Early sowing — a system for reduced seedbed preparation in Sweden

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Abstract

Conventional seedbed preparation for spring sown crops in Sweden includes 3–4 harrowings followed by sowing, but there is a great interest among farmers to reduce this tillage. Since the soil is normally at field capacity after winter, the conventional system implies a major risk of soil compaction and the farmer has to wait for the soil to dry before seedbed preparation can be started. A new technique that has been made possible by new types of seed drills and improved tyre equipment is early sowing of spring cereals without harrowing. It was tested in 74 field experiments in Sweden during 1992–1996, on soils with clay contents ranging from 6 to 57% (typically Eutric or Gleyic Cambisols). On an average, early sowing increased yield by 1% compared with that of conventional sowing. When early sowing was made more than 30 days before conventional sowing it increased yield by an average of 11%. There was no clear relation between yield response to early sowing and soil type. In four long-term experiments, there were no significant differences in bulk density or in saturated hydraulic conductivity between early and conventional sowing. As an average for all experiments, number of emerged plants was 6% lower for early than that for conventional sowing, but this factor did not seem to be decisive for crop yield. In an experiment, when barley (\textit{Hordeum vulgare}, L.) was grown after barley, there was a higher occurrence of leaf scald (\textit{Rhynchosporium secalis} (Sacc.) Shoemaker) and net blotch (\textit{Dreschlera teres} (Oudem) J.J. Davies) in early sown treatments, however, when all results are considered, the risk of increased plant pests due to early sowing seems small. In total, early sowing of spring cereals without harrowing may be beneficial to farmers since it reduces the cost of tillage and increases crop yield potential by lengthening the growing period.

Keywords: Crop yield; Plant establishment; Plant pathogens; Reduced tillage; Soil compaction; Sowing method

1. Introduction

Seedbed preparation and sowing, often referred to as secondary tillage, aim primarily to create suitable soil conditions for germination, plant emergence and subsequent crop growth. This means, for example: (1) The seed is placed at a desired depth, which is as shallow as possible for rapid emergence of seedlings. (2) The soil at sowing depth contains enough water and suitable temperature and aeration conditions for germination, and soil water is transported to the seed. (3) The seedbed should act as an evaporative barrier.
(4) The soil should not be over-compacted due to traffic during seedbed preparation. (5) Tillage operations should also control weeds.

In Sweden there has been much research concerning the desired features of the seedbed, especially for spring sowing followed by dry weather. Håkansson and von Polgar (1976) found that for reliable germination in dry weather, there should be a minimum of 0.06 kg kg\(^{-1}\) plant available water (w/w) on clay loams and clays. Kritz (1983) examined 300 spring sown fields and found that on heavy clay soils sowing depth should be at least 5 cm for the soil to contain enough plant available water, while it could be somewhat less on lighter soils. The main reason for harrowing is to reduce aggregate size, since aggregates 1–2 mm in diameter are most effective in reducing evaporation (Holmes et al., 1960; Heinonen, 1985). Henriksson (1974) recorded increased fineness of the seedbed and crop yield conducting up to eight harrowings plus two rollings on a clay soil. As regards soil compaction, Håkansson (1990) found that after autumn mouldboard ploughing the soil is too loose and there is a need for recompaction to obtain maximum yield.

Thus, this research supported the principle of seedbed preparation on medium and fine-textured soils in the spring being carried out by 3–4 harrowings with a spring-tined harrow. This was to be followed by sowing with a spring-loaded coulter, which put the seed on a firm seedbed bottom created by compaction caused by the harrowing tractor (Fig. 1a).

On self-mulching heavy clay soils, in particular, the method adopted is not really suitable because a 1–2 cm layer of small aggregates giving protection from evaporation is created by frost which diminishes the need for harrowing (Heinonen, 1985). Furthermore, since a fine layer is formed naturally, the central part of the topsoil dries very slowly, making the soil especially susceptible to compaction when normal seedbed preparation is carried out. The bottom part of the seedbed also dries very slowly. The farmer then waits for the soil to become trafficable and friable, and by the time the spring sown crops have developed into a fully transpiring stand, several weeks with good light and temperature for crop growth would have normally passed.

