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Effects of soil compaction on yield and fertilizer requirement of sugar beet

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SUMMARY

Five experiments (1967–9) on soils formed from calcareous drift examined the effects of soil compaction on seedling emergence and yield of sugar beet, also the interaction between compaction and response to nitrogen fertilizer (N) and phosphate fertilizer (P_2O_5). Some seedbeds were compacted in winter, others in spring and others prepared with the minimum of compaction; each was tested with 0·6, 1·2 and 1·8 cwt/acre N plus 0·8 cwt/acre additional P_2O_5. All plots were given a basal dressing of 0·8 cwt/acre P_2O_5 and enough of other major nutrients.

Compaction decreased seedling populations in four experiments but increased it in one year, when the weather was dry while the seeds were germinating. However, in every experiment compaction significantly decreased yield of roots and sugar. It also interacted with the fertilizer treatments, significantly on average, increasing nitrogen requirement and decreasing phosphate requirement. On average, 0·6 cwt/acre N and 1·6 cwt/acre P_2O_5 gave the greatest yield without compaction and 1·2 cwt/acre N and 0·8 cwt/acre P_2O_5 with compaction.

INTRODUCTION

Slow growth during spring and small yields of sugar beet at Saxmundham Experimental Station (Cooke, 1967) led to an investigation of the effects of soil compaction on sugar-beet emergence and yield. A seedbed with a fine tilth is necessary for good establishment of sugar beet, but on the difficult Saxmundham soil the cultivations needed to produce this can compact the soil. In the experiments, plots were cultivated to give different degrees of compaction before sowing sugar beet. The effect of three amounts of nitrogen and additional phosphate on yield was determined on each compaction treatment.

Few similar experiments have been made in Great Britain but several in the United States. Blake *et al.* (1960) found that compacting soil decreased yield of sugar beet and increased the number of fangy roots, and Stout, Snyder & Carleton (1956) that it affected the germination of sugar-beet seeds because it changed the soil-moisture percentage. Pendleton (1950) found that conventional tillage operations compacted soil and both deep cultivation and farmyard manure improved soil porosity and root shape of sugar beet. Kubota & Williams (1967) who compacted soil at Rothamsted and Woburn after sowing barley and globe beet, found this adversely affected germination, growth and nutrient uptake, especially of the beet.

Whisler, Engle & Banghman (1965) found that increased soil compaction increased the amount of ammonium nitrogen produced when the soils were incubated but decreased the amount of nitrate nitrogen produced in soils given various dressings of nitrogen. Even slight compaction affected the amount of nitrogen mineralised from soil organic matter when soils were incubated.

EXPERIMENTAL

Location and soils

Of five experiments made, two (one in 1967 and one in 1968) were at Saxmundham Experimental Station, East Suffok, and three (one in 1968 and two in 1969) at Broom's Barn Experimental Station near Bury St Edmunds, West Suffolk. The experiments at Saxmundham were on Grove Plot, where the soil is a sandy clay of the Ashley/Hanslope complex formed from Jurassic Boulder Clay. At Broom's Barn the experiments were on soils derived from Calcareous Boulder Clay; two of the experiments (1968 and 1969) were on clay loam of the

Table 1. *Soil analyses at Broom's Barn and Saxmundham*

	Year	Series	Organic carbon (%)	pH	Mechanical analysis (%) Clay	Silt	Fine sand	Coarse sand
Broom's Barn	1968/9	Ashley	0·97	7·5	24	23	35	15
	1969	Stretham	0·82	7·8	16	10	36	35
Saxmundham	1967/8	Ashley/ Hanslope	1·02	7·6	24	10	28	31

Ashley Series and one (1969) on a lighter soil of the Stretham Series. Table 1 gives further details of the soils.

Design and plot size

All of the experiments were of the same design. Compaction treatments were applied to main plots (0·0143 acres at Saxmundham, 0·0210 acres at Broom's Barn) and the fertilizer treatments to split plots (0·0036 acres at Saxmundham and 0·0053 acres at Broom's Barn). There were four replicates in all the experiments. The area harvested was 0·0019 acres at Saxmundham and 0·0022 acres at Broom's Barn.

