REPORT FROM LANDSCAPE PLANNING, HORTICULTURE AND AGRICULTURAL SCIENCE

Subsoiling starch potato

Higher yields of starch potatoes and improved water management

Djupluckring i stärkelsepotatis

Högre skörd och förbättrad bevattning av stärkelsepotatis

Johannes Albertsson
Joakim Ekelöf
Tora Råberg
Swedish University of Agricultural Sciences
Faculty of Landscape Planning, Horticulture and Agricultural Science
Department of Agriculture – farming systems, technology and product quality

Rapport 2010:40
ISSN 1654-5427
ISBN 978-91-86373-47-4

REPORT FROM LANDSCAPE PLANNING,
HORTICULTURE AND AGRICULTURAL SCIENCE

Subsoiling starch potato

Higher yields of starch potatoes and improved water management

Johannes Albertsson
Joakim Ekelöf
Tora Råberg
Swedish University of Agricultural Sciences
Faculty of Landscape Planning, Horticulture and Agricultural Science
Department of Agriculture – farming systems, technology and product quality

The project was
cofinanced by Lyckeby
starch and Partnerskap
Alnarp

Preface

The idea that soil compaction can be a yield-limiting factor, was raised within the project "Stay Green", where the different management strategies in growing starch potato were compared. After a couple of initializing pre-studies this project was initiated.

The focus of the project was to study if subsoiling could increase the amount of plant available water and thereby improve the water management. There was also a wish to study how subsoiling affect nutrient uptake.

Lyckeby Starch and Svensk Potatisforskning Alnarp (SPA) cofinanced the project to demonstrate the effect of subsoiling in starch potato were Lyckeby was the main financial partner.

Alnarp, December 2010

Joakim Ekelöf
Project manager
Department of Agriculture
SLU Alnarp

Erik Steen Jensen
Head of Department
Department of Agriculture
SLU Alnarp

Table of content

Abstract

Soil compaction due to heavy machinery and intensive cultivation causing yield reduction in potato is an increasing problem worldwide today. In this experiment inter-row subsoiling at the depth of 55 cm has been tested as a strategy to loosen the soil after planting and thereby increase the yield in starch potato production. The effects of subsoiling were tested in three different irrigation regimes. The results show that subsoiling can increase the starch potato yield significantly in sandy soils where a compacted plough pan is present. This holds true for all years and all cultivars tested. The effect was greater in dry years and decreased with increasing irrigation intensity. However, the starch content of the tubers was not affected by subsoiling but the total starch yield from the field increased with 0.86 ton/ha to 1.37 ton/ha, depending on year, cultivar and irrigation strategy.

Sammanfattning

Markpackning och skördereduktion till följd av trafik med tunga maskiner och intensiv bearbetning är ett växande problem i världen i dag. I försöket djupbearbetades jorden mellan kuporna efter sättning av stärkelsepotatis. Bearbetningen utfördes ner till 55 cm djup. Effekten av djupbearbetningen utvärderades dessutom vid tre olika bevattningsstrategier. Resultatet visar att djupluckring kan öka stärkelsepotatisskörden signifikant där det finns en kompakt plogsula. Resultatet var konsekvent under samtliga tre år och för alla sorter som testades. Effekten var större under torra år och minskade när bevattningsintensiteten ökade. Stärkelsehalten förblev opåverkad av djupluckringen, men den totala stärkelseskörden från fältet ökade med mellan 0,86 ton/ha och 1,37 ton/ha, beroende på år, sort och bevattningsstrategi.

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 & Gaye Burpee, 1995; Miller & Martin, 1986; Parker *et* al., 1989). Compacted soils may reduce the root system and limit the area from which the plant can extract water and nutrient (Miller & Martin, 1986; Ross, 1979; Ibrahim & Miller, 1989). Sandy soils, which often are used in potato production, seem to be especially susceptible to subsoil compaction (Miller & Martin, 1990; Westermann & Sojka, 1996). The soil compaction may reduce both yield and quality and also physically restrict the development of tubers (Westermann & Sojka, 1996; Parker *et* al., 1988; Pierce & Gaye Burpee, 1995; Sojka *et* al., 1993). Plant roots of most species can penetrate soils with pressure up to 2 to 3 MPa, but potato roots are more sensitive. Already at a pressure of 1 MPa the root growth is negatively affected (Stalham *et* al., 2007). The ideal soil for potato production is therefore deep, well-drained and loose (Pierce & 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 yields and tuber quality (Buxton & Zalewski, 1983). The sensitivity to drought is most often explained by the relatively shallow root system of the potato plants, 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 compaction and bulk density, this allows the roots to penetrate further down in the soil profile. It can lead to a reduced stress caused by inadequate water and nutrient supply (Miller & Martin, 1986). However, a restricted root system does not necessarily affect the tuber production negatively. If adequate soil moisture and nutrients are maintained at near optimum levels within the root zone, no beneficial effects are attributed to subsoiling (Ross, 1986; Miller & Martin, 1990).

