Effect of stubble breaking and ploughing at different depths on cultivation of peas

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Abstract. Field trials were conducted over the period 1998–2001 at the Voke Branch of the Lithuanian Institute of Agriculture on a sandy loam *Haplic Luvisol (LVh)*. Pea's precrop was winter rye. Crop residues were returned to the soil; straw was chopped at harvest. The aim of the investigation was to determine the effect of stubble breaking, ploughing at different depths on the weediness of cultivated crop, as well as on the crop yield.

Most couch-grass (*Elytrigia repens (L.) Nevski*) infested were unbroken-stubble and shallow-ploughed plots. It caused a yield reduction by 11–20%. The lowest numbers of weeds were counted and the highest pea's yield was obtained on broken stubble, 0.22–0.25 m depth ploughed.

Key words: stubble breaking, ploughing, straw, peas, weed infestation, yield

INTRODUCTION

Pea has always been regarded as a valuable plant because of its highly nutritive albuminous seeds and soil-improving properties. Pea is a good cover crop for winter crops (Stevenson & van Kessel, 1996; Swensson, 1988). Growing barley after beans and reducing nitrogen fertilisation, the yield was the same as growing barley after cereals (Kankanen et al., 1999).

Recently, successful growing of semi-leafless peas has been started. They perform well alone, unmixed with cereals as the short stem and tendrils make them rather resistant to lodging, thus they are sometimes called non-lodging. Semi-leafless peas are becoming more popular among farmers than their predecessors – leafed peas. Because of high yields and the possibility to be cultivated alone, their crops are expanding rapidly.

Introduction of simplified tillage brought about some problems such as worse loosening. However, in the opinion of some authors, soil compaction does not reduce the yield (Canarache et al., 2000; Droese & Szuecka, 1988).

Weed species variety and aerial mass are lowest under conventional tillage (Menalled et al., 2001). Non-intensive tillage favours the spread of weeds. Weed elimination should account for the level of weed infestation and is profitable when the damage caused by weeds exceeds a certain level (Lu et al., 1999; Lacko - Bartosova et al., 2000; Niemann et al., 2000). Stubble breaking and shallow ploughing are rather good means of weed fighting as they are labour- and money-saving (Kahnt & Eusterschulte, 2000; Tabesch, 1978).

Traditional tillage is not devoid of flaws as ploughing reduces the soil population of earthworms, which accelerate non-decomposed structures to be turned into humus (Chan, 2001). Intensive tillage reduces soil organic carbon levels (Chan, 2001). Lowered humus levels are known to worsen the water and air regime and other physical properties of soil.

The aim of the current work was to establish adequate tillage of light soils in autumn (expediency of stubble breaking and an optimum ploughing depth) when peas are grown after rye, with its straw chopped and spread out.

MATERIALS AND METHODS

Field experiments. The trials were conducted in 1998–2001 at the Vokė Branch of the Lithuanian Institute of Agriculture. The soil was a sandy loam luvisol – *Haplic Luvisol (LVh)* with the content of humus 17.5–18.7 g kg^{-1}, total nitrogen 1–1.05 g kg^{-1}, available phosphorus 190–225 and potassium 230–250 mg kg^{-1} of soil, pH 5.5–5.9.

A trial was started each year after winter rye. Straw was chopped and spread out with a Sampo combine. Stubble breaking was done with a PN-3-35 plough to a depth of 0.10–0.12 m on August 3–11. Late in September – early in October the soil was ploughed to a depth indicated in the scheme and cultivated with a KPS-4-01 cultivator to a depth of 0.10–0.12 m in plots of the 3rd treatments (Table 1).

Table 1. Scheme of the trial.

Treatment No.	Tillage type	Depth, m
1	Stubble broken, ploughed	0.22–0.25
2	Stubble broken, ploughed	0.15–0.17
3	Stubble broken, cultivated	0.10–0.12
4	No stubble broken, ploughed	0.22–0.25
5	No stubble broken, ploughed	0.15–0.17
6	No stubble broken, ploughed	0.10–0.12

In spring, superphosphate (P_{60}) and potassium chloride (K_{60}) were applied before cultivation. Before sowing, the first cultivation was done with a cultivator alone and the second (in a day or two) with a cultivator and harrow 3BZS-1.0. Pea 'Odin' were sown with a Saxonia A-201 seeding machine on April 20–25. The seed rate was 200–220 kg ha^{-1}.