Treatments

The land was ploughed in autumn or winter 10–12 in deep. Three compaction treatments were compared each year. For the 'winter compaction', the most severe, the ploughed soil was cultivated when dry enough during late winter and allowed to settle before preparing the seedbed in March by rolling and harrowing. For the 'spring compaction' the ploughed soil was broken with a spring-tined cultivator shortly before preparing the seedbed, and then rolled and harrowed several times. The 'no compaction' plots had the minimum of cultivations, after spring-tine harrowing, to give a seedbed in which sugar-beet seed could reasonably be sown.

Fertilizers were applied by hand: three amounts of nitrogen (0·6, 1·2 and 1·8 cwt/acre N as Nitro-Chalk) and 'extra' phosphate (0·8 cwt/acre P_2O_5 as triple superphosphate, with 1·2 cwt/acre N). Half the 'extra' phosphate was applied at the time of the winter cultivations and half to the seedbed; the nitrogen was applied to the seedbed. All plots had a basal dressing of other major nutrients which included 0·8 cwt/acre P_2O_5 as triple superphosphate The plots were sown in March or April with rubbed and graded seed (variety Sharpe's Klein 'E') and singled by hand to leave about 30000 plants/acre.

Harvesting and sampling

The sugar beet was harvested by hand and the roots from each plot counted. All the roots were washed, weighed and a sample analysed for sugar percentage.

RESULTS AND DISCUSSION

Averaged over fertilizer treatments and all experiments, winter compaction decreased root yield by nearly 2 tons/acre and sugar yield by 7 cwt/acre (Table 2). The sugar content of the roots was not affected but significantly fewer roots were harvested from plots compacted in winter. Spring compaction decreased yield of roots and sugar by about half as much as winter compaction, did not affect sugar content but decreased plant population slightly. As the plant populations on all the plots in each experiment exceeded 30000/acre, it is improbable that the small effect of compaction on the populations caused the yield losses.

Increasing the nitrogen dressing from 0·6 to 1·2 cwt/acre increased root and sugar yield significantly but decreased both sugar content of the roots (Table 2) and plant population, although not significantly. Increasing the nitrogen from 1·2 to 1·8 cwt/acre increased root and sugar yield slightly, greatly decreased the sugar content and decreased plant population; plots with 1·8 cwt/acre nitrogen had significantly fewer plants than those with 0·6 cwt/acre. The 'extra' phosphate increased root and sugar yield but not significantly on average.

Fig. 1 shows the sugar yields from the individual experiments and the mean of the five experiments for all combinations of compaction and fertilizer treatments. Results of the two experiments at Saxmundham were remarkably consistent. Winter compaction significantly increased the requirement of nitrogen fertilizer by the sugar beet for maximum yield; spring compaction had a similar but smaller effect. Sugar beet needed 1·8 cwt/acre nitrogen fertilizer for maximum yield on compacted plots but only 0·6 cwt/acre on uncompacted plots. 'Extra' phosphate increased yield of sugar with all treatments, but most on the 'no compaction' plots.

At Broom's Barn, the response to nitrogen was less than on the clay at Saxmundham (Adams, 1962, found that sugar beet on the heavy Suffolk

Table 2. *Mean effects of compaction and fertilizer on root and sugar yield, sugar content and plant population at harvest (means of five experiments* 1967–9)

	Root yield (tons/acre)	Sugar yield (cwt/acre)	Sugar content (%)	Plant population (1000 plants/acre)
'Winter' compaction	16·3	56·8	17·5	33·7
'Spring' compaction	17·2	60·0	17·5	34·5
No compaction	18·2	63·5	17·5	35·0
S.E.	±0·21	±0·77	±0·04	±0·39
0·6 cwt/acre N	15·9	56·8	17·8	35·0
1·2 cwt/acre N	17·3	60·5	17·6	34·6
1·8 cwt/acre N	17·9	61·0	17·1	33·6
1·2 cwt/acre N+ 'Extra' 0·8 cwt/acre P_2O_5	17·7	62·1	17·5	34·4
S.E.	±0·24	±0·89	±0·04	±0·45

The standard errors were obtained from experiments × treatments interaction.

