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Effects of compaction during drilling on sugar beet yield

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Abstract
Excessive soil compaction can reduce crop growth, but compaction can also have positive effects. For example, it can increase soil unsaturated hydraulic conductivity and thereby the capillary flow of water and nutrients to seeds and plants. There may thus be an optimum state of compactness for plant growth.
This study examined the effect of different levels of compaction on sugar beet growth and sugar yield in a total of 10 field experiments performed during 2006-2008. In most cases, the soil had been mouldboard ploughed in autumn. A newly constructed sugar beet seed drill with press wheels was used to create different levels of compaction directly around the seed. Greater compaction was achieved by 1 or 3 passes by tractor wheels over the soil. The actual degree of soil compaction was determined by measuring bulk density and penetration resistance. Crop growth was determined by measuring root and plant biomass in mid-June and final sugar beet yield. The concentration of plant nutrients in sugar beet foliage was also determined. Two additional experiments in 2009 examined different levels of traffic in combination with mouldboard ploughing or chisel ploughing to 10 or 20 cm depth.
On average, one pass with a tractor wheel increased yield compared with uncompacted soil, but increasing the compaction by press wheels on the seed drill had little effect on yield. In most cases, even three passes with tractor wheels had no harmful effect on sugar yield. The effect of traffic on nutrient uptake was also very small. In one experiment, shallow tillage with a chisel plough lowered yield compared with mouldboard ploughing. There was also an interaction between the effects of primary tillage and compaction in the spring, with more negative effects after shallow tillage.
Overall, the sugar beet crop was relatively insensitive to different levels of traffic applied at the time of sowing. The results indicate that the risk of yield losses due to compaction caused by normal traffic after autumn ploughing is low. However with ploughless tillage, soil bulk density may be too high for optimal growth regardless of traffic during seedbed preparation.
Keywords: Bulk density; Nutrient uptake; Mouldboard ploughing; Ploughless tillage; Shallow tillage

1. Introduction

Soil compaction is generally regarded as being negative within agriculture, since it can lead to impaired root growth, oxygen deficiency, waterlogging and decreased yield. In order to combat compaction effects the soil is therefore loosened, in Sweden mainly by mouldboard ploughing. However, the soil is generally too loose after ploughing to give maximum yield, so some reconsolidation at that point can often give a yield increase. This has been confirmed in Swedish and international studies (Carter, 1990; Håkansson, 1990; Lindstrom and Voorhees, 1994; Lipiec and Simota, 1994; Arvidsson, 1998). The main mechanisms by which a degree of reconsolidation leads to increased yield have not yet been clearly identified, but one obviously important factor is that the capillary transport of water increases in consolidated soil.
Previous experiments have produced different results concerning the sensitivity of sugar beet to compaction. In several studies in Great Britain (Jaggard, 1977; Hebbletwaithe and McGowan, 1980; Brereton et al., 1986), compaction caused substantial yield losses. Unfortunately plant establishment was also affected, which made it difficult to distinguish the direct effects of compaction on plant growth alone. In two experiments with controlled traffic conducted in Holland (Lamers et al., 1986), omitting traffic had no effect on sugar beet yield in one experiment, while it increased yield by 6% in the other. Subsoiling did not affect yield. Subsoiling increased sugar beet yield in a study in Michigan, while compaction caused by secondary tillage decreased yield (Johnson and Erickson, 1991).
A large number of experiments in Sweden on the effects of recompaction after ploughing on yield of different crops showed that some recompaction after ploughing generally increased yield, while repeated wheeling (4 passes with a tractor) reduced yield (Håkansson, 1990; Håkansson, 2000). Sugar beet, barley and winter wheat were less sensitive to compaction than other crops (oats, oilseed rape, peas and potatoes). A series of 11 Swedish experiments on controlled traffic for sugar beet after autumn

ploughing found that yield was mainly lower for no traffic compared with conventional traffic during seedbed preparation (Henriksson and von Polgar, 1987; Sockerbetsnäringens samarbetskommitté, 1987).