One way to partly solve the problems outlined above may be to sow very early without any other tillage in spring, placing the seed below the dry surface layer (Fig. 1b). In the present context “early sowing” is considered to be a system where the soil is tilled and levelled in the autumn, and drilled in the spring without harrowing 1–6 weeks earlier than the normal time for seedbed preparation, which is possibly followed by a single harrowing to create an evaporative barrier and to control weeds. This method has been made possible mainly by improved tyre equipment, and by new seed coulters that do not need a firm seedbed base to place the seed at the desired depth. This method could be expected to work best when the early sowing is followed by weather with low potential evapotranspiration and occasional rainfall, which diminishes the need for evaporation control and delays the conventional seedbed preparation. Possible benefits of early sowing are: increased yield due to a longer period for growth, reduced tillage costs and the increase in number of days that could be used for sowing. Soil compaction may be reduced due to lower traffic intensity, but may also increase due to higher water content at the time of traffic.

Some pilot experiments were started in 1989 (Arvidsson and Rydberg, 1994), and a total of 74
experiments with similar field plans were conducted during 1992–1996. The objective of these experiments was to study early sowing compared with conventional sowing with emphasis on: (1) crop yield, (2) soil physical properties, and (3) suitability on different soil types. Interactions between early sowing and other management practices showing their effects on crop yield could also be expected. For example, cool and wet conditions during germination might increase the optimum sowing rate for early compared with conventional sowing, whereas a longer time span for tillering might reduce the optimum sowing rate. The need for an even soil surface to perform early sowing in the spring might also change the optimum primary tillage method. Therefore, interactions between sowing method and suitable primary tillage system and sowing rate were studied in separate experiments. In some experiments, the effects of early sowing on plant pathogens were also studied.

2. Materials and methods

The experiments were conducted on soils with clay contents ranging from 6 to 57% covering the most important arable soil types in Sweden. Most of the soils were formed on glacial or postglacial marine or freshwater sediments and some on moraine deposits. No FAO soil classification was made, but based on classification of similar soils, most of the experimental sites can be categorised as Eutric Cambisols or Gleyic Cambisols (Tiberg, 1998).

2.1. Field plans

The field experiments included three sowing treatments:
(A) conventional seedbed preparation and sowing
(B) early sowing: sowing without harrowing 1–2 weeks before conventional sowing
(C) very early sowing: sowing without harrowing 2–3 weeks before conventional sowing (as early as possible)

The experiments were randomised in four blocks, the plot size was usually 12 × 20 m². Treatment A was conducted at the normal time for conventional sowing; normally at the beginning of April in southern Sweden, and at the end of April in central Sweden. In Treatment B, sowing was made when the soil surface was dry enough not to adhere to tractor tyres or seed drills. Treatment C was conducted under conditions similar to those of B; at the first possible occasion in the spring. A total of 70 experiments (location-years) were carried out during 1992–1996. The fields were levelled by harrowing in autumn after primary tillage. Sowing during spring season was done with a disc coulter without any previous tillage. The depth of sowing was regulated by wheels running on the soil surface. The early sowing was carried out when the soil surface had dried, but when the seedbed was not yet friable. Good tyre equipment (tyre inflation pressure generally not exceeding 50 kPa) was used in all experiments. The conventional treatment included 2–4 harrowings, and sowing with the same drill as in the early sown treatments.

