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Effects of short crop rotation and soil tillage on winter wheat development in central Lithuania

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Abstract. A three year (2005–2008) field experiment was conducted in Central Lithuania to study the effects of different crop rotations (spring oil-seed rape-spring barley-winter wheat; winter wheat-spring rape; winter wheat monocrop) in conventional (ploughing to a 20–22 cm depth) and reduced (stubble cultivation to a 10–12 cm depth) soil tillage systems on winter wheat yield and its components. Winter wheat grain yield increased in the three-course crop rotation in the conventional (ploughing) cultivation system. However, wheat grain yield decreased by only 1.4 % in reduced tillage (stubble cultivation) compared to conventional tillage. Shortening of crop rotations, or different soil tillage systems used, did not exert any adverse effect on the variation of the number of grains per ear and the length of straw. The results of the study indicate that the different crop rotations in two soil tillage systems in Central Lithuania did not significantly affect wheat grain yield components.

Key words: crop rotations, soil tillage, winter wheat

INTRODUCTION

Crop rotation is one of the major cultural practices in the farming system. Rapeseed, an important oilseed crop which has an intensive root system, is also known as a good previous crop for numerous crops. The successful inclusion of oilseed crops in cereal-based cropping systems has been shown to have positive agronomic and economic impacts. Johnston et al. (2002) reported that genetic improvement in oilseed crop yields will continue to make them economically competitive with cereals, wears Lafond et al. (1993), Dhuyvetter et al. (1996) and Zentner et al. (2002) reported that where oilseeds are adapted, their inclusion in rotation with cereals could increase net inversion return and reduce risk through improved production stability. In addition, Brand et al. (1995), Heenan (1995), and Anderson et al. (1999) found that the involvement of rapeseed crop in rotation systems led to an increase in wheat yield. In arable crops cultivation soil tillage is usually noted as having one of the greatest requirements for energy and labour consumption. Cereals, including winter wheat (*Triticum aestivum* L.) and spring barley (*Hordeum vulgare* L.), can achieve elevated grain yields at relatively low plant population densities (Acvi et al., 2007). An increase in seeding rate above that needed to reach this yield plateau serves only to increase production costs without increasing yield. Hay and Porter (2006) found that cereal seeding rates of 400 m^{-2} were usually sufficient to achieve optimum plant densities of 200–300 plants m^{-2}. In other research, Machado et al. (2008) reported, that tillage and year significantly influenced wheat grain yield but there were no significant tillage and year interactions. Wheat grain yields were highly correlated to both winter precipitation and growing season precipitation. However, Košutic et al. (2005) reported that there exist real possibilities of energy and labour saving due to utilization of non-conventional soil tillage systems in arable crops growing. The objective of this research was to asses the effects of three different crop rotations in two soil tillage systems on growth and yield components of winter wheat.

MATERIALS AND METHODS

A field experiment was conducted and repeated during the growing seasons of 2005–2006 (Yr 1), 2006–2007 (Yr 2) and 2007–2008 (Yr 3), at the Lithuanian Institute of Agriculture in Dotnuvato, to determine the effect of three different crop rotations in two soil tillage systems on winter wheat growth and yield. Experiments were conducted on a sandy loam (*Endocalcari-Endohypogleyic cambisol*) soil, the physicochemical characteristics of which were: silt 290 g kg^{-1}, clay 193 g kg^{-1}, sand 517 g kg^{-1}, with a humus content of 2.25 %, pH 7.2, available phosphorus 157 mg kg^{-1} and potassium 254 mg kg^{-1}.

A split-plot arrangement of treatments was employed in a randomized complete block design with four replicates. The main plots consisted of two soil tillage systems: conventional tillage (autumn ploughing 20–22 cm depth) with a reversible 4-body ‘Kverneland’ plough in combination with a compactor; Presowing tillage (shallow seed bed preparation with KLG-4.0 at a 4–5 cm depth); Reduced tillage (autumn stubble cultivation to a 10–12 cm depth) with a stubble cultivator ‘Rau-5’ consisting of disc coulters in combination with a heavy spiked roller; presowing tillage (shallow seed bed preparation with a stubble cultivator ‘Rau-5’ at a 6–8 cm depth). The three short crop rotations on the subplots were: Spring rape-spring barley-winter wheat; Winter wheat-spring rape; Winter wheat (monocrop).

The experiment involved the following crops: spring rape (*Brassica napa* L.) cv. ‘Maskot’, seeding rate 6.0 kg ha^{-1}, spring barley (*Hordeum vulgare* L.) cv. ‘Luokė’, seeding rate 4.0 mln. ha^{-1} (about 200 kg ha^{-1}), winter wheat (*Triticum aestivum* L.) cv. ‘Širvinta’, seeding rate 4.5 mln. ha^{-1} (about 220 kg ha^{-1}). All crops were grown each year in four replicates. Winter wheat stands were sprayed at BBCH 25-29 with Granstar 0.015 g ha^{-1} (Tribenuron methyl 750 g a.i. l^{-1}) plus Starane 0.4 l ha^{-1} (fluroksipir 180 g. a.i. l^{-1}), spring barley – at BBCH 28-30 with Duplosan Super 1.2 l ha^{-1} (mekoprop-P + MCPA + dichlorprop-P 130+160+310 g a.i. l^{-1}), spring rape – at BBCH 11-14 with Butisan 400 2.5 l ha^{-1} (metazachlor 400 g a.i. l^{-1}).