The above experiments were carried out in the field, but pot experiments have also been performed on sugar beet. In a study by Gemtos and Lellis (1997), compaction had little effect on aboveground growth but lowered root growth. Romaneckas et al. (2010) found that bulk density between 1.0-1.1 g cm^{-3} resulted in faster emergence and higher yield compared with 0.8 and 1.4 g cm^{-3}. Gemtos et al. (2000) reported increased yield after applying a stress of 50 kPa compared with uncompacted soil, whereas applying stresses of 200 kPa or higher severely reduced yield.

In total, recompaction after ploughing appears to increase sugar beet yield, while strong compaction may reduce yield. However it is unclear whether the whole topsoil needs to be recompacted or whether it is sufficient to recompact around the seed only, which could be done with press wheels on the seed drill. Most of the experiments referred to above were carried out on autumn-ploughed soil. However, the effect of applying traffic may be different in other tillage systems, for example after non-inversion tillage or spring ploughing. The main objectives of the present study were to determine:

1. The significance of reconsolidation for yield of sugar beet.
2. Whether pressure rollers can provide a sufficient degree of reconsolidation compared with tractor wheels.
3. Interactions between tillage method and reconsolidation requirement (autumn ploughing – spring ploughing – ploughless tillage).

During 2006-2008, a series of field trials were carried out with different degrees of reconsolidation by seed drill and tractor. In 2009, additional trials were carried out with different degrees of reconsolidation in tillage systems with and without mouldboard ploughing.

2. Materials and methods

2.1 Reconsolidation experiments with seed drill and tractor

2.1.1 Experimental plan

Three years (2006-2008) of field trials were carried out on a total of 10 sites in south-west Skåne in southern Sweden. In 2006, four trials were carried out on glacial tills in the area around the city of Lund: one at Ädelholm (Ädel1), two at Vragerup Farm (Vrag1 and Vrag2) and one at Stävie (Stäv1). The Ädel1 and Stäv1 trials were carried out on autumn-ploughed soil, while the Vragerup trials were located in the same field, one on autumn-ploughed soil (Vrag1) and one after shallow (5-10 cm) non-inversion tillage (Vrag2). In 2007, three trials were carried out, one at Vragerup (Vrag3), one at Ädelholm (Ädel2) and one at Borgeby (Borg1), all on autumn-ploughed soil. In 2008, a further three trials were carried out, one at Vragerup (Vrag4) and two on neighbouring sites at Borgeby (Borg2, autumn-ploughed; Borg3, spring-ploughed). Ploughing depth was 20-22 cm in all experiments. The trial plan, which was fully randomised in four blocks, included the following treatments:

A. Reconsolidation with pressure roller in the seed furrow, low pressure.
B. Reconsolidation with pressure roller in the seed furrow, normal pressure.
C. Reconsolidation with pressure roller in the seed furrow, high pressure.
D. Reconsolidation with tractor wheels, entire soil surface, one pass.
E. Reconsolidation with tractor wheels, entire soil surface, 3 passes (only in 2007 and 2008).

The treatments were applied in two rows between the tractor wheels, where the soil is otherwise left uncompacted. All passes in harrowing and consolidation were made with a specially designed tractor with extra large track width. The fields were harrowed as necessary, which as a rule meant two harrowings. The depth was adjusted for treatments compacted using the tractor to produce the same tillage depth in all treatments.

Seed was drilled using the Advancer seed drill developed by Edenhall (www.Edenhall.se), which allows reconsolidation to be hydraulically regulated by means of a special press wheel that runs in front of the seed coulters (Fig. 1). In the trials, treatment A was carried out with the lowest possible pressure on

Fig. 1. Seed drill used in trials, 2006-2008. Different levels of pressure can be applied on the press wheel in front of the drill. The disc coulter in front of the press wheel is for application of fertiliser.

the press wheels that still allowed the drill to operate normally. Treatment B used the pressure normally applied during drilling, while treatment C had approximately double the pressure used in B. Compaction with the tractor wheels was applied with the same tractor as used for harrowing (Fig. 2). The weight of the tractor was approximately 6 Mg, while the tyre inflation pressure used in front and rear wheels was 80 kPa (0.8 bar) in 2006 and 60 kPa in 2007 and 2008. Tyre size of the rear wheels was 600/65 R38.

Soil particle size distribution at the different sites is given in Table 1. Most of the soils were sandy loams and can be classified as Eutric Cambisols (FAO-UNESCO, 1994). The wheeling was carried out in direct connection with seedbed preparation in the spring. This meant that the surface soil was in a friable state, but that the central topsoil was at a moisture content close to or slightly below field capacity.