Most of these experiments were annual. To study the effect of early sowing on soil physical properties and the interaction between primary and secondary tillage methods, four long-term experiments (Alnarp, Backa, Beteby and Ultuna) were conducted from 1992 to 1996 (included in the 70 location-years). The experiments included two primary tillage treatments and three sowing treatments (Treatments A–C as above):
(1) Mouldboard ploughing
(2) Ploughless tillage

The mouldboard ploughing treatment was conducted during autumn to a depth of 20–25 cm. The ploughless tillage normally included 2–3 cultivations in the autumn to approximately 12 cm depth with a chisel plough or disc cultivator. The experiments had a randomised split-plot design in four blocks, with primary tillages as main plot and sowing methods as subplot. Particle-size distribution and organic matter content for the four experimental sites are given in Table 1.

To study the interaction between sowing method and sowing rate, 17 of the experiments included the subtreatments:
(I) low sowing rate (67% of normal)
(II) normal sowing rate (normal for the crop and the area 150–200 kg ha⁻¹ for cereals)
(III) high sowing rate (150% of normal)
Early sowing was also tested on light sandy soils in southern Sweden (total of four experiments during 1994–1996). These experiments included Treatments A and C of the field plan given above.

2.2. Soil properties

Soil texture was determined in all experiments by the pipette method (Robinson, 1922). Organic matter content was estimated by the loss on ignition during heating to 600°C, corrected according to Ekström (1927).

Measurements of soil physical properties were mainly done during the four long-term experiments. Dry bulk density and saturated hydraulic conductivity were determined on cylinders from Treatments 1A, 1C, 2A and 2C at Alnarp, Backa, Betby and Ultuna. Sampling was carried out after sowing in the year 1996. Four cylinders (72 mm diameter, 50 mm height) were sampled per plot in all four blocks in the 12–17 cm layer. Saturated hydraulic conductivity was measured with a constant-head method as described by Andersson (1955). The cores were then dried at 105°C to determine the bulk density.

Penetration resistance was measured in 1996 with a Bush Recording Penetrometer, 15 recordings per plot in all treatments, before sowing (Backa and Betby) and after sowing (Backa, Betby and Alnarp). Measurements were made at a water content assumed to be close to field capacity.

In 1994 and 1995, the properties of the seedbed in the Ultuna experiment were investigated immediately after sowing according to Kritz (1983). The soil water content in three layers of the seedbed (approximately 0–1.5, 1.5–3 and 3–4.5 cm depth) was determined gravimetrically, and the aggregate size distribution was determined by sieving (<2, 2–5, >5 mm) soil from an area of 0.25 m².}

<table>
<thead>
<tr>
<th>Site</th>
<th>Clay (g kg⁻¹)</th>
<th>Silt (g kg⁻¹)</th>
<th>Sand (g kg⁻¹)</th>
<th>Organic matter (g kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alnarp</td>
<td>180</td>
<td>320</td>
<td>500</td>
<td>25</td>
</tr>
<tr>
<td>Backa</td>
<td>530</td>
<td>370</td>
<td>100</td>
<td>62</td>
</tr>
<tr>
<td>Betby</td>
<td>160</td>
<td>150</td>
<td>690</td>
<td>26</td>
</tr>
<tr>
<td>Ultuna</td>
<td>610</td>
<td>360</td>
<td>30</td>
<td>88</td>
</tr>
</tbody>
</table>

2.3. Crop properties

The crops grown in the experiments were barley (50 experiments), oats (Avena sativa L., 14 experiments) and wheat (Triticum aestivum L., 10 experiments). Crop yield (approximately 20 m² was harvested in each plot) and lodging (visually estimated in the whole plot) were measured in all experiments. In 57 experiments, plant establishment (number of emerged plants per square metre) was measured within an area of 0.25 m² in each plot. The number of plants were counted when enough time had passed for the plants to emerge in the last sown treatment. In the long-term experiments, occurrence of plant pathogenic fungi was visually inspected in June or July each year. If such pests occurred, they were quantified; on 20 main shoots from each plot, the percentage leaf area infested was determined on the first, second, third and fourth leaf from top.