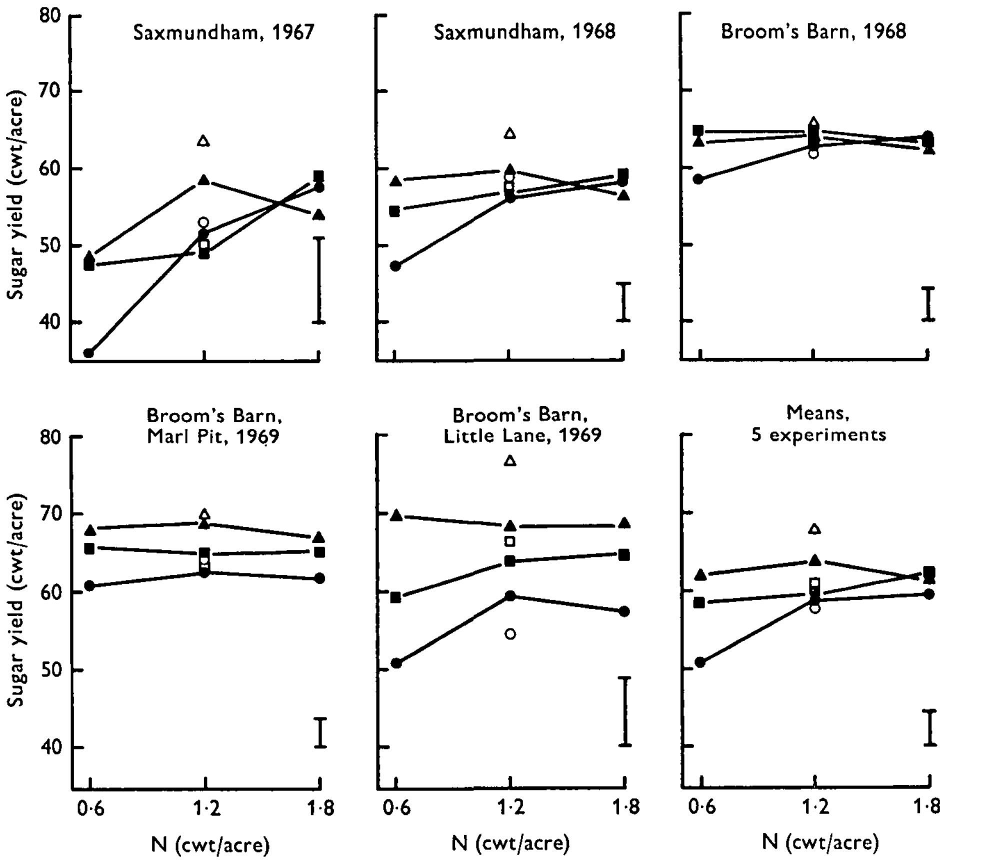

Fig. 1. Effect of soil compaction and fertilizers on sugar yield. I, L.S.D. at $P = 0·05$. ●, 'Winter' compaction (○, with 'extra' phosphate). ■, Spring compaction (□, with 'extra' phosphate). ▲, No compaction (△, with 'extra' phosphate).

Table 3. *Mean effects of compaction and fertilizer on seedling emergence*
(*Number of seedlings*, 1000/acre)

	Saxmundham 1967	Broom's Barn 1968	Broom's Barn Marl Pit 1969	Broom's Barn Little Lane, 1969	Mean
'Winter' compaction	55·2	210·4	243·1	236·8	186·4
'Spring' compaction	75·5	201·3	245·2	232·9	188·7
No compaction	92·3	219·7	252·2	232·3	199·1
0·6 cwt/acre N	71·8	217·5	255·1	244·6	197·3
1·2 cwt/acre N	72·9	208·0	247·8	236·3	191·3
1·8 cwt/acre N	76·0	210·1	238·6	222·2	186·7
1·2 cwt/acre N+ 'extra' 0·8 cwt/acre P_2O_5	76·6	206·3	245·9	232·9	190·4

Boulder Clay soils needed more nitrogen than average), but the effects of compaction on fertilizer requirement were similar on the two farms. Sugar beet needed most nitrogen fertilizer on plots after the winter compaction and least on plots not compacted. In 1969, in both experiments at Broom's Barn, no amount of nitrogen fertilizer made yields on compacted plots equal those on uncompacted ones; in contrast, at Saxmundham, the compacted plots yielded as much as those not compacted when given enough nitrogen. 'Extra' phosphate increased sugar yield significantly in only one of the Broom's Barn experiments (Little Lane, 1969); as at Saxmundham, it gave most benefit on the plots without compaction.