Material and method

The experimental setup was identical 2008 and 2009 except that two cultivars were grown 2009 (Kuras and Seresta) and only one (Kuras) 2008. Due to different experimental setup in 2007 the materials and methods from that year are presented separately under the subheading "Material and methods 2007".

Experimental setup

The experiment consisted of three irrigation strategies, (1) Non-irrigated, (2) High supply of soil moisture (10-30 kPa) and (3) Low supply of soil moisture (40-70 kPa). Each irrigation strategy consisted of one subsoiled and one conventional tilled plot. In 2009 the site was twice as big because two potato cultivars were grown. Four replicates were included which gives a total of 56 harvest plots 2009 and 28 harvest plots 2008. The experiment was irrigated with an automatic drip irrigation system, monitored with "IMetos tensiometers" and watermark sensors connected with an online ICA-box. The soil at the experimental site was a sandy loam with a documented plough pan at 25-30 cm, which was likely to restrict the root growth and elongation.

Planting

The tubers were planted the 8th of May 2008 and 17th of April 2009 with a row space of 75 cm. The sizes of the seed tubers were between 35-42 mm 2008 and 35-55 mm 2009. In 2008 and 2009 the in-row seed spacing was 20 cm and 35 cm, respectively. The experimental field was ploughed in the autumn and tilled three times before planting in spring.

Subsoiling

The subsoiling was carried out after planting and prior to emergence to avoid re-compaction during planting. The soil was loosened down to 55 cm in between the potato rows using an "Agrisem cultiplow" with two shanks.

Fertilizing strategy

The fertilizing strategy was the same both years. Two weeks after planting 700 kg of Promagna 11-5-18 (micro) was applied per ha. In the middle of June 250 kg/ha of N27 and 200 kg/ha of KMg was applied in bands. The total amount of fertilizer applied to the field was 212 kg N, 35 kg P, 176 kg K, 12 kg Mg and 36 kg S per ha.

Plant protection

All plots were treated in the same way regarding plant protection. Table 1 show treatments applied in 2008. In 2009 the treatments were more or less the same but the dates for application were different.

Table 1. Treatments applied to the experimental fields 2008.

Treatment	Product	Dose	Dates applied
Herbicides	Sencor + oil	0.4 + 0.5 l/ha	20/5
	Titus	30 g/ha + 0.3 l/ha	14/6
Insecticides	Sumi-Alpha	0.5 l/ha	14/6
	Biscaya	0.3 l/ha	14/7
	Sumi-Alpha	0.5 l/ha	3/9
Fungicides	Shirlan	0.3 l/ha	20/6
	Shirlan	0.4 l/ha	30/6. 22/7. 30/7. 7/8. 15/9
	Epok	0.5 l/ha	7/7. 14/7
	Rannman	0.2 l/ha	15/8. 25/8. 3/9
	Amistar	0.5 l/ha	3/9

Weather conditions

There were big differences in the weather conditions between the two years. In 2008 the first part of the growing season was rather dry while the second part was wet (table 2).

Table 2. Water budget for 2008 and 2009

Date	Evapotranspiration	Precipitation	Drained	Water deficit
2008				
May	36.5	6.4	0	30.1
Jun	63.6	37.4	0	26.2
Jul	51.1	43.2	0	7.9
Aug	55.1	149.8	20	+74.7
Sept	98.7	41.8	0	56.9
Sum	**305**	**278**	**20**	**46.4**
2009				
May	58.3	39.5	0	18.8
Jun	58.6	44.5	0	14.1
Jul	70	90.5	5	+15.5
Aug	94.9	49.6	0	45.3
Sept	38.1	22.1	0	16
Sum	**320**	**246**	**5**	**78.7**

In 2009 almost the opposite conditions occurred, with rather wet conditions during the first part of the growing season and dry during the second. The water deficit in August 2009 was 45 mm while in 2008 there was a surplus of 75 mm for the same period. In total there was a difference of 120 mm of rainfall in August between the years. In 2008 the accumulated precipitation was higher and the evapotranspiration lower compared to 2009. This resulted in a larger deficit (32 mm) in 2009 compared to 2008.