In the experiments with different sowing rates, the number of plants, shoots and axes per square metre were determined within an area of 0.25 m² in each plot.

2.4. Statistical analysis

For the statistical analysis, SAS (1982) was used. Arithmetic means of measured values within each plot were used for the analysis of variance and to calculate treatment means, except for saturated hydraulic conductivity where the median value from each plot was used (Dixon, 1986).

3. Results and discussion

3.1. Soil physical properties

Bulk density was significantly higher in the ploughless tillage than in the mouldboard ploughing plots at Backa, Betby and Ultuna (Table 2). There were no significant differences between sowing treatments or interaction between primary tillage and sowing treatments (Table 2). For saturated hydraulic conductivity there were no statistically significant differences between treatments (Table 2).

Before sowing at Backa and Betby, there was a large and statistically significant difference in pene-
tration resistance between the primary tillage treatments at all but the most shallow depths in the topsoil (Fig. 2). There were small and not significant differences between the sowing treatments, and no significant interaction between primary tillage and sowing treatments.

Penetration resistance after sowing at Backa, Beteby and Alnarp is shown in Fig. 3. The results for Backa and Beteby were similar to those attained before sowing, although at Backa, penetration resistance was significantly lower in the early sown compared with that in the conventional treatment (Fig. 3a and b). At Alnarp penetration resistance after sowing was significantly higher in the ploughless tillage treatment, but with insignificant differences between sowing treatments (Fig. 3c).

Results of the seedbed investigation at Ultuna in 1994 are shown in Fig. 4. The percentage of aggregates <2 mm in the bottom part of the seedbed (Fig. 4a) was much smaller for the early sown treatments than for the conventional. The water content in the upper and lower part of the seedbed and in the seedbed bottom at the time of sowing (Fig. 4b–d) was significantly higher in early sown plots. There were also significantly higher water contents in the ploughless tillage than in the ploughed treatment for the 0–1.5 cm depth range.

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Bulk density (Mg m$^{-3}$)</th>
<th>Saturated hydraulic conductivity (mm h$^{-1}$)</th>
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<tr>
<td></td>
<td>Alnarp</td>
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</tr>
<tr>
<td>(1) Mouldboard ploughing</td>
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<td>1.28</td>
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<td>(2) Ploughless tillage</td>
<td>1.52</td>
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<td>(A) Conventional sowing</td>
<td>1.48</td>
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<td>(C) Very early sowing</td>
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### Analysis of variance

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<td>Sowing method</td>
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</table>

* $P < 0.05$.  

Fig. 2. Penetration resistance before sowing in 1996 at (a) Backa and (b) Beteby. (*) Significant differences between primary tillage treatments ($P < 0.05$).
layer and the seedbed bottom. There was no significant interaction between primary tillage and sowing treatments for any of the investigated parameters. The results for 1995 were similar to those of 1994 (data not shown). The high water content and low proportion of small aggregates in the seedbed for Treatments B and C compared with A indicate that the soil was not friable, and that a conventional seedbed preparation could not have been carried out at the time of the early sowing.

In total, there were only small and inconsistent differences in bulk density, saturated hydraulic conductivity and penetration resistance due to the different sowing methods. In the ploughless tillage plots, the soil in the 12–17 cm layer had not been tilled since the start of the experiment. This means that the effect of traffic in the spring had been cumulative for 3–5 years, still with only small differences between treatments. The soil can be expected to be more sensitive to compaction during early sowing due to a higher water content. However, especially on self-mulching clay soils, drying beneath the surface layer occurs very slowly, as shown by the small difference in water content below the seedbed between sowing dates at Ultuna (Fig. 4d). Ljungars (1977) studied the effects of traffic in the spring on bulk density of seven Swedish soils. Within the variables studied (soil water content, number of passes, vehicle weight, tyre inflation pressure, wheel arrangement, vehicle speed and draught), the soil water content and the number of passes had the largest impact on bulk density. In the experiments presented here, it seems that the lower amount of traffic and the higher soil water content for early compared with conventional sowing resulted in similar soil conditions for both treatments. However, the results also imply that if a conventional seedbed preparation had been carried out at the time for early sowing, this would have resulted in excessive compaction.