Fig 2. Application of traffic track by track.

Table 1. Soil particle size distribution and organic matter content (g 100 g^{-1}) at the experimental sites

	Clay	Silt	Sand	O.M.
2006				
Vrag1	20.9	26.3	57.1	2.4
Vrag2	24	30.3	50.4	2.4
Stäv	20.8	31.1	53.8	3.6
Ädel1	19.7	28	55.4	1.2
2007				
Borg1	14	21	64	2
Ädel2	16	27	56	1
Vrag3	29	35	35	3
2008				
Borg2	14	22	63	2
Borg3	16	22	61	2
Vrag4	24	32	44	2
2009				
Lönnstorp	20	26	54	3
Ädelholm	14	27	57	1

2.1.2 Measurements of bulk density and penetration resistance

In 2006, penetration resistance after drilling was measured with an Eijkelkamp penetrologger (cone area 1 cm^2) with 35 insertions to 30 cm depth in each plot. Similar measurements were carried out in 2007, involving 14 insertions per plot. In 2006 and 2008, cylinders of soil were extracted for determination of dry bulk density mid-way under the seed furrow at 5-10 cm depth. In 2006, 4 cylinder samples (50 mm high, 72 mm diameter) were taken from each plot in all four blocks. In 2008, 3 cylinder samples per plot were taken from the same depth in three blocks.

2.1.3 Measurements of emergence, plant properties and yield

Plant counts to determine final emergence were carried out around 1 month after sowing. Within each plot, the number of plants was counted in two seed rows with 9 row-metres in each.

At the end of June, sugar beet foliage and roots were weighed separately (fresh weight in the field) for 20 plants per plot. In 2007 and 2008 the plants were then dried and analysed for N, P, K, Ca, Mg, Na, Mn, Cu, Zi, B, Fe, Al, and S content. Beet yield was determined plot-wise, in two seed rows with 9 row-metres in each, as for plant counting. Sugar concentration of the harvested beets was also determined plot-wise.

2.2 Reconsolidation in cultivation with and without ploughing

The two additional trials in 2009 were carried out on glacial till soils with reconsolidation after different tillage operations in the previous autumn. These trials were also located in south-west Skåne, at Lönnstorp and Ädelholm, with the following two-factorial plan:

A= Mouldboard ploughing to ~20 cm
B= Chisel ploughing to ~20 cm
C= Chisel ploughing to ~10 cm

1= No reconsolidation
2=1 pass with tractor
3=3 passes with tractor
4=6-8 passes with tractor

The trials were laid out in a similar way to those in 2006-2008. Primary tillage in treatments A-C was carried out in autumn 2008. Reconsolidation in spring was carried out using a tractor with a total weight of ~6 Mg and a tyre inflation pressure of 60 kPa. Harrowing was adjusted per plot to give a satisfactory seedbed in all treatments. Drilling was carried out using a conventional beet drill without consolidation during drilling (not Edenhall Advancer). Penetrometer measurements were carried out in October 2008 after primary tillage in the autumn. Bulk density was measured on soil cores sampled at 10-15 cm depth in the summer of 2009, three cores per plot.

2.3. Statistical methods

The SAS procedure GLM (SAS, 1982) was used to statistically analyse the results. Statistically significant differences are presented at three levels of significance, *=P<0.05, **=P<0.01 and ***=P<0.001.

3. Results

3.1 Reconsolidation experiments with seed drill and tractor

3.1.1 Bulk density and penetration resistance

Bulk density is shown in Table 2 and penetration resistance at two of the sites is shown in Fig. 3. The trends were similar for both these parameters. Tractor traffic gave an increase in bulk density which was statistically significant in most cases. In 2006, increasing the pressure on the press wheel seemed to increase dry bulk density but differences were not significant. There were no consistent differences in dry bulk density between the different pressures applied on the press wheels in 2008. The increased pressure on the press wheels gave a slight increase in penetration resistance, but the values were clearly highest for tractor traffic. The results from only two experiments are shown in Fig. 3, but the results were similar for all sites. In all experiments tractor traffic increased penetration resistance significantly at 5-10 and 10-15 cm depth. Differences between the press wheel pressures were generally not statistically significant.

