EFFECT OF SOIL DEEP PLOUGHING ON WINTER WHEAT DEPENDING ON SOIL CONDITIONS

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Abstract. Soil deep ploughing has a significant role on packing prevention technologies of soil layer beneath topsoil. It demands high energy consumption. This investigation was intended to clarify the effectiveness of deep ploughing in various field relief conditions. The experiments were arranged in LUA RFS Vecauce Ltd during the years 2001 - 2007. Field trials were settled in loamy sand sod-podzolic soils with equalized micro-relief during the years 2001-2004. Winter wheat was grown after clover - timothy mixture. The field was treated with glyphosate herbicide after harvesting of fore-crop. Soil tillage included soil deep ploughing in the following treatments: untreated (without tillage), deep ploughing at 0.25, 0.35 and 0.50 m depth. Subsequent soil treatment included soil ploughing at 0.22 – 0.25 m depth and direct sowing. Field trials in production fields were carried out in the years 2004-2007. Soil tillage included soil deep ploughing at the depth of 0.35 and 0.50 m. All observations were carried out in certain field points detected by GPS. The chosen fields had wavy meso-relief. Grain yield was determined by CLASS LEXION 420 GPS-established harvest maps. Soil deep ploughing at the depth of 0.50 m gave the winter wheat yield increase by 7.3% or 0.4 t ha^{-1} on average of three year field trials in 2001-2004. A significant positive effect of soil deep ploughing at the depth of 0.35 and 0.50 m on yield of winter wheat in the next year was determined. The impact on soil resistance from soil deep ploughing was significant only on the trail of tine and 0.10 m away from it. Significant increase of soil resistance was determined at the depth of 0.30 to 0.50 m in treatments with soil ploughing what showed formation of plough pan, but that was determined only in treatments without soil deep ploughing. Lower soil resistance in the subsoil layer was detected in production fields in the years 2004-2007 but only in treatments with soil deep ploughing in the depth of 0.50 and 0.35 m. Soil had higher moisture content in subsoil at the depth of 0.20-0.25 m if soil deep ploughing at the depth of 0.50 m was done. A significant effect of relative height of specific site, thickness of A horizon and content of organic matter on soil moisture in topsoil and also below topsoil was determined in treatments with and without soil deep ploughing. Soil moisture had an effect on soil resistance in all soil layers up to 0.50 m in both deep ploughed and non-ploughed treatments. Analysis of yield maps from the trial years 2004-2007 did not confirm a positive effect of soil deep ploughing on the winter wheat grain yield in the first year after soil deep ploughing, but if the next year characterised with increased amount of precipitations, soil deep ploughing resulted in a significant decrease of the winter wheat grain yield. The recommendations, which are designed for soil deep ploughing in levelled field conditions, do not give a positive effect in production conditions in areas with marked differences in relative height.

Keywords: soil ploughing, deep ploughing, direct drilling, soil resistance.

Introduction

Soils in Latvia are diverse by different parameters of soil characteristics. This could cause significant crop yield differences inside one field boundaries. Thus, it can increase production costs and could cause inexpedient waste of resources. Using precision field management techniques we can reduce these costs. One of the most expensive soil treatments is soil ploughing, what is also a very energy-consuming process [1-3]. To reduce these costs we should know how different types of soil management effect the yield and soil properties. These questions were investigated in the following trials.

Materials and methods

Field trials were settled in LUA RFS Vecauce Ltd in loamy sand sod-podzolic soils with equalized micro-relief during years 2001-2004. Winter wheat was grown after clover - timothy mixture. The field was treated with glyphosate herbicide *glifoss* 3 l ha^{-1} after harvesting of fore-crop. Soil tillage–drilling technologies included the following treatments: factor A - soil deep ploughing (A1 - untreated (without tillage), A2 - ploughing at depth of 0.25 m, A3 - at depth of 0.35 m, A4 - at depth of 0.50 m); factor B - subsequent soil ploughing (B1 - untreated (without ploughing), B2 - ploughing at 0.22-0.25 m depth); factor C - sowing technique (C1 - using the disc driller with local incorporation of mineral fertilizers (Rapid 400 C), C2 - using the anchor-type driller with vertical power harrow and dispersion of fertilizers before sowing (Amazon AD-403 super)). The grain yield was determined by using the trial harvester Hege-140.

Field trials in production fields were carried out in the years 2004-2007. Soil tillage included soil deep ploughing at the depth of 0.35 and 0.50 m. All observations were carried out in certain field points detected by GPS. The chosen fields had wavy meso-relief with relative height differences up to 20 m. The agrotechnology used in wheat cultivation was equal in the whole field. The grain yield was determined by CLASS LEXION 420 creating GPS-established harvest maps.

