote *0.95 confidence intervals*).

In Experiment 2, the boxes were repeatedly irrigated to keep the soil at suitable water content. Therefore, the final number of plants emerged was high and similar for all treatments (data not shown). However, as shown in Fig. 6 there was a difference between the two soils in growth rate of the seedlings.

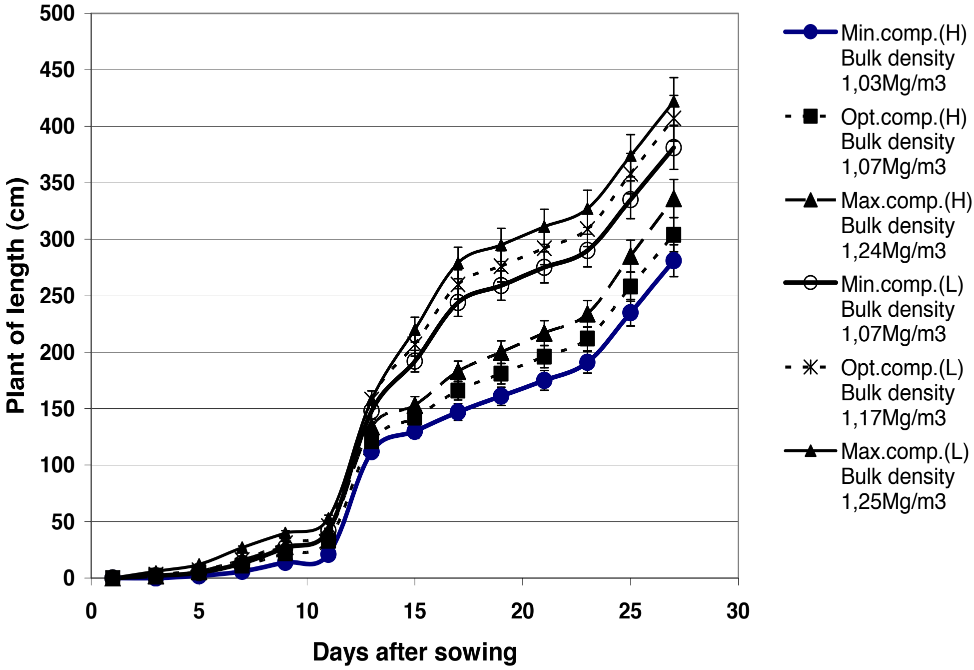

Fig. 6. Length (over the soil surface) of barley plants sown in silty sand (Sa) or clayey silt (Cl) with three bulk densities (ρ) of the soil layer under sowing depth in Experiment 2. Duration of laboratory tests 14.03.02 – 10.04.02 (Bars denote *0.95 confidence intervals*).

The likely reason is a difference in the rate of water uptake due to higher unsaturated hydraulic conductivity in the lighter soil than in the heavier one. In both soils, there was a tendency to increased growth rate with increased density of the basal layer. Even in this case, differences in unsaturated hydraulic conductivity is the most likely reason, since this is generally believed to be improved by compaction, except at very low matric tensions. The result is in agreement with the general experience among farmers in areas with a dry spring. In fine-textured soils in such areas, placement of the seed directly onto a firm seedbed base seems to be a prerequisite for good crop establishment. This experience is supported by results presented by Stenberg (1998).

CONCLUSIONS

Sowing deeper than necessary reduces crop emergence and leads to a delay of the emergence and plants with lower energy status. In a soil with unstable structure, irrigation or rainfall soon after sowing followed by dry weather causes early hardening of the surface layer and a substantial reduction of crop emergence. However, loosening of this layer as soon as it starts hardening may eliminate a considerable part of the detrimental effect. Moderate compaction of the layer under the seed improves crop emergence.

ACKNOWLEDGEMENT
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