Subsoiling in starch potato growing in Sweden
Investigations to determine whether new deep tillage techniques can lead to higher yields of starch potatoes and better water management

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**Introduction**

The summer of 2008 has provided relatively good growing conditions for potatoes, although, the first two months were dry. The experiment has successfully been carried out according to the plan and the results seem interesting. The interest from growers and the public has also been great during the year. In total almost 650 people has visited the experimental site.

As recommended by the board of Lyckeby research foundation a new setup has been formed for the project “Subsoiling in starch potato growing in Sweden”. The reference group agreed upon that the influence of irrigation on the effect of subsoiling was the most important factor to focus the study on. Further on, it was agreed that 4 replicates should be included and that the soil factor should be excluded.

Since no extra funding was approved for the suggested changes in the experimental setup we had to find other solutions to save costs. Therefore, it was decided to merge the subsoiling field trial with an ongoing irrigation trial at Helgegården (HS-Kristianstad). In this way it was possible to include three different irrigation strategies in a complete block design for a reasonable cost. Having the experiment situated at Helgegården was also beneficial since the trial easily could be demonstrated to farmers during potato event days. Further on, having experienced research staff on site was of course beneficial.

**Background**

Agricultural practices today include the use of heavy machinery, not only for seedbed preparation but also during growth and harvest of the crop. Heavy machines cause high pressure on the soil which may lead to soil compaction (Pierce and Gaye Burpee 1995; Miller and Martin 1986; Parker et al. 1988). Compacted soils may reduce the root system and limit the area from which the plant can extract water and nutrient (Miller and Martin 1986; Ross 1979; Ibrahim and Miller 1989).

Sandy soils, which often are used in potato production, seem to be especially susceptible to subsoil compaction (Miller and Martin 1990; Westermann and Sojka 1996). The soil compaction may reduce both yield and quality and also physically restrict the development of tubers (Westermann and Sojka 1996; Parker et al 1988; Pierce and Gaye Burpee 1995; Sojka et al. 1993b). Plant roots can normally penetrate soils with strength up to 2 to 3 M Pa, but potato roots are more sensitive. Already at a pressure of 1 M Pa the root growth is negatively effected (Stalham, Allen et al. 2007). The ideal soil for potato production is therefore deep, well-drained and loose (Pierce and Gaye Burpee 1995).

Potato plants are more sensitive to water stress and soil water fluctuations than most other crops. They require high water availability with minimum variation in the soil moisture in order to produce high yield- and tuber quality (Buxton and Zalewski 1983). The sensitivity to drought is most often explained by the potato plants relatively shallow root system, and low root: shoot ratio, which limit its capacity to extract water.

Subsoiling is a way to loosen up the plough pan by deeper tillage. During the process vertically fixed blades with an angled extension are cutting and lifting the soil in order to
break the compaction. In general subsoiling decrease soil strength and bulk density which allows the roots to penetrate further down in the soil profile. This can lead to a reduced stress caused by inadequate water and nutrient supply (Miller and Martin 1986).

However, a restricted root system does not necessarily affect the tuber production negatively. If adequate soil moisture and fertility are maintained at near optimum levels within the root zone no beneficial effects are attributed to subsoiling (Ross 1986; Miller and Martin 1990).

Material and methods
A new experimental setup was constructed after interpreting last years result and other international research. The major improvement for this year was that irrigation was added as a treatment. This allowed us to determine under which soil moisture conditions subsoiling was beneficial. New for this year was also that four replicates were included instead of two which we had last year.

Experimental setup
Figure 1 below shows the experimental setup for 2008. Three soil moisture levels were included, 1 No irrigation, 2 high soil moisture (10-30 KPa) and 3 low soil moisture (30-70 KPa). Each moisture treatment had one subsoiled plot and one untreated plot. The subsoiled plots are marked with gray colour in the figure. Four replicates were included in a completely randomized block design. The experiment was irrigated with an automatic drip irrigation system, monitored with IMetos tensiometers connected with an ICA-box. Letter B stands for Bevattningsprogns (irrigation model) which was a treatment in the irrigation trial (not included in the subsoling trial).

![Figure 1. Schematic view over the experimental field. Each plot consists of four sampling rows and two protection rows, marked in red color.](image-url)
Soil conditions at the experimental site
The soil at the experimental site was a sandy loam with a documented plough plan at 25-30 cm.

Plant protection
All plots were treated in the same way regarding plant protection. Table 1 below shows which treatments that has been done and when they have been carried out.