Table 2. Soil bulk density (Mg m^{-3}) at the experimental sites, measured in 2006 and 2008

	Vrag1	Vrag2	Stäv1	Ädel1	Vrag4	Borg2	Borg3	Mean (all)	Mean (2008)
Low pressure	1.42	1.43	1.38	1.35	1.57	1.58	1.56	1.47	1.57
Normal pressure	1.44	1.52	1.44	1.35	1.50	1.56	1.54	1.48	1.53
High pressure	1.46	1.48	1.45	1.39	1.51	1.59	1.53	1.49	1.54
Tractor wheels	1.55	1.57	1.56	1.39	1.60	1.63	1.57	1.55	1.60
Tractor 3 passes				1.61	1.65	1.62		1.63	
Signif. level	**	*	*	n.s.	*	n.s.	n.s.		
LSD	0.05	0.06	0.11		0.08				

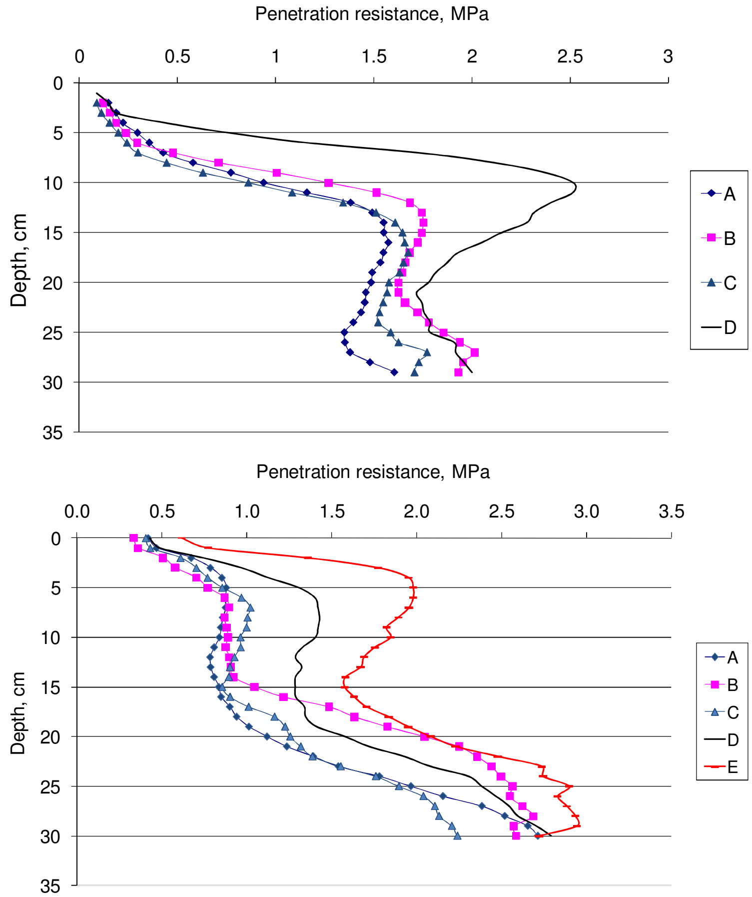

Fig. 3. Soil penetration resistance at Vra1 in 2006 (top) and Borg1 in 2007 (bottom). A=low pressure with press wheels, B=normal pressure, C=high pressure, D=tractor traffic, one pass, E=tractor traffic, three passes.

3.1.2 Plant emergence, root and leaf growth, sugar yield

Plant emergence at all sites is shown in Table 3. The number of plants was relatively stable, with 6.8 m^{-2} as the lowest and 9.3 m^{-2} as the highest value, and most values round 8 m^{-2}. On average, the number of plants was highest for low pressure on the seed drill and lowest for the highest pressure on the drill. Differences between treatments were in most cases not significant. In those cases when there were significant differences between treatments, the number of emerged plants was generally higher for low compared with normal or high pressure on the drill press wheels.

Fresh weight of roots in mid-June is presented in Table 4. On average, root weight was higher for normal and high pressure on the seed drill than for low pressure. This was even more pronounced for aboveground biomass (Table 5). In experiments where differences were significant, root weight was generally higher with increased pressure on the seed drill, and lowest after three passes with the tractor.

