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THE EFFECT OF PRIMARY SOIL TILLAGE METHODS ON SUGAR BEET GROWTH ON A LIGHT LOAM LUVISOL

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Abstract

Different primary soil tillage methods intended for sugar beet were investigated at the Experimental Station of the Lithuanian University of Agriculture during the period 2001-2005. The aim of the trial was to ascertain the influence of reduced soil tillage intensity on soil physical properties, sugar beet yield and quality. Treatments of the trial: 1. conventional (22-25 cm) ploughing with a mouldboard plough (CP); 2. shallow (12-15 cm) ploughing with a mouldboard plough (SP); 3. deep (25-30 cm) tillage with a chisel cultivator (DC); 4. shallow (10-12 cm) tillage with a disc harrow (SC); 5. no-tilled soil (NT).

The reducing of primary soil tillage intensity had no significant influence on soil bulk density. In top layers the highest amount of moisture before sugar beet seed germination was observed in no-ploughed soils. Germination of sugar beet seed was poor in no-tilled soil (zero tillage), however this had no serious negative effect on sugar beet yield and quality.

Key words: sugar beet, primary tillage, soil properties, yield, quality.

Introduction

Long-term trials have shown that yields may be maintained with reduced tillage systems, as long as the problems with weeds, residue management and sowing technique are overcome. There is considerable yield variation between years, in both positive and negative directions, possibly due to the interactions between weather conditions and the changes in soil structure that occur when ploughing is omitted. The trials done in Norway show that average yields without ploughing but with autumn harrowing are usually at least 95 % of those obtained with ploughing. With spring harrowing only, the long-term yield is likely to be in the region of 90-95 %, whilst direct drilling may give somewhat great yield reduction /Riley, 2005/. According to the results of ploughing depth investigations carried out for 17 years in Sweden, the shallow ploughing is more effective in light soils and gives 10 % addition of cereal yield /Håkansson et al., 1998/.

The minimisation of primary soil tillage in autumn is possible in tamed soils /Stancevičius et al., 1990; Arlauskas, 1993; Velykis et al., 1996/. Different soil tillage and sowing methods did not have any significant effect on soil bulk density, structure and total porosity /Auškalnis, 2005/. Marginally cultivated soils in spring contain more moisture than in the case of intensive tillage /Cannel, Hawes, 1994; Lafond et al., 2006; Tsuji et al., 2006/. Sometimes at decreasing intensity of soil tillage physical properties of

the soil are constantly improving, although this is observed only after 4-5 years of this soil tillage system application /Håkansson, 1993/. However, the content of organic matter had higher influence on soil physical properties, than soil tillage systems /Arvidsson, 1998/.

The aim of our study was to investigate the influence of soil tillage intensity on soil bulk density and moisture content, productivity and quality of sugar beet root crop. The hypothesis states that decreasing intensity of soil tillage has no significant influence on physical properties of soil, germination of sugar beet seed, crop formation, productivity and quality of roots.

Materials and methods

The trial was conducted on a light loam soil at the Experimental Station of the Lithuanian University of Agriculture during 2001-2005. The soil reaction was slightly alkaline or neutral with a lot of phosphorus and normal amount of potassium. Treatments: 1. Conventional (22-25 cm) ploughing with a mouldboard plough (CP) (control treatment); 2. Shallow (12-15 cm) ploughing with a mouldboard plough (SP); 3. Deep (25-30 cm) cultivating with a chisel cultivator (DC); 4. Shallow (10-12 cm) cultivating with a disc harrow (SC); 5. No-tilled soil (NT).

The trial was replicated four times. Randomized block design was applied. The sugar beet seeds were sown with 45 cm spaces between rows. Winter wheat was the preceding crop of sugar beet. The crops were fertilized with N_{60+60} P_{80} K_{160}. Soil bulk density and moisture content were determined before and after soil tillage till sugar beet seed germination by the cylindrical method of Nekrasov. Soil samples were taken in 4 places per each plot. Sugar beet seed germination was observed by counting seedlings in 8 rows per plot (25.2 m^2). Sugar beet crop density before harvesting, root yield and quality were determined in the samples taken from an area of 9 m^2 per each plot. The express analyses of sugar beet root quality were done in the laboratory of the Kėdainiai sugar factory. The test data were statistically evaluated by ANOVA (LSD_{05}).