The number of plants was counted after shooting and before harvesting; weed composition, number and air-dried mass in pea crops were determined late in June – early in July. These indices were established for all plots by calculation and sampling in two 0.25 m^2 plots.

The peas were thrashed with a Sampo combine. Before thrashing, 1 kg of samples was analyzed for seed moisture, purity and 1,000 seed mass. Pea yields were recalculated for 15% moisture.

The initial length of a test plot was 15 m, with the width of 4 m and the area of 60 m^2. The area of the accounting plots was $10 \times 2.35 = 23.5$ m^2. Trials were made in four replications.

Analytical methods. Basic soil properties were estimated using the following methods: mobile P and K extracted with a lactate-acetate-ammonium mixture – spectrophotometrically (GOST 26208-91, 1993), total nitrogen – by Kjeldahl instrument (GOST 26107-84, 1985, ISO 11261, 1995), humus content - by Tyurin.

Statistics. The data of number of couch-grass, air-dry mass of weeds and grain yield of peas were processed using the software ANOVA. The data were treated by employing the Fisher's criteria (F) and LSD_{05} (Little & Hills, 1978; Tarakanovas & Raudonius, 2003).

RESULTS AND DISCUSSION

In autumn, when the stubbly soil was ploughed, the quality of ploughing was lower than in plots with previously broken stubble. This tendency was observed every year. In spring, the surface of the plots with stubble-broken and ploughed soil was always smoother and less overgrown with couch-grass than in plots only ploughed. The pre-sowing tillage of the upper layer of the soil was rather well done in all treatments. The evenly distributed chopped rye straw had no effect on stubble breaking or ploughing and on cultivation and sowing in spring.

Every year peas showed good rooting, independently of autumn tillage, and even shooting (on average 96 units per m^2); no distinct and logical differences were found. During harvesting, the average number of pea plants reached 71 units m^{-2}.

In pea crops, the prevailing weeds were couch-grass (*Elytrigia repens* (L.) Nevski), field pansy (*Viola arvensis* Murr.), white goosefoot (*Chenopodium album* L.), odourless dog-fennel (*Tripleurospermum inodorum* (L.). Field sow-thistle (*Sonchus arvensis* L.), dead nettle (*Stachys palustris* L.), field mint (*Mentha arvensis* L.), and other weeds were not numerous.

The differences in the number of couch-grass plants in separate years can be explained by the fact that the trials were set on soils with a different level of couch-grass distribution (Table 2).

Table 2. Number of couch grass (*Elytrigia repens* (L.) Nevski) stems m^{-2}.

Primary soil tillage	1999	2000	2001	Average
Stubble broken, ploughed 0.22–0.25 m	38	9	21	23
Stubble broken, ploughed 0.15–0.17 m	71	4	16	30
Stubble broken, cultivated 0.10–0.12 m	102	49	26	59
Ploughed 0.22–0.25 m	67	26	130	74
Ploughed 0.15–0.17 m	97	35	90	74
Ploughed 0.10–0.12 m	189	71	108	123
LSD_{05}	73	38	48	31

The density of couch-grass in pea crops was highest in 1999 and lowest in 2000. Also weather conditions influence weed emergence and growth of weeds and cereals during the growing (Tørresen et al., 1999). In our case in 1999, conditions did not favour plant growth and development and the yield of peas was not high. In 2000, the end of April and the beginning of May were very warm and dry. There was a lack of humidity also in mid-June, however, the peas did not suffer great losses. Later on, the conditions were more favourable for pea vegetation. The precipitation was sufficient, the plants recovered, and the harvested yield was close to a mean of several years in Voke. In 2001, the dry period occurred early in May and the precipitation was insufficient in June when peas grow intensively. However later, in July, when pods develop, the precipitation was sufficient and, therefore, the yield was rather high for light soils. If there had not been the rather dry weather in June, which hampered the growth of peas, the warm and humid weather of July would have allowed to ripen a high yield of pea seeds.