Sugar yield is presented in Table 6. On average, the yield was 1% higher for normal and high pressure on the seed drill than for low pressure. One pass with a tractor increased yield by 4% compared with no traffic. In the experiments which included three passes, both one and three passes increased yield by 2% compared with no traffic. Differences between treatments were statistically significant in only one experiment, and close to significant in two experiments. In these three experiments, sugar yield was increased by tractor traffic, while increased pressure on the seed drill had a positive effect on yield in one experiment and a negative effect in two.

There were no significant differences in content of nitrogen and phosphorus in sugar beet leaves (June 2007 and 2008) in any of the experiments (Tables 7 and 8, respectively). The same was true for all other nutrients analysed except for potassium in one experiment (data not shown).

Table 3. Number of emerged sugar beet plants (plants m^{-2}) at the experimental sites, 2006-2008

	2006				2007			2008			Mean	
	Vrag1	Vrag2	Stäv1	Ädel1	Vrag3	Ädel2	Borg1	Vrag4	Borg2	Borg3	All	2007-08
Low pressure	7.8	6.8	8.8	7.7	8.3	8.4	8.4	8.6	8.8	9.1	8.3	8.6
Normal pressure	7.1	8.1	8.4	7.4	7.6	8.1	7.9	8.3	8.1	9.3	8.0	8.2
High pressure	7	8.1	7.7	7.3	7.3	8.1	7.8	8.8	8.2	9.3	8.0	8.3
Tractor 1 pass	8.1	8.5	9	8.8	8.3	8	8.2	8.2	8.8	8.8	8.5	8.4
Tractor 3 passes				8.5	7.8	8.6	8.1	8.3	8.8	8.4		
Signif. level	p=0.09	p=0.05	*	n.s.	*	n.s.	p=0.12	n.s.	*	n.s.		
LSD		1.2	0.8		0.8				0.6			

Table 4. Weight of sugar beet roots (g fresh weight/plant) at the experimental sites, 2006-2008

	2006				2007			2008			Mean	
	Vrag1	Vrag2	Stäv1	Ädel1	Vrag3	Ädel2	Borg1	Vrag4	Borg2	Borg3	All	2007-08
Low pressure	5.2	34	16	4.4	116	66	112	120	52	68	59	89
Normal pressure	4.4	33	18	4.5	129	65	121	137	62	75	65	98
High pressure	4.9	34	22	5.1	129	63	112	134	54	68	62	93
Tractor 1 pass	4.1	26	18	6.9	127	64	132	130	50	78	64	97
Tractor 3 passes				131	50	122	98	53	70		87	
Signif. level	n.s.	n.s.	n.s.	*	n.s.	p=0.13	n.s.	**	n.s.	n.s.		
LSD				1.5				20				

Table 5. Weight of sugar beet shoots (g fresh weight/plant) at the experimental sites, 2006-2008

	2006				2007			2008			Mean	
	Vrag1	Vrag2	Stäv1	Ädel1	Vrag3	Ädel2	Borg1	Vrag4	Borg2	Borg3	All	2007-08
Low pressure	40	168	104	37	244	171	313	170	100	120	147	186
Normal pressure	35	151	125	35	279	183	352	200	105	135	160	209
High pressure	40	182	143	40	298	169	306	205	105	125	161	201
Tractor 1 pass	34	128	116	48	276	169	332	160	90	125	148	192
Tractor 3 passes				276	129	296	130	95	110		173	
Signif. level	n.s.	n.s.	n.s.	**	n.s.	p=0.11	n.s.	***	n.s.	n.s.		
LSD				7				30				

Table 6. Sugar yield (Mg ha^{-1}) and relative values (low pressure with press wheels=100) at the experimental sites, 2006-2008

	2006				2007			2008			Mean	
	Vrag1	Vrag2	Stäv1	Ädel1	Vrag3	Ädel2	Borg1	Vrag4	Borg2	Borg3	All	2007-08
Low pressure	12.4	12.9	9.2	8.6	17.2	15.8	13.5	17	15.5	15.7	13.8	15.8
Normal pressure	94	105	98	101	95	99	108	104	100	104	101	102
High pressure	101	106	93	100	96	99	102	99	103	107	101	101
Tractor 1 pass	105	98	113	109	94	99	109	99	105	104	104	102
Tractor 3 passes				99	92	109	98	105	106		102	
Signif. level	p=0.11	n.s.	*	n.s.	n.s.	n.s.	p=0.09	n.s.	n.s.	n.s.		
LSD			11									