The following factors were studied: thickness of the soil Ap horizon, organic matter content (determined in certified soils laboratory), soil penetration resistance of soil layers up to the depth of 0.50 m. Soil penetration resistance as well as soil moisture in both arable layer and in subsoil were determined twice in the vegetation period – in autumn at crops one-two leaf stage (BBCH 11-12) and in spring at wheat tillering stage (BBCH 21-29). Soil penetration resistance was determined using the Eijkelkamp soil penetrometer, but soil moisture was determined with the Erisearch Equipment moisture measuring device.

Results and discussion

Comparison of different factors showed that the highest impact on the grain yield had treatments of soil deep ploughing and soil ploughing. No significant differences were observed between reduced soil tillage treatments and direct drilling if the sum precipitations were within normal limits. Drilling without soil ploughing gave significantly higher grain yield only in 2002 when the sum of precipitation in autumn was extremely low (Table 1).

Table 1

Winter wheat grain yield, t ha^{-1}, depending on soil ploughing before sowing

Soil ploughing treatments, factor B	2002	2003	2004
Direct drilling (without ploughing)	4.59	7.93	5.05
Autumn ploughing at depth of 0.22-0.25 m	4.87	6.60	5.05
$RS^{B}_{0.05}$	0.33	0.32	0.18

The analysis of interaction of the factors showed that in the situation with lack of precipitations as it was in the autumn of 2002 soil deep ploughing gave a significant negative effect to soil ploughing (Table 2). The same relationship, although insignificant (P>0.05), was observed in other trial years, what proves the hypothesis of the trial that doing soil deep ploughing following soil ploughing is unnecessary.

Table 2

Effect of interaction between soil ploughing and soil deep ploughing on winter wheat grain yield, t ha^{-1}

The depth of soil deep ploughing, m (factor A)	Year and soil ploughing treatment					
	2002		2003		2004	
	B1	B2	B1	B2	B1	B2
untreated	4.32	4.12	8.00	6.53	4.92	4.97
0.25 m	4.58	5.10	7.70	6.10	5.01	4.87
0.35 m	4.47	4.82	7.87	6.54	5.16	5.06
0.50 m	4.97	4.54	8.17	7.23	5.11	5.29
$RS^{AB}_{0.05}$	0.67		0.63		0.35	

B1 – direct drilling (without ploughing); B2 – autumn ploughing at depth of 0.22-0.25 m

The analysis of interactions of the effects showed that usage of power harrow together with drilling has negative tendencies to formation of grain yield on the background of soil deep ploughing although this correlation was not significant (P>0.05). None of the tested sowing techniques showed significant advantages using the variation of the yield data S% as a criterion. The significance of soil deep ploughing changed in different sowing technologies depending on the weather conditions. Drilling with an anchor-type driller with vertical power harrow gave significant yield increase in 2002 on the background of soil ploughing, but in growing conditions as it was in 2003 this technique showed significant decrease of the winter wheat yield. Intensive soil tillage in the autumn of 2002 with lack of precipitations caused decrease of the winter wheat grain yield (Table 3).

Table 3

Effect of drilling technologies on winter wheat grain yield depending on soil ploughing, t ha^{-1}

Soil ploughing treatments, factor B	2002		2003		2004	
	C1	C2	C1	C2	C1	C2
Direct drilling (without ploughing)	4.40	4.77	7.82	8.05	5.07	5.03
Autumn ploughing at depth of 0.22-0.25 m	5.11	4.63	6.43	6.78	5.16	4.94
$RS^{BC}_{0.05}$	0.47		0.45		0.25	

C1 – using the disc driller with local incorporation of mineral fertilizers, C2 - using the anchor-type driller with vertical power harrow and dispersion of fertilizers before sowing

Table 4

Efficacy of soil deep ploughing and soil ploughing in next year in repeated winter wheat sowings, yield, t ha^{-1}

Soil ploughing treatments, factor B	Depth of soil deep ploughing, m (factor A)				$\overline{X}_B$
	0.00 m	0.25 m	0.35 m	0.50 m	
Effect from trial in 2002 to yield in 2003					
Direct drilling (without ploughing)	4.56	5.21	5.47	6.17	5.35
Autumn ploughing at depth of 0.22-0.25 m	5.26	6.08	5.86	6.31	5.88
$\overline{x}_A$ $RS^{A}_{0.05}$ = 0.41	4.91	5.65	5.67	6.24	
$RS^{AB}_{0.05}$ un $RS^{B}_{0.05}$	0.69				0.41
Effect from trial in 2003 to yield in 2004					
Direct drilling (without ploughing)	4.50	4.44	4.86	4.76	4.64
Autumn ploughing at depth of 0.22-0.25 m	3.87	4.37	4.64	4.95	4.46
$\overline{x}_A$ $RS^{A}_{0.05}$ = 0.35	4.19	4.41	4.75	4.85	
$RS^{AB}_{0.05}$ un $RS^{B}_{0.05}$	0.69				0.49

The studies found a significant positive effect of soil deep ploughing at the depth of 0.35 and 0.50 m to the following winter wheat yield (Table 4). The effect of soil ploughing differs depending on the year's growing conditions.

