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The influence of grain legumes on spring wheat yield formation and phytosanitary state

L. Sarunaite, I. Deveikyte, R. Semaskiene and Z. Kadziuliene

Lithuanian Institute of Agriculture, Instituto al. 1, Akademija, Kedainiai LT-58344, Lithuania; e-mail: lina@lzi.lt

Abstract. The aim of the present study was to determine the influence of grain legumes on spring wheat yield, its quality and phytosanitary state in an organic farming system. The experiment was carried out in 2007 and 2008 at the Lithuanian Institute of Agriculture in Dotnuva on a loamy *Endocalcari-Ephypogleyic Cambisol*. Grain legumes – pea, lupine, bean, vetch and wheat were sown as intercrops and sole crops, and were grown organically for grain. The productivity and phytosanitary state of spring wheat sole crops or intercrops depended on the species of grain legume, however, the results varied over the experimental years. In 2007, the vetch and wheat intercrop produced a significantly higher grain yield than wheat in sole crop or in other intercrops. In 2008, no advantages of legume and wheat intercrops were revealed. The nitrogen content was higher in wheat when it was grown with legumes.

Key words: intercrops, leaf diseases, nitrogen content, weed

INTRODUCTION

Wheat is a valuable crop in organic farming, and much effort has been put into optimizing the yield and quality of organically grown wheat. In many areas, farmers prefer to grow wheat, and to achieve the highest possible yield and quality, they grow it after the best pre-crops in the crop rotations. Calculations made in Lithuania show that cereal productivity on an organic farm declines by 47 % compared with that on a conventional farm (Zemeckis & Ribasauskiene, 2005). On organic farms the limited availability of nitrogen often leads to unsatisfactory yields and qualities (Loges et al., 1999). There is a pressing need to develop cereal growing methods that require much lower inputs of nitrogen fertiliser and other agrochemicals than conventional farming by exploring organic nitrogen of legumes as a potential nitrogen source for subsequently grown crops (Dhont et al., 2002; Neumann et al., 2005). Intercropping research has shown that a cropping system using relay cropping, overseeding, interseeding and double cropping may serve to provide and conserve nitrogen for grain crops, reduce soil erosion and weed pressure, and increase soil organic matter content (Carruthers et al., 2000; Bergkvist, 2003; Kadziuliene & Kadziulis, 2006). However, yield reduction can be caused not only by no nitrogen fertilisation but also by diseases, pests and weeds (Mäder et al., 2002; Sarrantonio & Gallandt, 2003). Research on the biological products, characterised by an antagonistic effect on pathogen, was carried out at the Lithuanian Institute of Agriculture, however, their efficacy under field conditions was found to be low (Semaskiene & Dabkevicius, 2000; Kadziuliene et al.,

2005). As observed by Finckh et al. (2000), cultivation of different plant species in the intercrops is considered to be one of the main plant protection practices reducing disease damage. Improvement of the competition with weeds has been emphasised as the benefit of the increasing sowing density or using intercrops (Auskalniene & Auskalnis, 2008; Liebman & Davis, 2000).

The aim of the present study was to determine the influence of grain legumes on spring wheat yield, its quality and to establish the efficacy of grain legume and spring wheat dual intercrops on disease and weed control under organic farming conditions.

MATERIALS AND METHODS

A field experiment was carried out in 2007 and 2008 at the Lithuanian Institute of Agriculture in Dotnuva (55˚ 24‘N) on a loamy *Endocalcari-Epihypogleyic Cambisol*. The soil pH was around 7.5, humus content was 2.3%, available P 74-79 mg kg^{-1} and K 135-140 mg kg^{-1}. Field pea (*Pisum sativum* L.), lupine (*Lupinus angustifolius* L.), bean (*Vicia faba* L.), vetch (*Vicia sativa* L.) and spring wheat (*Triticum aestivum* L.) were sown as sole crops. All legumes were grown in dual mixed intercrops with spring wheat and grown for grain. The experimental plots were laid out in a complete one-factor randomised block design in three replicates. Spring wheat cv. SW Estrad was sown at 5.5, pea cv. Pinochio – 1.0, bean cv. Scirocco – 0.6, vetch cv. Topaze – 2.5 and lupine cv. VB Derliai – 1.5 million seed ha^{-1}. The intercrop design was based on the proportional replacement principle, with mixed legume grain and wheat grain at the same depth in the same rows at relative frequencies of 50:50. Crops were cultivated according to organic management practices.

Soil chemical samples were analysed using the following methods: pH_{KCl} ionometrically; total nitrogen by the Kjeldahl method; available P and K by A-L method. The crops were harvested at complete maturity stage. After threshing, the grain dry matter yield was determined. The assessment of plant nitrogen concentration in the dry matter (DM) was conducted by the Kjeldahl method. The development of leaf diseases was monitored in spring wheat by sampling 15 plants from the trial plots. Random tillers were selected per plot and the top three leaves were scored for disease severity by using the 1, 5, 10, 25, 50 and 75% scale (EPPO Standards, 2004). Growth stage (BBCH) was recorded at disease severity assessment (Meier U., 1997). Observations of disease severity were made approximately every 10-14 days on each plot starting at the stem elongation and continuing through the late milk stage. Air-dry mass and botanical composition of weeds were determined in an area of 0.25 m^2 in 4 places per plot at grain filling stage. Weed mass data were transformed to $Y=\sqrt{x+1}$. The experimental data were statistically processed using analysis of variance.