Table 7. Nitrogen content (%) in sugar beet leaves at the experimental sites, sampled in mid-June 2007 and 2008

	2007				2008			
	Vrag3	Stäv2	Ädel2	Borg1	Vrag4	Borg2	Borg3	Mean
Low pressure	3.5	3.7	3.6	3.5	3.3	3.8	3.4	3.5
Normal pressure 3.3	3.5	3.7	3.9	3.3	4.0	3.7	3.6	
High pressure	3.5	3.5	3.7	4.0	2.8	4.0	3.5	3.6
Tractor 1 pass	2.8	3.4	3.6	3.5	3.4	3.9	3.4	3.4
Tractor 3 passes	3.2	3.0	3.2	3.8	3.1	4.0	3.6	3.4

Table 8. Phosphorus content (%) in sugar beet leaves at the experimental sites, sampled in mid-June 2007 and 2008

	2007				2008			
	Vrag3	Stäv2	Ädel2	Borg1	Vrag4	Borg2	Borg3	Mean
Low pressure	0.27	0.37	0.35	0.32	0.22	0.28	0.31	0.30
Normal pressure	0.27	0.32	0.36	0.33	0.25	0.29	0.32	0.31
High pressure	0.28	0.36	0.37	0.32	0.25	0.32	0.31	0.32
Tractor 1 pass	0.28	0.37	0.33	0.32	0.26	0.31	0.31	0.31
Tractor 3 passes	0.28	0.43	0.34	0.32	0.26	0.31	0.31	0.32

3.2 Reconsolidation in cultivation with and without ploughing

Penetration resistance after tillage in the autumn 2008 is shown in Fig 4. The different tillage depths resulted in large differences in penetration resistance at both Lönnstorp and Ädelholm.

Bulk density measured in the summer of 2009 was higher with increased number of passes, and was higher after shallow tillage (Table 9). There was also a clear interaction between tillage and traffic, which was statistically significant at Ädelholm. In treatments with no traffic applied in the spring, bulk density was much higher for shallow tillage than for mouldboard ploughing. Traffic resulted in a large increase in bulk density when the soil was loosened by mouldboard ploughing or deep chisel ploughing, while the effect of traffic was small in the treatment with shallow tillage (Table 9).

At Lönnstorp, three passes with the tractor gave a significant increase in sugar yield compared with one pass or no traffic (Table 10). There were no significant differences in sugar yield between the tillage treatments. The interaction between tillage and compaction was close to significant (p=0.07), with the greatest yield loss for the strongest compaction in shallow tillage. At Ädelholm, yield was similar for 0, 1 and 3 passes, and significantly lower for 6-8 passes. Sugar yield was also significantly lower for shallow

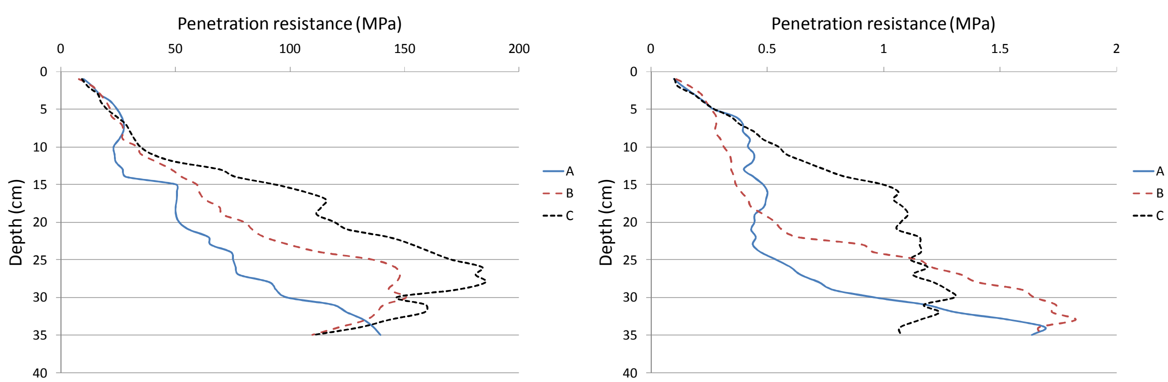

Fig. 4. Soil penetration resistance at Lönnstorp (left) and Ädelholm (right) in 2009. A=mouldboard ploughing, B=chisel ploughing to 20 cm, C=chisel ploughing to 10 cm.