Measurements

Yield estimates were conducted twice during the growing season, 20 and 60 days after emergence (DAE) in 2008 and 50 and 125 (DAE) in 2009. Petiole samples were collected approximately 25 (DAE) and analysed for nutrient content. At harvest tubers were collected and analysed for nutrient content. Final tuber yield, size grading and starch content were measured both years. The soil compaction was measured with a penetrometer three times during the growing season; the first one right after planting (before subsoiling), the second one three weeks after subsoiling and the third one some days before harvest. The measurement was taken both in the subsoiled plots and in the normal tilled plots.

Material and methods 2007

In 2007 the experiment was situated at six different farms in Kristianstad. At each farm one experimental plot was prepared (figure 2). The experimental plot contained two different treatments, subsoiling to a depth of 35 cm and conventional soil tillage. Each treatment had two replications per field. Subsoiling was in this case carried out 1-2 weeks prior to seedbed preparation in the opposite direction to the ridges. In the conventional cultivated plots regular seedbed preparation was made. Total yield and starch content was measured at harvest. Several other measurements were also made taken but were not included in the report, since there was no possibility to make any statistical analysis of the data these measurements.

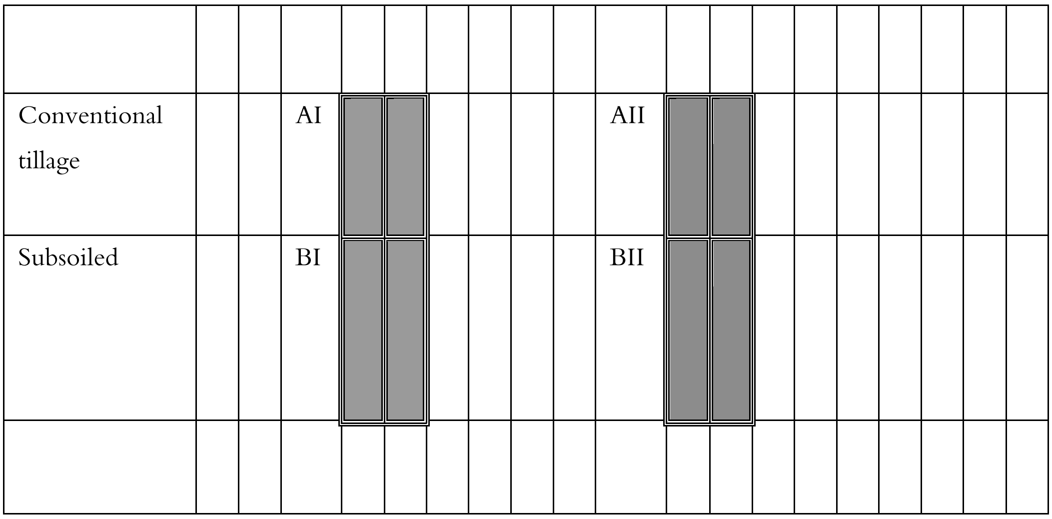

Figure 2. The experimental setup 2007

Results

Final yield

In 2008 subsoiling significantly increased the yield when analysing all three irrigation regimes together and compared them with the control (figure 3). The yield increase was approximately six percent or four tonnes per ha. However, when analysing the two different soil management techniques within each irrigation strategy, 40-70 kPa was the only one showing significant effect of sub-soiling.

A significantly yield increase of subsoiling could also be seen in 2009 for both Kuras (figure 3) and Seresta when analysing all three irrigation regimes together. The yield increase was 10 % for Kuras and 8 % for Seresta. In contrast to the results in 2008 all irrigation regimes, except the 10-30 kPa for Kuras, showed significant higher yields in the subsoiled plots in 2009.