In all years of the study, stubble breaking followed by deep ploughing was the most efficient means against couch-grass. According to the mean data of the three years, the number of couch-grass stems was also lowest under the same way of tillage. Interestingly, an effective way to fight couch-grass was stubble breaking and ploughing to a depth of 0.15–0.17 m.

Stubble breaking showed a positive effect in all years of the study. The average data of the study show that at the same depth of ploughing, the number of couch-grass stems on the stubble broken soil was half as low as on the stubble-unbroken soil (the difference was essential).

An analysis of ploughing depth showed that the deeper was ploughing, the less was the number of couch-grass plants. Stubble breaking was particularly efficient in 2000 and 2001, but also the mean data of three years showed that stubble breaking reduced the number of couch-grass plants nearly by half.

We do not present data on all perennial weeds. These are very similar to the data on couch-grass density, as the latter was the prevailing perennial weed, and the single plants of other perennial weeds could not influence the data on couch-grass density.

White goose-foot (*Chenopodium album* L.) was not numerous in all years of the study, and its density in pea crops showed no essential dependence on the way of soil tillage.

Also the number of odourless dog-fennel (*Tripleurospermum inodorum* L. sch. Bip.) was low in all years. However, the overwintered samples, growing in the weakly competitive pea crop, can produce 10–20 stems and lower significantly the pea yield. The number of dog-fennel plants was highest in 2000 on a stubble broken and cultivated soil (15 units m^{-2}). The high number resulted from the favourable meteorological conditions, as in the autumn, after stubble breaking, dog-fennel plants managed to shoot and gain vigour and, therefore, the subsequent cultivation in the autumn did not destroy all dog-fennel plants. They overwintered, and many of them survived in spring after the pre-sowing tillage.

In the other tillage treatments, dog-fennel plants were eradicated by autumn ploughing. In spring, dog-fennel shoots were sparse and less harmful, weaker than those overwintered.

Stubble breaking and ploughing showed no essential influence on the number of annual grass plants.

Table 3. Air-dry mass of weeds, g m^{-2}.

Primary soil tillage	1999	2000	2001	Average
Stubble broken, ploughed 0.22–0.25 m	133	142	60	111
Stubble broken, ploughed 0.15–0.17 m	161	121	49	110
Stubble broken, cultivated 0.10–0.12 m	186	150	96	144
Ploughed 0.22–0.25 m	163	145	74	127
Ploughed 0.15–0.17 m	169	129	92	130
Ploughed 0.10–0.12 m	256	154	98	169
LSD_{05}	65	74	51	37

The air-dried mass of all weeds was lowest in 2001, as the period following the sowing was rather dry and the number of weed plants grown from seeds was low (Table 3). In the dry weather the peas performed poorly. After rains the peas gained height and suppressed the shooting weeds, thus the weed mass was comparatively low.

Weed mass in all years was highest on stubble unbroken soils later ploughed to a depth of 0.10–0.12 m. It was somewhat lower on the stubble-broken and then on the cultivated soil.

According to the mean data of the three years, the lowest weed mass was obtained on stubble broken soils ploughed to 0.22–0.25 and 0.15–0.17 m. Weed mass was somewhat higher on stubble unbroken soil ploughed to the above-mentioned depths.

Pea seed yield was lowest in 1999 because of droughts (Table 4).

Table 4. Grain yield of peas, t ha^{-1}.

Primary soil tillage	1999	2000	2001	Average
Stubble broken, ploughed 0.22–0.25 m	1.86	2.78	2.50	2.38
Stubble broken, ploughed 0.15–0.17 m	1.69	2.29	2.34	2.10
Stubble broken, cultivated 0.10–0.12 m	1.51	2.16	2.24	1.97
Ploughed 0.22–0.25 m	1.73	2.55	2.36	2.21
Ploughed 0.15–0.17 m	1.55	2.28	2.10	1.98
Ploughed 0.10–0.12 m	1.32	1.84	2.11	1.76
LSD_{05}	0.21	0.36	0.35	0.18

In all years of the study, pea seed yield was highest on stubble-broken soil ploughed to 0.22–0.25 m. The yield was somewhat lower on stubble-unbroken soil ploughed to the same depth. In all years, the yield was higher on stubble-broken than on the unbroken soil, the depth of ploughing being the same.