tillage (10 cm) compared with mouldboard ploughing or tillage to 20 cm with a chisel plough (Table 10). Sugar yield as a function of bulk density at the two sites is shown in Fig. 5. At Lönnstorp there was a curvilinear relationship, with the highest yield at intermediate bulk densities. At Ädelholm, there was a negative correlation between yield and bulk density. However, 0-3 passes after mouldboard ploughing or chisel ploughing to 20 cm resulted in bulk densities in the range 1.55-1.65 g cm^{-3}, where there was no clear relationship with yield.

Table 9. Soil bulk density at Lönnstorp and Ädelholm, 2009. Values within the same row or column followed by different letters are significantly different ($p<0.05$)

	Lönnstorp				Ädelholm			
	MP[1]	C20	C10	Mean	MP	C20	C10	Mean
No traffic	1.57	1.59	1.64	1.60b	1.56	1.57	1.73	1.62b
1 pass	1.55	1.62	1.63	1.60b	1.57	1.61	1.75	1.64b
3 passes	1.60	1.63	1.65	1.63ab	1.64	1.62	1.67	1.64b
6-8 passes	1.66	1.66	1.64	1.65b	1.70	1.77	1.68	1.71a
Average	1.60b	1.62ab	1.64a		1.62b	1.64b	1.70a	

[1]MP=Mouldboard ploughing, C20=chisel ploughing to 20 cm, C10=chisel ploughing to 10 cm

Table 10. Sugar yield (Mg ha^{-1}) at Lönnstorp and Ädelholm, 2009. Values within the same row or column followed by different letters are significantly different ($p<0.05$)

	Lönnstorp				Ädelholm			
	MP	C20	C10	Mean	MP	C20	C10	Mean
No traffic	15.6	16	15.3	15.6b	14.0	13.6	12.8	13.5a
1 pass	14.7	15.7	15.8	15.4b	14.5	13.5	12.8	13.6a
3 passes	16.7	15.8	16.3	16.3a	14.0	13.9	12.3	13.4a
6-8 passes	15.7	15.2	14.2	15.0b	12.8	12.7	11.5	12.3b
Mean	15.7	15.7	15.4		13.8a	13.4a	12.4b	

[1]MP=Mouldboard ploughing, C20=chisel ploughing to 20 cm, C10=chisel ploughing to 10 cm

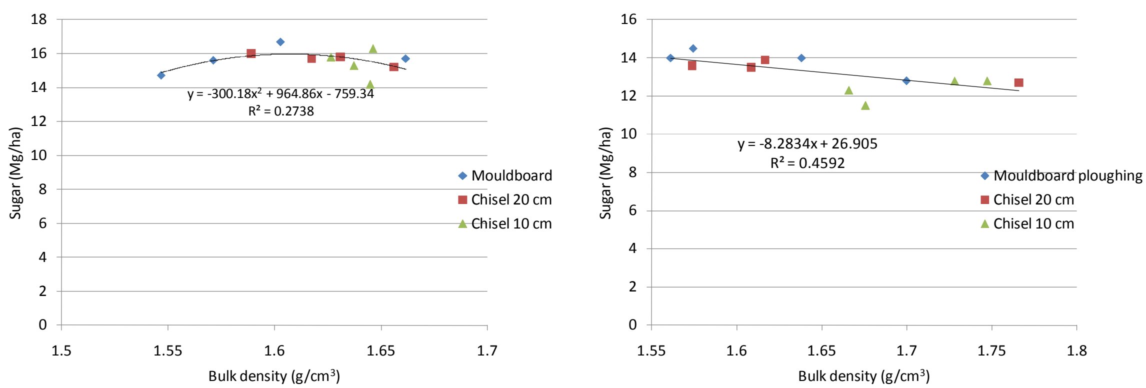

Fig. 5. Sugar yield as a function of soil bulk density at Lönnstorp (left) and Ädelholm (right) in 2009.