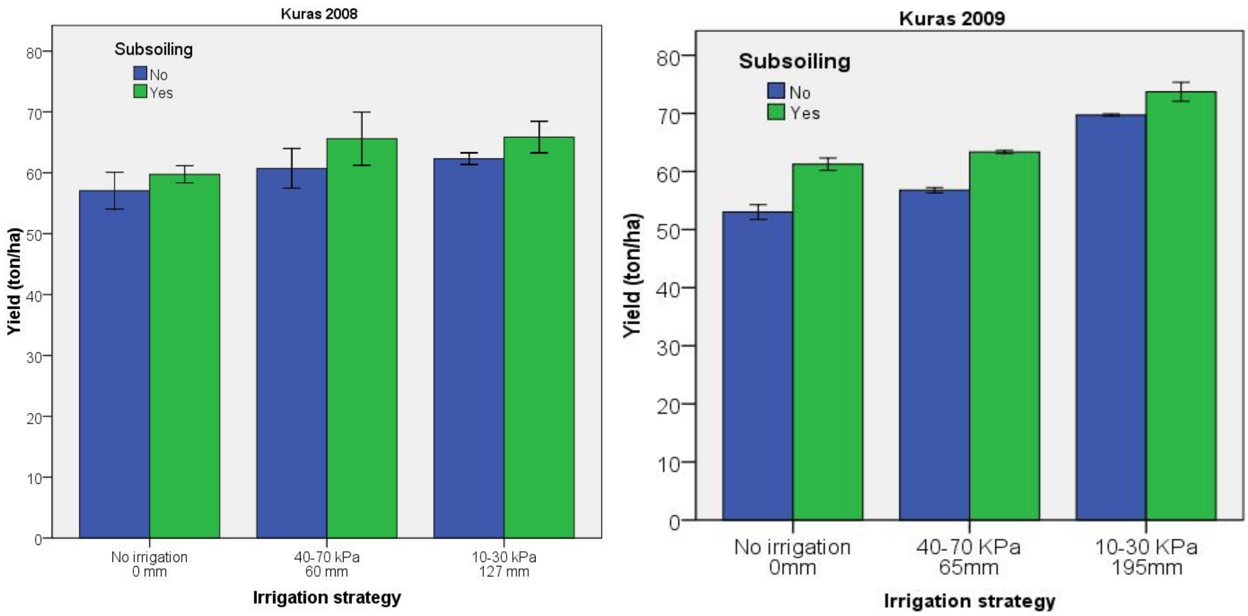

Figure 3. Final yield 2008 and 2009 (Kuras) affected by moisture and subsoiling. Error bars: +/- 1 SE

Starch content and starch yield

The starch content was not affected by the subsoiling and varied between 23.5 % and 25.6 %. However, as there was a yield increase of the subsoiled plots the total starch yield increased with; 0.90 ton/ha (Kuras, 2008), 0.86 ton/ha (Seresta, 2009) and 1.37 ton/ha (Kuras, 2009). The increases were statistically significant.

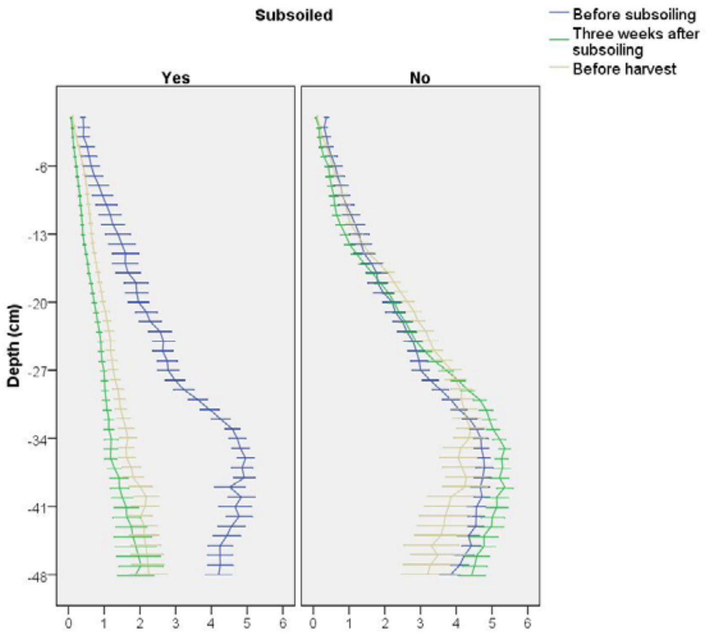

Figure 4. Penetration resistance as influenced by subsoiling.