In contrast, soil physical properties were much affected by primary tillage method. Penetration resistance was much higher in treatments which were not mouldboard ploughed, especially on the light soil at Beteby but also at Backa and Alnarp. Bulk density was significantly higher in the ploughless tillage than in the mouldboard ploughing treatments at three of the sites,
but with no significant effects on saturated hydraulic conductivity. This could to some extent be caused by a higher variability in the measurements of hydraulic conductivity. However, the results confirm reports of a better pore continuity in non-tilled compared with tilled soil, so that the saturated hydraulic conductivity may be satisfactory although bulk density is increased (Ryderb, 1987; Wu et al., 1992).

3.2. Crop yield

3.2.1. Crop yield — soil type

On an average, crop yield was 1% higher in Treatments B and C than in Treatment A. In a regression analysis, there was no significant correlation between the relative crop yield in Treatment C ($A = 100$) and the soil clay content (Fig. 5). If the experiments are divided into groups based on the clay content, crop yield in Treatment C compared with A was 2% higher for soils with 0–15% clay ($P = 0.44$), 3% lower for soils with 16–30% clay ($P = 0.18$), and 2% higher for soils with more than 30% clay ($P = 0.45$).

Soils with high silt and intermediate clay concentrations are most prone to slaking, crusting and hard-setting (Heinonen, 1982; Mullins et al., 1987). At low

Fig. 4. Seedbed properties at Ultuna in 1994: (a) proportion of aggregates<2 mm in the bottom part of the seedbed, (b) water content in the 0–1.5 cm layer, (c) water content in the 3–4.5 cm layer, (d) water content in the seedbed bottom. Treatments: (A) conventional sowing, (B) early sowing, (C) very early sowing.

Fig. 5. Relative yield ($A = 100$) in the earliest sown Treatment C as a function of soil clay content.
soil temperatures, there is a long time between sowing and crop emergence when the bare soil could be subjected to rainfall. This could be a reason to avoid early sowing on soils with crust problems. The occurrence of crusts was not quantified in these experiments, but it was sometimes seen in early sown treatments. In principle, early sowing could be expected to work best on soils where a particle size range of 1–2 mm forms naturally without harrowing, i.e. on light soils and self-mulching clay soils (Heinonen, 1985).

3.2.2. Crop yield — plant establishment — sowing rate

Plant establishment was on an average somewhat poorer in early sown treatments than in conventional, with 5 and 7% lower numbers of emerged plants for Treatments B and C, respectively. In Treatment B, there was a weak, although statistically significant, correlation between crop yield and plant establishment compared to Treatment A:

Relative yield \( (A = 100) = 79.2 + 0.218 \times \text{relative number of plants } (A = 100), \)

\[ R^2 = 0.19, \quad P < 0.001. \] (1)

For Treatment C there was no such correlation, low and high populations numbers of plants compared with that of Treatment A produced, on an average, similar yields.

The results of the experiments with different sowing rates are shown in Table 3. Despite somewhat poorer plant establishment with early sowing, crop yield was the same as for conventional sowing. The yield response with increasing sowing rate was similar between the sowing methods. In individual experiments, there were statistically significant interactions: in some experiments, increasing the sowing rate was more beneficial in early than in conventional sowing, in other experiments the result was the opposite. A somewhat poorer plant establishment for early sowing might increase the optimum sowing rate. On the other hand, early sowing means that early growth occurs under lower temperature and shorter daylength compared to conventional sowing, which increases the time span available for tillering (Kirby and Ellis, 1980; Bleken and Skjelvåg, 1986) and may reduce optimum sowing rate. On an average the results from our experiments did not indicate any difference in optimal sowing rate between the sowing methods.