RESULTS AND DISCUSSION

The cultivation conditions were different in 2007 and 2008, therefore the results varied in the same experimental sites in the first and second experimental years. The results of the grain yield measurements are shown in Table 1. In 2007, the total yield of spring wheat and vetch intercrop was significantly higher compared with wheat grown as a sole crop. The grain yield of pea sole crop did not significantly differ from that of bean, whereas the yield of vetch sole crop was significantly lower.

Table 1. The grain yield of spring wheat and legume grown as sole crops and in dual mixed intercrops, 2007 and 2008.

Treatment	Plant species	Grain yield t ha^{-1}		Nitrogen (% of dry matter)		Nitrogen (kg ha^{-1} of grain yield)	
		2007	2008	2007	2008	2007	2008
Wheat	cereal	4.13	2.81	2.01	1.77	83	49.4
Pea	legume	3.37	1.11	3.49	3.79	117	42.0
Lupine	legume	2.71	0.44	3.77	3.82	103	16.6
Bean	legume	3.22	1.01	4.55	4.50	146	45.9
Vetch	legume	2.27	2.21	5.67	4.51	128	99.5
Wheat+pea	cereal	3.51	2.03	2.03	1.91	70.9	38.9
	legume	0.37	0.48	3.70	3.73	13.4	17.9
	total	3.88	2.51			84.3	56.8
Wheat+lupine	cereal	3.51	1.49	2.04	1.89	80.4	28.1
	legume	0.37	0.14	3.88	3.78	4.0	5.40
	total	4.04	1.63			84.4	33.5
Wheat+bean	cereal	2.87	1.99	2.06	1.75	58.7	34.6
	legume	0.62	0.68	4.05	4.39	25.6	29.8
	total	3.49	2.67			84.3	64.4
Wheat+vetch	cereal	3.86	1.54	2.13	1.87	82.1	27.4
	legume	0.52	1.11	6.04	4.52	31.9	49.9
	total	4.39	2.65			113.9	77.3
$P > 0.05$	total	0.229	0.446	0.25	0.11	12.2	16.7

Generally, the yield was significantly lower or trends towards decrease were observed in grain legume sole crops compared with the total wheat and legume yield in dual intercrops. In 2008, percentage of grain legume was higher in the structure of the yield of dual intercrops, however the total yields of intercrops were approximately 50 % less than in 2007. This resulted from the droughty weather conditions in 2008 when grain legume was able to use resources of moisture by their taproot from a deep soil layer better than wheat. The grain yield of vetch was significantly higher compared with that of other sole crops.

A significantly higher nitrogen concentration accumulated in the yield of bean grown as a sole crop, however, bean did not have any marked effect on the nitrogen concentration in the yield of intercrops compared with other legumes. It was dependent on the amount of legume in dual intercrops. In the intercropping publication reviewed by Hauggaard-Nielsen et al. (2006) it is reported that a relative proportion of pea in dual mixed intercrops around 40–50% is needed in order to achieve a level of intraspecific competition inducing improvement in wheat quality parameters. Our experimental data suggest that cultivation of wheat and vetch in dual mixed intercrop was most effective and plants were in minimal competition with each other. This dual intercrop was defined as having significantly higher concentration of nitrogen in grain compared with other intercrops. The differences between the concentrations of nitrogen in yields of vetch sole crop and dual intercrop were regarded as insignificant.

The trend of nitrogen concentration in lupine grain was similar to that in vetch, but the nitrogen concentration in bean grain yield was significantly higher in sole crop than in dual mixed intercrop. Taking into account the fact that nitrogen concentration in legume grains was insignificantly different regardless of their cultivation method

(sole cropping or mixed dual intercropping), and that there was a trend towards higher nitrogen concentration in the wheat grain of mixed dual intercrops, we can presume that legume and wheat intercrops could be grown in intercrops without strong competition and assimilate nutrients from natural sources. In 2007, the weather conditions were conductive to the spread of diseases, since warm and wet weather prevailed. In the second year (2008) of the experiment, the weather conditions were adverse for the spread of diseases, because of the droughty summer period. Therefore, the pressure of diseases was lower compared with that in 2007. Leaf spotting diseases, such as septoria leaf blotch (*Septoria* spp.) and tan spot (*Pyrenophora tritici-repentis*) prevailed in spring wheat during 2007 and 2008. Tan spot began to spread earlier compared to septoria leaf blotch, however, at grain filling stage septoria leaf blotch developed faster (Table 2).