Penetrometer measurements

A decrease in soil compaction in the subsoiled plots could be seen in the entire soil profile (figure 4). At 30 to 40 cm depths subsoiling decreased compaction from approximately 5 to 1 MPa compared to normal tillage.

Nutrient analysis

The phosphorous content of the petioles 2008 was significantly higher in the subsoiled plots compared to the control, while magnesium was significantly lower. Potassium, iron and manganese content in the leaflets were not affected by subsoiling. The nutrients content of the tubers were also measured at the final harvest 2008. The nutrient content in the tubers was not affected by subsoiling with one exception, sulphur, which had a significantly lower content in the subsoiled plots.

In 2009 the nutrient content in the petioles was not affected by subsoiling. The only exception was the cultivar Seresta, which had significantly higher phosphorous content in the subsoiled plots compared to the control.

Yield estimates

The plant development was studied during the growing season in all years. No significant differences were found in plant weight between the subsoiled plots and the control in the yield estimates made 2008. Two yield estimates were made in Kuras and Seresta 2009. At the first yield estimate the plant weight was significantly higher in the subsoiled plots compared to the control in Seresta, while no difference could be seen in Kuras. Both cultivars had a significantly higher weight in the subsoiled plots compare to the control at the second yield estimate 2009. In conclusion, it seems like the effects of subsoiling arises during the second part of the growing season since the second and final digging always showed the greatest effects.

Tuber size distribution

The size distribution for Kuras was erratic between the years. In 2008, subsoiling increased the fraction ">65 mm" significantly compared with the control. However, the following year the fractions "<42 mm" and "42-55 mm" was positively affected by the subsoiling and not "55-65 mm" and ">65 mm". Seresta had significantly higher yields in the fractions "55-65 mm" and ">65 mm" in the subsoiled plots compared to the control.

Results 2007

The experiment setup 2007, with six different fields and only two replicates on each site, made it hard to draw conclusions about the effect of subsoiling. The mean harvest (ton/ha) of the subsoiled plots was higher in two fields and lower in four, compared to the conventionally tilled plots. There were also large differences in mean harvest (ton/ha) between the fields at the subsoiled plots; 58.5 ton/ha to 24.1 ton/ha.

The starch content varied between fields, but hardly within each field. The highest starch content was 25.5 % and the lowest 19.8 %. Due to the experimental setup it was not possible to make any valid statistical analyse of the data.

The penetrometer measurements showed that there were small effects of the subsoiling, indicating that a recompaction had occurred during seeding. Furthermore, during the growing season precipitation was intense which might have decreased the need for subsoiling.

Discussion

The result from this study shows that subsoiling can increase the yield of starch potatoes grown in Sweden, if carried out properly. A positive effect was seen both in 2008 and 2009 for the cultivar Kuras. An increase in yield was also seen in the cultivar Seresta, which was solely grown in 2009. The results are contradictory to results from Copas *et* al. (2009), where subsoiling did not show any increase in yield. However, in that study the subsoiling was carried out in the autumn or before planting while in this experimental setup it was conducted after planting put before emergence. The differences in timing could be one reason why Copas *et* al. (2009) didn't have any effect of subsoiling. The idea is further supported by the penetrometer measurements made in their study, where only small differences in penetration resistance could be seen between normal tillage and subsoiling. In contrast, a decrease in soil compaction could be seen in the entire measured soil profile in the subsoiled plots (figure 5).

Few other studies have achieved the same great yield response from subsoiling as this study. In a review paper on subsoiling in potato only 28 out of 83 trials showed significant increase in yield (Stalham *et* al., 2005). There are three factors that might explain the unique results of this particular trial: The cultivation depth, the timing of the management and the machinery used. It is also important that the subsoiling was carried out before the potatoes are starting to sprout, as subsoiling at later growth stages risks disturbing the root system (Halderson *et* al., 1993).

The cost of subsoiling is around 900 SEK/ha with the Swedish fuel price 2009. In our study an increase between 0.86 and 1.37 ton starch/ha could be seen due to an increase in potato harvest. Since the price of 1 ton of starch is around 3000 SEK (2009), it makes the subsoiling economically profitable based on the results from both 2008 and 2009 with both cultivars.