4. Discussion

In these experiments the sugar beet crop was relatively insensitive to applied traffic, although some previous studies have identified sugar beet as being sensitive to compaction, e.g. Johnson and Erickson (1991). In some earlier experiments compaction during seedbed preparation also affected plant establishment, which made it difficult to study the effect of compaction on plant growth only (Jaggard, 1977; Hebbletwaithe and McGowan, 1980; Brereton et al., 1986). In the experiments presented here,

seedbed preparation was adjusted to obtain similar seedbed conditions regardless of compaction treatment. Plant establishment was also generally good, with small differences between treatments (Table 3).
In relation to previous studies carried out in Sweden, there were small negative effects of compaction. Yield was lower (although the differences was not statistically significant) for three passes compared with one pass or no traffic in only one out of nine experiments. In contrast, Håkansson (1990) reported a strong reduction in yield for four passes with a tractor. However that tractor was lighter (total weight 3000-4000 kg) but inflation pressure considerably higher (approx. 160 kPa compared with 60 kPa in our experiments), which might explain the differences in crop response. The results indicate that for seedbed preparation under normal conditions, excessive soil compaction can normally be avoided by the use of tyres with low inflation pressure.
In the trials in 2006-2008, a certain degree of reconsolidation after ploughing increased yield (4% increase for one pass with a tractor compared with no traffic), which is in agreement with previous studies (Håkansson, 1990; Lindstrom and Voorhees, 1994; Lipiec and Simota, 1994; Arvidsson, 1998). However, differences in individual experiments were usually not statistically significant. An increase in pressure on the press wheel of the seed drill increased bulk density and penetration, especially in 2006, although to a much lesser extent than tractor traffic, but had little effect on crop yield. It appears that changes in soil physical properties brought about by the press wheel were too small to have a significant effect on crop yield. There was also no clear difference in crop response depending on whether the soil was ploughed in autumn or spring (Borg2 compared with Borg 3).
There were small effects of compaction on plant nutrient uptake. At two of the sites (Ädel2 and Stäv2), nitrogen content was lowest in the most compacted treatments, but differences were not statistically significant. This is remarkable, since compaction affects root growth as well as nutrient transport through diffusion and mass flow (Kemper et al., 1971; Kooistra et al., 1992). Soil aeration status also affects nitrogen turnover and the oxidation status of manganese and iron. Large effects of compaction on plant nutrient uptake have been reported, for example by Lipiec and Stepniewski (1995) and Arvidsson (1999).
The interaction between primary tillage and application of traffic was studied in two separate experiments in 2009. Soil bulk density was considerably higher after shallow cultivation compared with after mouldboard ploughing, which resulted in a yield decrease in one of the experiments. An interesting result is that three passes with a tractor on mouldboard-ploughed soil resulted in lower bulk density than on shallow-cultivated soil with no traffic. In previous Swedish experiments with shallow tillage, sugar beet yields have been reported to be lower on average than for mouldboard ploughing (Arvidsson et al., 2009). Koch et al. (2009) and Jabro et al. (2010) found that increasing tillage depth slightly increased sugar beet yield. However, Becker (1998) found no effect of cultivation depth in conservation tillage in a series of 8 experiments with sugar beets in Germany.

5. Conclusions

Overall, the sugar beet crop was relatively insensitive to different compaction levels arising from traffic applied in the spring, since even three passes with a tractor did not decrease yield compared with no traffic. Differences between treatments were only statistically significant in a very few cases. Recompaction with a drill press wheel had only minor effects on soil physical properties and crop yield. However, moderate recompaction by tractor traffic had a positive effect on sugar beet yield.
Soil bulk density was higher for shallow tillage and no spring traffic than for mouldboard ploughing and three passes in the spring. Shallow tillage also lowered yield compared with mouldboard ploughing in one experiment. The results imply that the risk of yield losses due to compaction is low for normal traffic during seedbed preparation after autumn ploughing. Instead, sugar beet seems capable of near optimum growth at a relatively wide range of bulk densities. However, with ploughless tillage, bulk density may be too high for optimal growth regardless of compaction during drilling.

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Arvidsson, J., 2010. Effects of compaction during seeding on the yield of sugar beets. Proc. 72nd IIRB Congress, 22-24/06/2010, Copenhagen (DK).
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En artikel är också planerad till Betodlaren.

Övrig resultatförmedling

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