Table 2. The severity of leaf diseases in spring wheat sole crop and in dual mixed intercrops, 2007 and 2008.

Treatment	Disease severity %									
	BBCH 37		BBCH 45-51		BBCH61-69		BBCH 75-77		BBCH 83	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
	Septoria leaf blotch									
Wheat	0	0	0	0	0.06	0	1.51	2.13	14.9	-
Wheat+pea	0	0	0	0	0.10	0	1.66	2.89	17.1	-
Wheat+lupine	0	0	0	0	0.05	0	0.98	1.89	12.0	-
Wheat+bean	0	0	0	0	0.06	0	1.36	3.89	18.2	-
Wheat+vetch	0	0	0	0	0.03	0	2.46	2.51	15.2	-
P>0.05	0	0	0	0	0.04	0	2.46	1.58	6.66	
	Tan spot									
Wheat	0.09	0	0.73	0.11	1.55	0.01	2.63	1.10	7.93	-
Wheat+pea	0.07	0	0.88	0.13	1.16	0.01	1.96	0.57	7.40	-
Wheat+lupine	0.24	0	0.70	0.14	1.59	0.06	2.42	0.59	6.16	-
Wheat+bean	0.12	0	0.84	0.03	1.17	0	1.89	0.60	8.18	-
Wheat+vetch	0.18	0	0.72	0.08	1.36	0.01	2.01	0.59	7.04	-
P > 0.05	0.24		0.33	0.04	0.40	0.49	0.83	0.87	3.92	

Table 3. Weed incidence of spring wheat and grain legumes in sole crops and dual mixed intercrops, 2007 and 2008.

Treatment	Air-dry mass of weeds g m^{-2}					
	Annual		Perennial		Total	
	2007	2008	2007	2008	2007	2008
Wheat	1.9	24.8	9.8	0.7	11.7	25.6
Pea	5.8	90.8**	10.7	7.4	16.6	98.2**
Lupine	19.0**	151.2**	9.5	25.8*	28.4	177.0**
Bean	27.6**	162.2**	12.7	39.8**	40.3	202.0**
Vetch	3.4	25.0	1.6	3.1	5.0	28.1
Wheat+pea	3.1	32.8	3.2	7.0	6.3	39.8
Wheat+lupine	1.5	32.0	6.1	23.1*	7.6	55.1*
Wheat+bean	4.4	29.0	4.4	1.3	8.8	30.3
Wheat+vetch	1.8	11.2	7.0	11.2	8.8	22.3

*Note. * -differences significant at 95 % probability level, ** - at 99%.*

In wheat, septoria leaf blotch spread exhibited a trend of decreasing in pea or lupine dual mixed intercrops. The similar trend was observed in another experiment with pea and wheat intercrops (Kadziuliene et al., 2008). Experiments performed at LIA showed that at the severity of leaf spotting diseases above 5%, a significant yield reduction occurred in most cases compared with wheat at grain filling stage completely protected from diseases (Ronis et al., 2007). In our experiments, leaf spotting disease severity in wheat sole crop and dual intercrops was higher than 5% only in 2007, therefore yield decrease due to leaf spotting disease in wheat was probable only in 2007.

In 2007 and 2008, air-dry mass of weeds was higher in pea, bean and lupine sole crops (Table 3). Data of both experimental years suggested that spring wheat and grain legume intercrops significantly reduced the mass of annual weeds compared with sole grain legume crops, except vetch. The highest air-dry mass of *Chenopodium album* L., *Lamium purpureum* L. and *Galega orientalis* Lam. was determined in both experimental years. The intercrops effectively reduced the air-dry mass of dominating weeds. Lupine intercrop efficiently suppressed *Chenopodium album* L. Vetch exhibited the best competitive power compared to all other grain legumes investigated.

CONCLUSIONS

1. In 2007, spring wheat and vetch intercrop produced significantly more grain than wheat grown as a sole crop or in other dual mixed intercrops. The differences in grain yields of pea and bean sole crops were insignificant, whereas the yield of vetch was significantly lower. In 2008, the yield of vetch was significantly higher compared with other legume sole crops.
2. The concentration of nitrogen was higher in grain yield, when spring wheat had been grown in dual mixed intercrops. Wheat and vetch dual mixed intercrop accumulated significantly more nitrogen in grain compared with other intercrops.
3. Septoria leaf blotch and tan spot occurred in the spring wheat grown both in sole and dual intercrops in the organic crop rotation. In most cases, the diseases reached the highest severity during the grain filling stage. Spring wheat cultivation in dual mixed intercrops did not reveal any significant effect on the disease development in the crops, since the observed trends of the reduction of the severity of individual wheat diseases were not always consistent.
4. Vetch exhibited the best suppressing ability on weeds compared to all other grain legumes investigated. Weed incidence in vetch sole crop was significantly lower than that in other legume sole crops. The total weed mass in spring wheat mixtures with legume crops was by 1.3–6.6 times lower compared to that in the sole crop.

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