The weather conditions were different during the experimental period. In 2001 the average air temperature was higher than the long-term average of Lithuania. The amount of precipitation was by about 100 mm higher, too. The sugar beet growing season was dry in 2002. It resulted in lower root yield but higher sugar content. In 2003 sugar beet seed germination was complicated because of low soil temperature, which resulted in lower plant density in the field. In 2004 the weather conditions during the growing season were close to average conditions in Lithuania. In 2005 the period of sugar beet germination was too wet, and the distribution of rainfall was uneven, which had a negative effect on sugar beet growth.

Results and discussion

Soil physical properties. Soil tillage intensity had no significant influence on soil bulk density in springtime, before pre-sowing soil tillage. In the surface layer (0-10 cm) soil bulk density varied from 1.34 to 1.40 Mg m^{-3} (zero tillage) and in deeper layer (10-20 cm) from 1.36 to 1.46 (zero tillage) Mg m^{-3} (Table 1).

Significantly higher moisture content was determined in unploughed soils, while the highest one – 25.8 % in not tilled soils.

Table 1. Soil physical properties before pre-sowing soil tillage
1 lentelė. *Dirvožemio fizikinės savybės prieš pavasarinį žemės dirbimą*
2001-2005

Treatment *Variantas*	Soil moisture content % *Dirvožemio drėgnis %*		Soil bulk density Mg m^{-3} *Dirvožemio tankis Mg* m^{-3}	
Sampling depth *Mėginių ėmimo gylis*	0-10 cm	10-20 cm	0-10 cm	10-20 cm
Conventional ploughing (CP) *Įprastas arimas*	22.8	24.7	1.34	1.36
Shallow ploughing (SP) *Seklus arimas*	22.6	25.6	1.35	1.37
Deep cultivation (DC) *Gilus purenimas*	24.9	24.9	1.34	1.42
Shallow cultivation (SC) *Seklus purenimas*	24.1	26.3	1.38	1.40
No-tilled (NT) *Nulinis žemės dirbimas*	25.8*	23.8	1.40	1.46
LSD_{05} / R_{05}	1.51	1.68	0.103	0.127

* $P < 0.05$

In deeper layers the highest amount of moisture was observed in shallow-harrowed soils.

Sowing operation exerted negative effect on soil bulk density increase in no-tilled plots (Table 2). Soil bulk density in soil surface layers increased to 1.45 Mg m^{-3}. Generally, after sugar beet sowing no-tilled soil stayed dense. However, bulk density of the soil did not increase significantly.

Table 2. Soil physical properties after sowing till sugar beet germination
2 lentelė. *Dirvožemio fizikinės savybės po sėjos, iki cukrinių runkelių sudygimo*
2001-2005

