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Effect of agrotechnical methods on occurrence of diseases and productiveness of cereals in organic agriculture

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Abstract. The occurrence of diseases and productiveness in organic agriculture depending on sowing time, tillage method and use of manure was studied during 2006, 2007 and 2008. Infection of spring wheat with Septoria leaf blotch and powdery mildew and infection of spring barley with net and leaf blotch in the case of early and 2–2.5 weeks late sowing did not differ significantly towards the end of the vegetation period. The severity of common root rot was also virtually similar. Differences of yield favoured the earlier sowing. The severity of some diseases in spring barley did depend on tillage method. In the case of autumn ploughing the spring barley had less infection with common root rot and foliar diseases compared to the reduced autumn tillage. Yield differences also favoured autumn ploughing. The positive effect of manure on the severity of foliar diseases and common root rot was low or absent, but manure positively influenced productiveness of the cereals.

Key words: organic agriculture, cereal diseases, agrotechnical methods

INTRODUCTION

In organic agriculture no mineral fertilizers or chemical plant protection products are used, creating conditions of plants growth that differ from conventional agriculture, affecting the yield formation as well appearance of diseases, pests and weeds. Most widespread cereal diseases such as common root rot, powdery mildew, rusts and several leaf blotch diseases are also important yield decreasing factors in organic agriculture. Still, in conditions of organic agriculture the appearance of diseases and especially disease prevention and control problems are poorly studied; as a result, there is also a lack of globally or locally effective disease control recommendations. It is widely known that the occurrence of diseases could be diminished by the use of certain agricultural techniques: resistant cultivars, optimum sowing time, using disease-free seed, eradication of infected residues by ploughing, enriching the soil with antiphytopathogenic microflora (manure, compost etc). The application of farmyard manure stimulates vesicular-arbuscular mycorrhizae while fertilizers decrease the mycorrhizal propagules (Harinikumar & Bagyaraj, 1989). Kos (1982) reports a slight decrease in disease severity in winter wheat cropping after application of farmyard manure. However shallow straw incorporation into soil compared with ploughing had an unfavourable effect on the germination, emergence and tillering of winter wheat and resulted in lower yields (Prew, Lord, 1988; Smallfield, 1992). In barley, early sowing favours development of diseases such as net blotch (Wallwork et al., 2001). Diminishing the harmfulness of plant pests and improvement of the growth conditions, together with meteorological conditions, are important factors. Data concerning the efficacy of some agrotechnical measures in growing organic grain are often controversial; data related to Estonian conditions are poor. In Estonian studies concerning organic grain the objective has mainly been the comparison of yield and quality; less attention has been dedicated to the occurrence of diseases (Tamm et al., 2007). The objective of the current study was to determine the effect of sowing time, tillage and manure use on disease occurrence (intensity) and yield.

MATERIALS AND METHODS

Field trials in organic agriculture were conducted from 2006–2008 at Kuusiku Testing Centre of the Agricultural Research Centre on a *Calcaric Luvisol* (organic C 1,8%, and pH_{KCl} 6,7). The trials were designed as systematic complete blocks with a three-way factorial and four replications. Plot size was 7,5x 10 m. The following factors were represented: a) sowing time – 1. sown at first possible soil cultivation time (1.time); 2. sown 2-2.5 weeks later (late). b) Soil cultivation method in autumn – 1. reduced tillage (RT) 2-times (8-10 cm); 2. ploughing (P) only (18-25 cm); c) Manure application in autumn – 1. no manure; 2. manure (25% dry mass content) 30 (cereals) or 45 t ha^{-1} (turnip rape). Stubble cultivation and reduced tillage (RT) used disk harrow and chisel cultivator. For sowing, certified seed was used with seed rate 550 germinating seed m^{-2}. Yield was harvested by ripening: in 2006 spring wheat – 02.08; spring barley - 27.07; in 2007 spring wheat – 06.08; barley – 03.08; in 2008 – early sown spring wheat – 14.08, late sown – 19.08; spring barley – 14.08. Factors were studied in the organic crop rotation system - red clover/timothy – red clover/timothy – spring wheat – turnip rape or pea – spring barley with undersown red clover/grasses. In spring 2007, the turnip rape was replaced with the pea, as the turnip rape had failed in previous years. Disease occurrence in spring wheat on the background of autumn ploughing compared with early and late sowing was studied during 2006-2008. Infection of spring barley in conditions of different tillage methods (autumn ploughing versus autumn reduced tillage) was studied during 2006-2008 with autumn manure application. The effect of manure fertilizing on the infection of spring barley was studied on the background of the named 2 tillage variants in 2008.