During the crop rotation period the rates of application of mineral fertilisers were as follows: for winter wheat $N_{120}P_{60}K_{90}$, for oil seed rape $N_{120}P_{60}K_{60}$, for spring barley $N_{90}P_{60}K_{90}$. Before sowing, Phosphorus (granular superphosphate, 20% of P_2O_5) and potassium (KCl, 60% of K_2O) fertilizers were broadcast onto the soil surface and incorporated. Nitrogen was given as ammonium nitrate (35% N). For winter wheat this was broadcast on the soil surface in spring, just after the resumption of crop growth, and for spring crops it was broadcast on the soil surface before crop emergence.

The crop density was determined during each year after crop emergence in autumn, and in spring just after the resumption of crop growth. A few days before the harvest of wheat, the plants along a 1m length of the interior rows of each plot in two replications were removed, with their, roots for morphological measurements. In addition, all of the wheat plots were harvested for seed yield. Yield and yield components such as seed weight per spike, harvest index, seed yield and 1000 seed weights were recorded. A combinedover the growing season analysis of variance (ANOVA) was performed for yield and components described previously. Analysis of variance was performed using the computer programmes ANOVA and STAT_ENG.

RESULTS AND DISCUSSION

The number of winter wheat plants in conventional tillage treatments in autumn ranged from 290 to 319 seedlings per m^{-2}, and in stubble cultivation treatments from 284 to 316 seedlings per m^{-2} (Table 1). In general, the number of winter wheat plants during the winter season were not significantly affected by tillage treatments or the different short crop rotations. The number of winter wheat plants, were also not significantly affected by tillage or the different short crop rotations in spring and before harvest. However, the number of winter wheat plants before harvest in different tillage and short crop rotations was significant lower compared to those in autumn and spring. During the whole growing season the number of winter wheat plants was from 2 to 10.5% lower in two field crop rotations compared to the other two short crop rotations, except in conventional tillage before harvesting. In addition, the number of winter wheat plants before harvesting in three short crop rotations, independent from tillage treatments, was from 32 to 47% lower compared to in autumn and spring.

Table 1. Winter wheat plants as affected by different short crop rotations.

Crop rotation	Preceding crop***	Winter wheat plants per m^{-2}					
		In autumn		In spring		Before harvesting	
		CT*	SC**	CT	SC	CT	SC
Three fields	B	303	316	301	314	194	177
Two fields	R	290	284	286	281	168	174
Monocrop	W	319	316	317	313	168	169
R_{05}		21.9		22.0		26.5	

CT* conventional tillage, SC** stubble cultivation, B*** spring barley, R spring rape, W winter wheat.

When averaged over growing seasons the winter wheat highest productive number of stems was recorded in the two field crop rotation (winter wheat–spring rape) in both tillage systems (429–463 stems per m^{-2}) (Table 2). Also, in this crop rotation the highest coefficient of productive tillering and greater plant lengths were found. contrarily, the least number of productive stems was found in the winter wheat monoculture. In particular, the coefficient of productive tillering of winter wheat was highest in the two field crop rotation compared to the three-course crop rotation or monocrop under conventional tillage system. No significant differences between crop rotations were found under reduced tillage. However, Fischer (2008) has reported that under normal conditions, approximately 30 to 50% of the grain yield of wheat comes from the main stem, and 50 to 70% comes from the tillers.

Table 2. Productive stems, coefficient of productive tillering and plants length as affected by different short crop rotations.

Crop rotation	Preceding crop	Productive stems per m^{-2}		Coef. of productive tillering		Plant lengths cm	
		CT	SC	CT	SC	CT	SC
Three fields	B	412	443	2.3	2.6	107.1	104.4
Two fields	R	429	463	2.6	2.7	107.8	106.1
Monocrop	W	345	415	2.3	2.6	105.7	104.2
R_{05}		33.7		0.29		1.85	

Averaged over all growing seasons, winter wheat ear length in all treatments either in a deep ploughed or in a shallow cultivated soil was similar, and varied from 9.7 to 10.2 cm (Table 3). The greatest grain number per ear was recorded in the two field crop rotations, when alternating winter wheat with spring rape. Fischer (2008) reported that grain number is a basic cause in determining wheat yield. The 1000-grain weight in the three course crop rotation (spring rape-spring barley-winter wheat) was slight higher in the conventional (ploughing) cultivation system. During the above-mentioned period in a shallow cultivated soil, the highest 1000 grain weight was found in the wheat monocrop.

Table 3. Ear length, grain number per ear and 1000 grain weight as affected by different short crop rotations.