Keeping in mind that most soils in Latvia are not placed on even terrain conditions the question arose how soil deep ploughing effects the soil penetration resistance and grain yield on uneven meso-relief conditions. The following trial was arranged to examine yield differences among different soil tillage treatments and to determine the changes of soil resistance and soil moisture in different layers of soil.

The data analysis of soil resistance showed an insignificant effect of soil deep ploughing to soil resistance at the depth of 0.40 to 0.50 m among treatments in the first year after soil deep ploughing (Figure 1).

A significant difference between soil deep ploughing at the depth of 0.50 and 0.35 m was determined in 2006 (Figure 2).

Analysing the effect of soil deep ploughing on the winter wheat grain yield, a significant decrease of the yield after deep ploughing at the depth of 0.35 m in the 1st year but after deep ploughing at the depth 0.50 m in the 2nd year should be noted (Figure 2).

The changes in soil moisture did not differ significantly in the first year after soil deep ploughing, but significantly higher moisture content was observed after soil deep ploughing at the depth of 0.50 m in the second year (Figure 3).

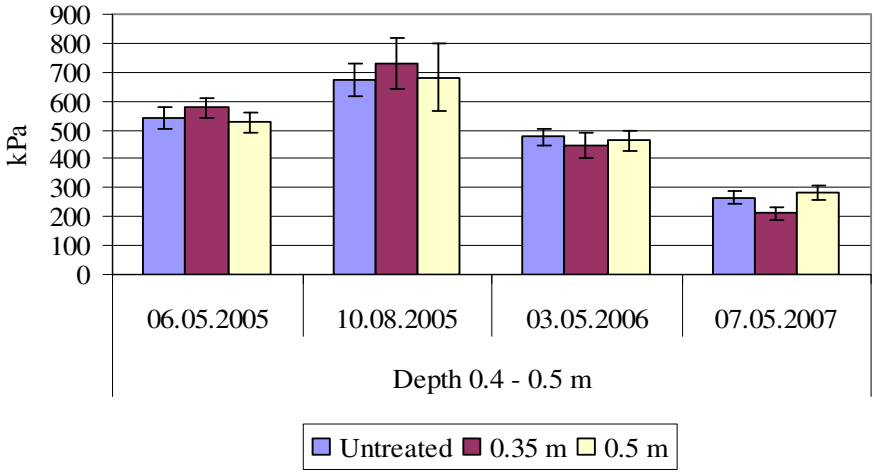

Fig. 1. **Changes of soil resistance in subsoil after soil deep ploughing**

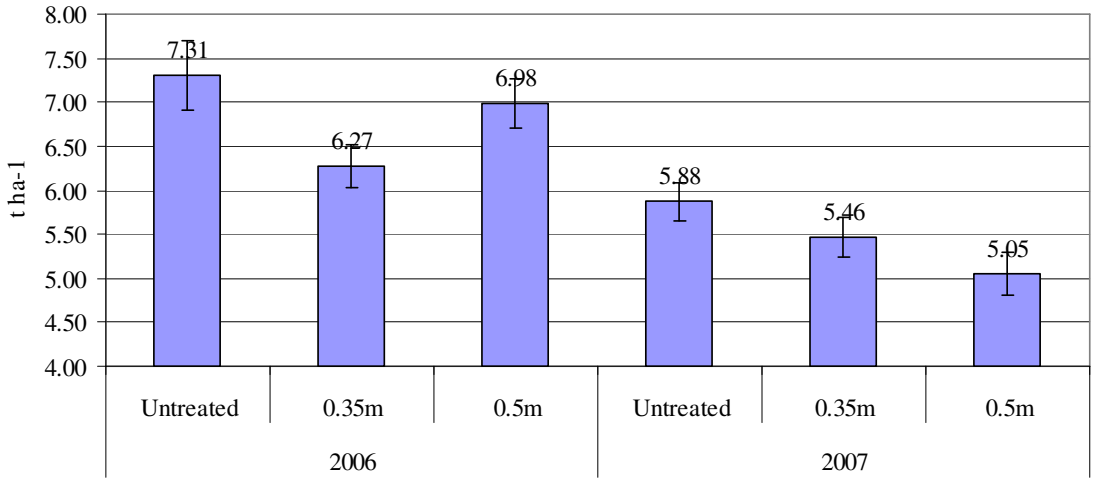

Fig. 2. **Direct impact of soil deep ploughing on the yield in the 1st and 2nd year**