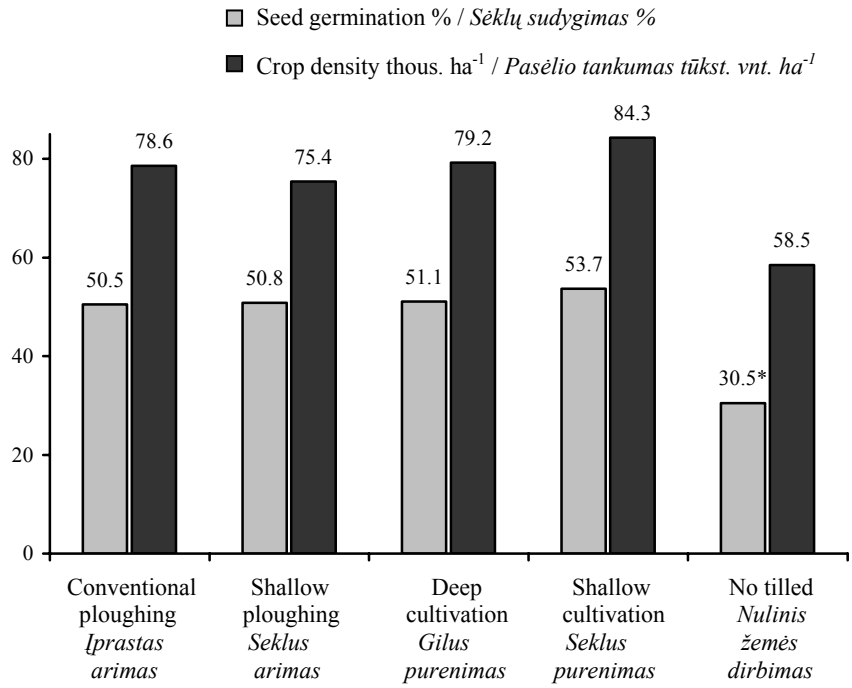
Treatment *Variantas*	Soil moisture content % *Dirvožemio drėgnis %*		Soil bulk density Mg m^{-3} *Dirvožemio tankis Mg* m^{-3}	
Sampling depth *Mėginių ėmimo gylis*	0-10 cm	10-20 cm	0-10 cm	10-20 cm
Conventional ploughing (CP) *Įprastas arimas*	20.6	22.6	1.37	1.42
Shallow ploughing (SP) *Seklus arimas*	19.8	21.4	1.34	1.44
Deep cultivation (DC) *Gilus purenimas*	22.2*	22.7	1.35	1.45
Shallow cultivation (SC) *Seklus purenimas*	22.1*	21.2	1.34	1.43
No-tilled (NT) *Nulinis žemės dirbimas*	22.9*	21.9	1.45	1.47
LSD_{05} / R_{05}	1.45	1.48	0.108	0.142

* $P < 0.05$

There were no significant differences in soil bulk density in deeper layers. Soil bulk density varied from 1.42 to 1.47 Mg m^{-3}.

The surface layer (0-10 cm) of ploughed soils dried the most rapidly after sowing and it contained from 19.8 to 20.6 % of moisture during the period of seed germination. Moisture content of 22.1-22.9 % was observed in no-ploughed soils because of winter wheat straw mulch. The differences were significant. These conditions are most favourable for germination of sugar beet seed. However, in our experiment soil moisture had no significant influence on seed germination because of the problems with sowing technique, which was not favourable for sowing seed into mulched soils.

Sugar beet germination and productivity parameters. Sugar beet seed germination in cultivated soil was similar despite the different soil moisture conditions during the period of germination. Germination of sugar beet seed directly sown into stubble was poor as thick layer of straw at the soil surface blocked incorporation of seeds during sowing. Some of the seeds remained not buried. Poor germination of seeds had negative influence on crop formation (Figure).



* P < 0.05

Sugar beet germination and crop density before sugar beet harvesting, 2001-2005 (LSD_{05} for seed germination – 8.4, for crop density – 22.2)

Cukrinių runkelių sėklų sudygimas ir pasėlio tankumas prieš derliaus nuėmimą, 2001-2005 (R_{05} sėklų sudygimui – 8,4, pasėlio tankumui – 22,2)

According to the average data of 2001-2005, the sugar beet that had been sown into stubble produced similar yield of root irrespective of the crop density. Productivity of root crops varied from 42.6 to 47.9 t ha^{-1} (Table 3). Significant differences between treatments were not determined. However, in 2004 and 2005 reducing of soil tillage intensity had significant negative influence on root yield in the treatment of no-tilled soil because of 50-80 % lower field germination of seed and poor crop density (data are not presented).

Different soil tillage methods had no marked influence on the yield of white sugar. Losses of white sugar yield were determined only in the treatment of direct sowing. In 2004 and 2005 this difference was more significant.