Soil compactions may influence factors such as reduced soil porosity, leading to lower water holding capacity and lower soil O_2 concentrations, as well as reduced diffusion and mass flow of nutrients. Due to mechanical resistance to root growth and root elongation the area from where the plant can take up water and nutrients can also be limited (Copas *et* al., 2009). The reason for the increased yield seen in our study is not fully understood. The nutrient content in the tubers and in the leaflets was not higher in the subsoiled plots compared to the control. The only exception was the phosphorous content in the petioles in Kuras 2008 and Seresta

2009. Since the increase of phosphorous was not seen in all nutrient measurements it could not explain the increases solely. Other factors like the water availability may also play an important role. But since the average yield was higher in all the subsoiled plots compared to normal tillage, independent off moisture treatments, it cannot solely be responsible for the increases. It is therefore most likely that both water and nutrient are of importance for the responsiveness of potato to subsoiling.

In 2009, the second part of the growing season was rather dry. In this case, the yield effects of subsoiling declined with increasing irrigation intensity. Similar results were also found in previous studies (Miller & Martin, 1990; Henriksen *et* al., 2007; Ibrahim & Miller 1989). In 2008, the second part of the growing season was rather wet and there was in general less effect of the irrigation. In this case the positive effect of subsoiling was similar regardless of irrigation strategy, which might be explained by increased uptake of nutrient, which had leached below normal rooting depth.

References

Buxton, D.R., and Zalewski, J.C. (1983). Tillage and cultural management of irrigated potatoes. *Agronomy journal* 75: 219-225.

Copas M. E., Bussan A. J., Drilias M. J., Wolkowski R.P. (2009). Potato yield and quality response to subsoil tillage and compaction. *Agronomy Journal* 101: 82-90

Halderson, J.L., McCann, I.R., Stark, J.C. (1993). Zone tillage for potato production. *American society of agricultural engineers.* Vol. 36(5) p. 1377-1380.

Henriksen, C.B., Mølgaard, J.P., Rasmussen, J. (2007). The effect of autumn ridging and inter-row subsoiling on potato tuber yield and quality on a sandy soil in Denmark. *Soil and tillage research.* Vol. 93 p. 309-315.

Ibrahim, B.A. and Miller, D.E. (1989). Effect of subsoiling on yield and quality of corn and potato at two irrigation frequencies. *Soil science society of America journal* 53: 247-251.

Miller, D.E. and Martin, M.W. (1986). The effect of irrigation regime and subsoiling on yield and quality of three potato cultivars. *American potato journal* 64: 17-25.

Miller, D.E. and Martin, M.W. (1990). Responses of three early potato cultivars to subsoiling and irrigation regime on a sandy soil. *American potato journal* 67: 769-777.

Parker, C.J., Carr, M.K.V., Jarvis, N.J., Evans, M.T.B., Lee, V.H. (1989). Effects of subsoil loosening and irrigation on soil physical properties, root distribution and water uptake of potatoes (*Solanum tuberosum*). *Soil and tillage research* 13: 267-285.

Pierce, F.J. and Gaye Burpee, C. (1995). Zone tillage effects on soil properties and yield and quality of potatoes (*Solanum tuberosum L.*). *Soil and tillage research* 35: 135-146.Ross, C.W. (1986). The effect of subsoiling and irrigation on potato production. *Soil and tillage research* 7:315-325.

Ross, C.W. (1979). Tillage pans and the effect of subsoiling on potato production in the Columbia basin, Washington. Dissertation abstracts international. Section B, *The sciences and engineering* 40: 23.

Sojka, R.E., Westermann, D.T., Kincaid, D.C., McCann., I.R., Halderson, J.L., Thornton, M. (1993b). Zone-subsoiling effects on potato yield and grade. *American potato journal* 70: 475-484.

Stalham, M. A., Allen E. J., Rosenfeld A. B., Herry F.X. (2007). "Effects of soil compaction in potato (*Solanum tuberosum*) crops." *Journal of Agricultural Science* 145: 295-312.

Stalham, M. A., Allen, E. J. & Herry, F. X. (2005). A review of the effect of soil compaction on potato growth and its Alternation with cultivation. *Research Review* Ref. R261. Oxford: British Potato Council.

Westermann, D.T. and Sojka, R.E. (1996). Tillage and nitrogen placement effects on nutrient uptake by potato. *Soil science society of America journal* 60: 1448-1453.