Table 1. Plant protection treatments.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Product</th>
<th>Application level</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeds</td>
<td>Sencor + olja</td>
<td>0,4 + 0,5 l/ha</td>
<td>05-20</td>
</tr>
<tr>
<td></td>
<td>Titus</td>
<td>30 g/ha + 0,3 l/ha</td>
<td>06-14</td>
</tr>
<tr>
<td>Insects</td>
<td>Sumi-Alpha</td>
<td>0,5 l/ha</td>
<td>06-14</td>
</tr>
<tr>
<td></td>
<td>Biscaya</td>
<td>0,3 l/ha</td>
<td>07-14</td>
</tr>
<tr>
<td></td>
<td>Sumi-Alpha</td>
<td>0,5 l/ha</td>
<td>09-03</td>
</tr>
<tr>
<td>Fungus</td>
<td>Shirlan</td>
<td>0,3 l/ha</td>
<td>06-20</td>
</tr>
<tr>
<td></td>
<td>Shirlan</td>
<td>0,4 l/ha</td>
<td>06-30; 07-22; 07-30; 08-07; 09-15</td>
</tr>
<tr>
<td></td>
<td>Epok</td>
<td>0,5 l/ha</td>
<td>07-07; 07-14</td>
</tr>
<tr>
<td></td>
<td>Rannman</td>
<td>0,2 l/ha</td>
<td>08-15; 08-25; 09-03</td>
</tr>
<tr>
<td></td>
<td>Amistar</td>
<td>0,5 l/ha</td>
<td>09-03</td>
</tr>
</tbody>
</table>

Subsoiling
The subsoling was carried out after planting, prior to emergence to avoid re-compaction during planting. The soil was loosened down to 55 cm using an Agrisem cultiplow with two shanks.

Measurements
Yield estimates were conducted twice during the growing season, 20 and 60 days after emergence (d.a.e). Petioles were collected 25 days after emergence and will be analyzed for nutrient content in case there is money left for it. Final tuber yield and size grading were measured at harvest and starch content will be determined during the fall. All statistical analysis was analyzed using the Tukey’s test in the general linear model in SPSS 16.0.
Results

*Yield at first harvest (20 d.a.e)*
All three soil moisture levels resulted in significantly different plant weights (Figure 2). No significant differences were found in yield between the subsoiled plots and the non treated plots.

*Tuber number at first harvest (20 d.a.e)*
All three soil moisture treatments resulted in significantly different tuber number (Figure 3). No significant differences were found in tuber number between the subsoiled plots and the non treated plots.

*Yield at second harvest (60 d.a.e)*
Plants within the irrigated plots weighted significantly more than plants within the non irrigated plots (Figure 4). No difference was found between the 10-30 treatment and 30-70 treatment. No significant differences were found in yield between the subsoiled plots and the non treated plots.
Effects of subsoiling (no wheel track)
Subsoiling greatly reduced the soil resistance (Figure 5.) At 30 cm depth subsoiling reduced the soil resistance from 9 to 1 KPa. The vertical lines shows the standard deviation calculated from the four replicates. The measurements were made 30 d.a.e.

Effects of subsoiling (wheel track)
During the ridging, one pass had to be made with a tractor. The soil resistance was therefore measured after ridging to be able to evaluate the re-compaction. Figure 6 shows how the soil resistance has increased as a result of the extra crossing.

Total yield at final harvest
The total yield within the irrigated plots were significantly higher than the yield within the non irrigated plots. No significant difference in yield was found between the 10-30 treatment and 30-70 treatment. (Figure 7). Subsoiling significantly increased the yield when analysing all three soil moisture levels together. That correspond to a yield increase of approximately six percent or four tonnes per ha. However, when analysing the soil moisture treatments separately, 30-70 KPa was the only one showing significant effects of subsoiling.

Starch content
No significant differences in starch content were found between the treatments. But since the total yield was different between the treatments the total starch yield also differed significant. Subsoling resulted in approximately 1 ton more starch per hectare than the untreated plots.
Tuber size distribution

Result from the grading shows that increased irrigation frequency gives a higher tuber number. It was mainly the fractions 42-55 mm and 55-65 mm that was positively affected.

Subsoiling affected the fraction “bigger than 65 mm” significantly. No other fractions were significantly affected by subsoiling.
Discussion
The result from this experiment shows that subsoiling can increase the yield of starch potatoes grown in Sweden. It is, however, at this stage unclear if the yield increase was a result of reduced water stress or increased nutrient uptake. Since the main difference in yield evolved during the second half of the growing season, when soil moisture conditions were rather wet, it is likely that the increased yield was due to an enhanced nutrient uptake. The fact that medium soil moisture (30-70 KPa) treatment responded more than the un watered treatment further support that theory. Nutrient status of the tubers will therefore be analyzed later on in the fall.

The greatest effect of subsoiling was found among the big tubers (> 65 mm) within the medium soil moisture treatment (30-70 Kpa). This is great results since the medium soil moisture treatment is the one which is most similar to conventional irrigation strategies. It is, however, not in line with other international trials in which the un irrigated treatment responded the most to subsoiling (Ibrahim and Miller 1989). So far the results seem promising but we still have to wait for the final nutrient and starch analysis before making any final conclusions.

Making the subsoiling after planting, prior to emergence, seemed to give a more loose soil with less resistance than subsoiling prior to planting as was done last year. Although when measuring the resistance on top of the ridge it was possible to detect higher resistance right under the ridge (results not shown). Making the subsoiling in between the rows therefore seemed to fail in loosening the whole subsoil area. For next season it may be wise to make one subsoiling of the whole subsoil area prior to emergence and one after planting.

References
All references have been taken used during the work in this project. Not all are cited in this report.