Quality of sugar beet roots. According to the average data of 2001-2005, reduction of soil tillage intensity had a negative effect on sugar beet root ramification (Table 3). Fewer ramified roots were observed in ploughed soils – from 14.3 to 15.6 %. The highest amount of ramified roots (24.7 %) was found in no-tilled soil. In 2001-2003 these trends were not observed. In no-tilled plots much higher ramification of roots was recorded in 2005 because of uneven distribution of rainfall during the sugar beet growing season.

Table 3. Sugar beet yield and quality
3 lentelė. *Cukrinių runkelių derlingumas ir kokybė*
2001-2005

Treatment *Variantas*	Root yield t ha^{-1} *Šakniavaisių derlingumas* *t ha^{-1}*	Root ramification % *Šakniavaisių šakotumas* *%*	Sugar content % Cukringumas *%*	Sugar output % *Cukraus išeiga* *%*	White sugar yield t ha^{-1} *Balto cukraus derlius* *t ha^{-1}*
Conventional ploughing (CP) *Įprastas arimas*	47.9	14.3	16.9	12.95	6.22
Shallow ploughing (SP) *Seklus arimas*	47.2	15.6	16.9	13.12	6.21
Deep cultivation (DC) *Gilus purenimas*	46.2	20.5	17.1	13.21	6.11
Shallow cultivation (SC) *Seklus purenimas*	47.0	22.5	17.2	13.50	6.32
No-tilled (NT) *Nulinis žemės dirbimas*	42.6	24.7	16.9	12.73	5.41
LSD_{05} / R_{05}	12.72	14.36	1.33	0.837	0.975

Neither soil tillage intensity nor crop density had significant effect on sugar content in roots. This suggests that crop density reduction from 84 to 58 th. ha^{-1} had no significant effect on sugar content in sugar beet roots in our trial.

The highest sugar output was determined in the sugar beet after shallow disk-cultivation (harrowing) (13.50 %) because of the highest sugar content in the roots and comparatively high yield. Significant differences were not defined.

Conclusions

1. Reduction of primary soil tillage intensity had no significant effect on soil bulk density. The highest soil bulk density and moisture content in the surface layers (0-10 cm) were observed in no-tilled soils. This relationship was not revealed in deeper soil layers.

2. Different soil tillage methods had no marked negative effect on sugar beet root yield and quality. The sugar beet that had been sown directly into stubble exhibited poor germination, formed thin crop, which had a negative effect on root crop productivity and sugar yield. Significant differences were not established.

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PAGRINDINIO ŽEMĖS DIRBIMO ĮTAKA CUKRINIŲ RUNKELIŲ AUGIMUI LENGVO PRIEMOLIO DIRVOJE

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Santrauka

Lietuvos žemės ūkio universiteto Bandymų stoties lengvo priemolio *Luvisol* dirvoje 2001-2005 m. tirti pagrindinio žemės dirbimo metodai cukriniams runkeliams. Tyrimų tikslas – nustatyti žemės dirbimo intensyvumo mažinimo įtaką dirvos fizikinėms savybėms, cukrinių runkelių derlingumui ir kokybei. Bandymo variantai: 1. Įprastas (22-25 cm gyliu) arimas verstuviniu plūgu. 2. Seklus (12-15 cm gyliu) arimas verstuviniu plūgu. 3. Gilus (25-30 cm gyliu) purenimas sunkiuoju kultivatoriumi. 4. Seklus (10-12 cm gyliu) purenimas lėkštiniu kultivatoriumi. 5. Neįdirbta dirva (nulinis dirvos dirbimas).

Pagrindinio žemės dirbimo intensyvumo mažinimas neturėjo esminės įtakos dirvos tankiui. Didžiausias drėgmės kiekis paviršiniame sluoksnyje buvo nustatytas neartoje dirvoje. Žemės visai nedirbant, cukrinių runkelių sėkla blogai dygo, tačiau tas neturėjo rimtos neigiamos įtakos cukrinių runkelių derlingumui ir kokybei.

Reikšminiai žodžiai: cukriniai runkeliai, pagrindinis žemės dirbimas, dirvos savybės, derlingumas, kokybė.