3.2.3. Crop yield — difference in sowing time

Relative yield \( (A = 100) \) as a function of the difference in time between conventional sowing and sowing without harrowing is shown in Fig. 6. There was a trend that the larger the difference in sowing date, the greater the yield increase due to early sowing. At the time of conventional seedbed preparation excluding harrowing yield was reduced by 4%. The results imply that the early sowing should be carried out at the first possible opportunity in the spring. The 4% yield decrease when harrowing was excluded at conventional sowing time is in accordance with previous research (Henriksson, 1987).
In practice, both early and conventional sowing could be used on the same farm. This would increase the timeliness of tillage operations, and a larger area could be sown using the same machinery.

3.2.4. Crop yield in the long-term experiments

Relative crop yield (mouldboard ploughing, conventional sowing ≈ 100) in the long-term experiments as an average for each site is given in Table 4. Early sowing and ploughless tillage resulted in higher yield than did conventional sowing and mouldboard ploughing at Backa and Beteby and somewhat lower at Alnarp and Ultuna. On an average for all the sites and years, differences between treatments were small and not statistically significant, although there were significant differences in individual years. At Backa, there was a significant interaction between primary tillage and sowing methods in some years; early sowing gave a larger yield increase when the soil was mouldboard ploughed. This may be explained by difficulties in creating a conventional seedbed due to the uneven surface of the ploughed soil.

3.3. Effects on plant pathogens

In most of the cases there were only small occurrences of pests in the long-term experiments. An exception was the Ultuna site in 1995, the period when barley was grown after barley, and large infestations of leaf scald and net blotch were observed. The occurrence of pests was significantly higher in the ploughless tillage than the mouldboard ploughed treatment, and for early compared to conventional sowing. There was also a significant interaction between primary tillage and sowing method.

Table 4

<table>
<thead>
<tr>
<th></th>
<th>Alnarp (5)</th>
<th>Backa (5)</th>
<th>Beteby (4)</th>
<th>Ultuna (3)</th>
<th>Average (17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouldboard ploughing</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Ploughless tillage</td>
<td>97</td>
<td>101</td>
<td>102</td>
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<td>99</td>
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<tr>
<td>(A) Conventional sowing</td>
<td>100</td>
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<td>(B) Early sowing</td>
<td>99</td>
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<td>(C) Very early sowing</td>
<td>99</td>
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<td><strong>Mouldboard ploughing</strong></td>
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<td>(A) Conventional sowing</td>
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It has often been found that foliar diseases increase in a reduced tillage system due to larger amounts of plant residues (Cook et al., 1978), as in this experiment. The much larger infestation when the field was not mouldboard ploughed shows the importance of crop rotation in a reduced tillage system. The larger infestation of plant pathogens in the early sown treatments can probably be explained by very cool and moist conditions in the spring, in which there was a lot of time for the pests to develop on the small plants that emerged early (Rothrock, 1992). Considering all experiments, the risk of increased plant pests due to early sowing seems small.

4. Conclusions

On an average for 74 location-years of field experiments, there was a 1% yield increase for early compared with conventional sowing. The yield increase was greater when the difference in time between early and conventional sowing was greater. The hypothesis that the method of early sowing could be expected to work best on single-grained soils and self-mulching clay soils could not be supported by statistically significant results in the experiments presented here. In four long-term experiments, there were no significant differences in soil compaction or in saturated hydraulic conductivity between early and conventional sowing. There was no interaction between primary tillage and sowing method in effect on yield. As an average for all experiments, plant establishment was somewhat poorer for early than for conventional sowing. This factor did not seem to be decisive for crop yield and there was no indication in the results that sowing rate should be altered due to sowing method. In an experiment, when barley was grown after barley, there was a higher occurrence of leaf scald and net blotch in early sown treatments, however, on the basis of results from all experiments, the risk of increased plant pests due to early sowing seems small.

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References