Crop rotation	Preceding crop	Ear length cm		Grain number per ear		1000-grain weight g	
		CT	SC	CT	SC	CT	SC
Three fields	B	10.2	10.0	40.9	41.2	51.6	50.0
Two fields	R	10.2	9.9	41.4	41.8	50.9	50.1
Monocrop	W	9.7	10.0	40.2	41.3	50.7	52.5
R_{05}		0.47		1.46			

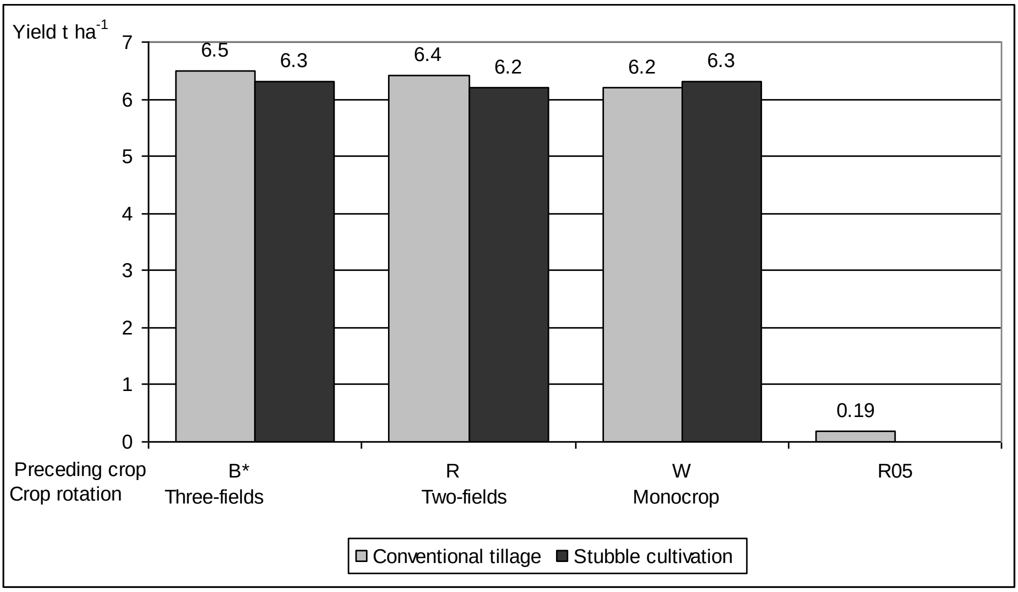
A strong relationship between wheat grain yield and its biological parameters was found (Table 4).

Table 4. Assessment of the efficacy of factors affecting grain quality indicators.

Yields structural components	Regression equation	R
	Three field rotation under conventional tillage system	
Number of grains per ear	y=12.85+4.38x	0.82*
	Three field rotation under stubble cultivation system	
Plants per m^{-2} in autumn	y=1.22+0.02x	0.99**
Plants per m^{-2} in spring	y=1.23+0.02x	0.99**
	Two field rotation under conventional tillage system	
Number of grains per ear	y=1.77+6.15x	0.84*
	Two field rotation under stubble cultivation system	
Plants per m^{-2} in autumn	y=2.98+0.01x	0.82*
	Monocrop	
1000–grain weight g	y=1.02+7.99x	0.94**

*–differences are statistically significant at 95 % probability level.

**– differences are statistically significant at 99 % probability level.



B*-spring barley, R-spring rape, W-winter wheat;

Fig. 1. Grain yield of winter wheat t ha^{-1} was affected by of three different crop rotations in two soil tillage systems.

Winter wheat productivity under a conventional (ploughing) cultivation system depended on the interval of its return to the same field. The grain yield of winter wheat grown in the same field over a two year period was 6.5 t ha^{-1} (a significant yield increase), whereas after a one year period this was 6.4 t ha^{-1},and in the case of continuous cultivation it was 6.2 t ha^{-1} (Fig. 1). Heenan, (1995) reported that, particularly with rapeseed as a previous crop, the yield of wheat increased.. Heenan (1995) found that wheat yield increased 84 and 86 % when rapeseed was grown as previous crop. The differences between our study and previous studies can be attributed to shortening of the crop rotation period. Several studies (Lafond at al., 1993; Dhuyvetter et al., 1996) indicated that where oilseeds are adopted, their inclusion in rotation with cereal could increase net return and reduce risk through improved production stability.

Averaged over all growing seasons, winter wheat yield under a stubble cultivation system was similar in three short crop rotations and varied from 6.2 to 6.3 t ha^{-1}.

CONCLUSIONS

The results of this study indicate that:

1. Short crop rotations or different soil tillage systems used did not significantly affect the winter wheat plant number, the productive stems number, coefficient of productive tillering, grain number per ear or 1000-grain weight.

2. Grain yield of winter wheat grown in the same field after a two-year period was 6.5 t ha^{-1}, whereas after a one year period was 6.4 t ha^{-1},and in the case of continuous

cultivation was 6.2 t $ha^{-1.}$ Under reduced tillage (stubble cultivation) system winter wheat grain yield was similar and varied from 6.2 to 6.3 t ha^{-1}.

For farmers of central Lithuania there exist real possibilities of energy and labour saving due to utilization of non-conventional (reduced) soil tillage systems.

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