With decreasing the depth of ploughing every year, the pea productivity decreased. The productivity was lowest on stubble-unbroken soil ploughed to 0.10–0.12 m depth. The results of long-term experiments with different depths of ploughing in Sweden conclude that it may be profitable to plough sandy soils annually as deep as 30 cm (Håkansson et al., 1998).

The reasons for different yields have been highlighted by assessing an interrelation between seed yield and weed infestation. Fig. 1 shows that the data points reveal an inverse rectilinear dependence of pea seed yield on the number of couch-grass plants. The determination coefficient R^2 = 0.6375 shows that the number of couch-grass plant stems is decisive (64%) for pea seed yield.

Pea yield was found to depend even stronger on the air-dried mass of weeds (Fig. 2). In this case, the coefficient of inverse dependence determination was even higher and reached 0.73.

The data presented in Figures 1 and 2 showed the degree to which pea seed productivity depends on weed infestation and the high importance of the agrotechnical means of fighting against weeds.

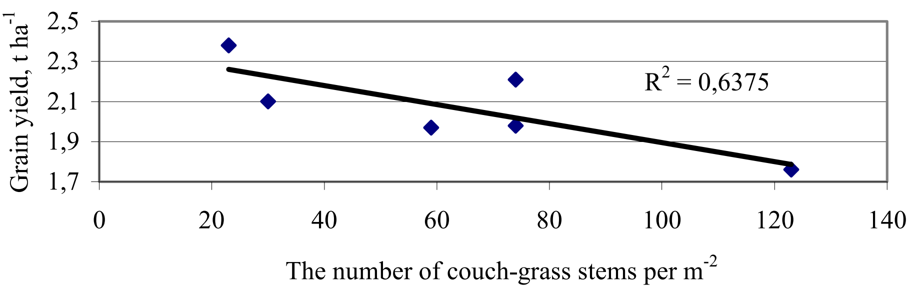

Fig. 1. Influence of number of couch-grass stems on the grain yield of peas (1999–2001 average).

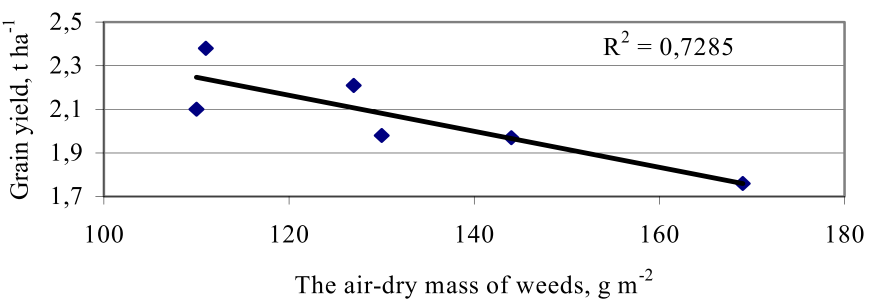

Fig. 2. Influence of air-dry mass of weeds on the grain yield of peas (1999–2001 average).

CONCLUSIONS

1. The most effective means against couch-grass was stubble breaking to a depth of 0.10–0.12 m followed by deep ploughing. Decrease in a number of couch-grass on deep ploughed plots, compared to non-stubble-broken and shallow-ploughed plots, made up to 5.3 times.

2. Weed mass was lowest when stubble breaking and deep ploughing had been applied (111 g m^{-2}). Weed mass was highest on only stubble-broken or only shallow-ploughed soil (169 g m^{-2}).

3. The highest pea seed yield (2.38 t ha^{-1}) was obtained when stubble had been broken to a depth of 0.10–0.12 m and the soil ploughed deep (to 0.22–0.25 m); shallow ploughing alone gave the lowest pea seed yields – 1.76 t ha^{-1}. Pea seed yield showed a regular decrease with decreasing the depth of ploughing (R^2 = 0.73).

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