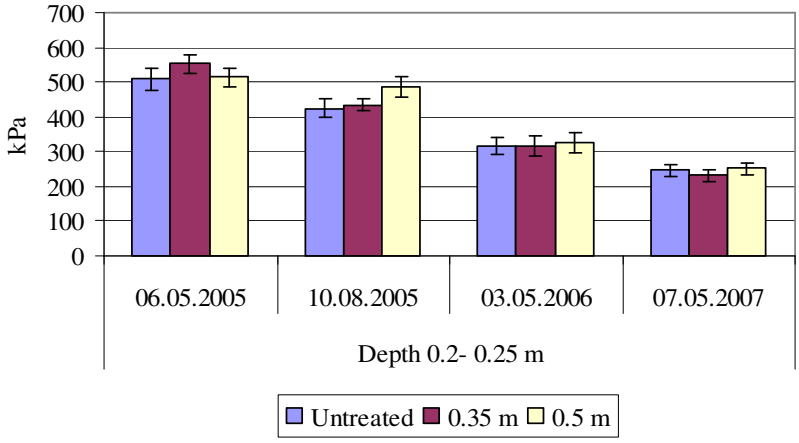

Fig. 3. **Changes of soil moisture in topsoil after soil deep ploughing**

Significantly higher moisture content was determined in subsoil after soil deep ploughing at the depth of 0.50 m compared to the depth of 0.35 m in the first year after deep ploughing, but significant differences compared to untreated were determined in the second year (Figure 4).

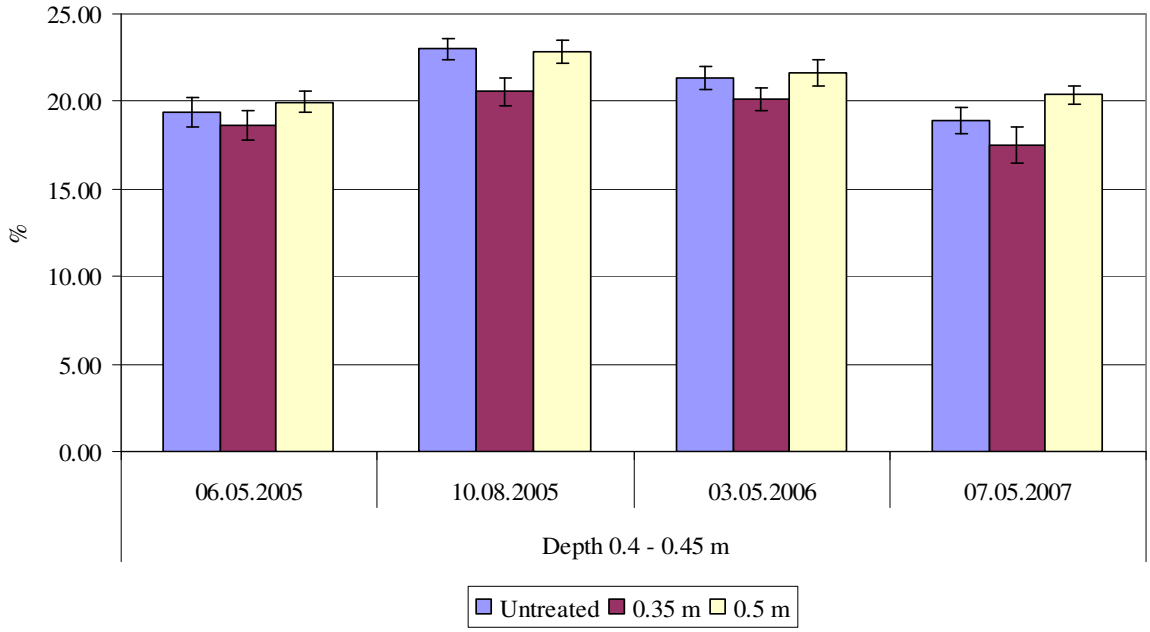

Fig. 4. **Changes of soil moisture in subsoil after soil deep ploughing**

Conclusions

1. No significant differences in winter wheat grain yield were observed between autumn soil ploughing and direct sowing without soil reversing in trials for 2001 to 2004.
2. Soil deep ploughing showed a positive effect on winter wheat yield formation.
3. Trials in the period form 2001 to 2007 showed that the field test results on the effectiveness of soil deep ploughing in conditions of even terrain were not applicable to the production conditions in fields with uneven meso-relief. As the primary cause of this relationship was found changes in soil moisture resulted of soil deep ploughing in uneven fields.

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