On average of the five experiments (also shown in Fig. 1), nitrogen significantly increased sugar yields after winter compaction but not on uncompacted plots. The negative interaction between compaction and nitrogen fertilizer was significant. 'Extra' phosphate increased sugar yield only on uncompacted plots.

The seedlings that emerged were counted before singling in four of the experiments (Table 3); on average, they were fewer with either compaction or nitrogen. Compaction usually slightly diminished seedling numbers, although in the first experiment it had a large effect; fertilizer effects were not consistent. Seedlings were not counted at Saxmundham in 1968 because dry weather and poor soil conditions caused the seeds to germinate over a period of several weeks and plants were still emerging at singling time. However, observations in early May left no doubt that here, in contrast to the other four experiments, compaction improved establishment, presumably because it increased the moisture retained in the soil, as found by Stout *et al.* (1956).

Bulk density of the soils was measured for the two experiments in 1969 by weighing a constant volume of soil (Table 4). On Marl Pit field spring compaction increased the bulk density by 0·17 at 0–2 in. and winter compaction increased it by 0·31. Soil below 2 in was not affected. On Little Lane, the treatments had little effect on bulk density, except that winter compaction increased it at 2–4 in. None of the treatments in either field in 1969 seems to have affected the bulk density appreciably below 4 in.

Table 4. *Effect of compaction treatments on bulk density (g/ml) of the soil at the end of April* 1969

Depth (in)	No compaction	'Spring' compaction	'Winter' compaction
		Marl pit	
0–1	1·28	+ 0·08	+ 0·14
0–2	1·39	+ 0·17	+ 0·31
2–4	1·55	0	+ 0·02
4–6	1·63	− 0·03	− 0·09
		Little Lane	
0–1	1·21	+ 0·08	+ 0·04
0–2	1·40	+ 0·07	+ 0·09
2–4	1·59	0	+ 0·14
4–6	1·59	+ 0·09	+ 0·06

The compaction of 2–4 in on Little Lane field appeared to produce anaerobic conditions in the soil with slight gleying, which persisted until well after sowing and greatly decreased yield. Plants excavated on these plots during October had roots of a good shape but smaller than those from plots not compacted. The tap roots penetrated the compacted layer of soil and their development seemed normal, but the fibrous roots seemed fewer in the compacted than in the uncompacted plots. This suggests that the yield is affected not because the compacted zone prevented penetration by the tap root, but because the compacted zone affected the soil below and prevented full growth of the root system. Whether the increased requirement of nitrogen fertilizer on compacted plots was because the plants had a smaller root system, or because changes in the soil atmosphere led to denitrification of nitrogen, needs further investigation.

REFERENCES

ADAMS, S. N. (1962). The response of sugar beet to fertilizer and the effect of farmyard manure. *J. agric. Sci., Camb.* **58**, 219–26.

BLAKE, G. R., OGDEN, D. B., ADAMS, E. P. & BOELTER, D. H. (1960). Effect of soil compaction on development and yield of sugar beets. *J. Am. Soc. Sug. Beet. Technol.* **11**, 236–42.

COOKE, G. W. (1967). Rotation I experiment. *Rep. Rothamsted exp. Stn* 1966. p. 249.

KUBOTA, T. & WILLIAMS, R. J. B. (1967). The effects of changes in soil compaction and porosity on germination, establishment and yield of barley and globe beet. *J. agric. Sci., Camb.* **68**, 221–33.

PENDLETON, R. A. (1950). Soil compaction and tillage operations effects on sugar beet root distribution and seed yields. *Proc. Am. Soc. Sug. Beet Technol.* **6**, 278–85.

STOUT, B. A., SNYDER, F. W. & CARLETON, W. M. (1956). The effect of soil moisture and compaction on sugar beet emergence. *J. Am. Soc. Sug. Beet. Technol.* **9**, 277–83.

WHISLER, F. D., ENGLE, C. F. & BANGHMAN, N. M. (1965). The effect of soil compaction on nitrogen transformations in the soil. *Bull. W. Va Univ. agric. Exp. Stn* 516T, 1–12.