Assessment of foliar diseases and common root rot was carried out 3 times in stages: tillering-stem elongation (GS 21-32), stem elongation-emergence (GS 35-59), flowering-milk development (GS 69-77). To assess the common root rot (*Cochliobolus sativus, Fusarium* spp.) methodics by Koršunova, Čumakova, Ščekočihina (1976) was used. For averaging, 50–60 sample plants were collected from ten locations on every plot, on every variant by diagonals, 4 average samples. In laboratory the samples were washed and the occurrence and severity of common root rot on roots and crown roots were assessed. Foliar diseases were assessed on the same samples. To estimate the intensity of diseases in every sample all leaves of 20 plants were assessed and the surface area damaged by disease was expressed in per cents. To assess foliar diseases EPPO guidelines were used, for Septoria leaf blotch (*Leptosphaeria nodorum* E. Müller; *Mycosphaerella graminicola* (Fuckel) Schröter), powdery mildew (*Blumeria graminis* (DC) Speer) and scald (*Rhynchosporium secalis* (Oudem.) J. Davis)

EPPO/OEPP 1984, Nr. 79, for net blotch (*Pyrenophora teres* Drechsler) PP 1/29 (2). Trial data were processed statistically by dispersion analysis. Weather data were acquired from the local automatic weather station located in immediate proximity (150–200 m) of trials (Table 1).

Table 1. Weather characteristics in 2006–2008.

Year	Average monthly temperatures (°C)					
	April	May	June	July	August	mean
2006	5.7	12.5	17.9	19.3	18.1	14.7
2007	8.5	13.0	17.3	17.6	19.6	13.6
2008	7.2	10.7	14.6	16.7	15.6	13.0
1961–1990	3.6	10.2	14.5	15.9	14.9	11.8
Year	Monthly precipitation (mm)					
	April	May	June	July	August	mean
2006	22.2	36.0	30.6	10.2	27.2	25.2
2007	42.6	79.2	40.8	98.4	32.4	58.7
2008	42.4	25.2	108.4	53.4	247.0	
1961–1990	39.0	42.0	56.0	87.0	83.0	

Table 2. Soil temperature (°C) in 2006–2008.

Year	Average monthly temperatures (°C)					
	April	May	June	July	August	mean
2006	1.6	9.0	13.8	16.5	16.6	11.5
2007	4.8	9.8	14.6	15.8	16.5	12.3
2008	5.5	9.6	13.3	14.9	15.0	11.7

RESULTS AND DISCUSSION

Effect of sowing time in spring wheat

The impact of sowing times on infection was studied during 2006-2008. In 2006, the first opportunity for sowing came later than in 2007 and 2008. Also in 2006, both the average air and soil temperatures in April (Table 1, 2) were considerably lower than those of the following years. In 2006, it was not possible to sow until 26 April; the following years, sowing occurred on the 12th and 16th of April. Infection of Septoria leaf blotch in the case of early sowing took place depending on the temperature in May – in the end of May (2007) or in the beginning (2006 and 2008): in the case of late sowing infection occurred somewhat later, as shown also by disease severity data in Table 3. Although in the case of early sowing the severity of Septoria leaf blotch was somewhat higher during the first half of the vegetation period, the parameters started to equalize closer to the end of growth period, in milk development stage (GS 71). When Septoria leaf blotch and powdery mildew occurred simultaneously, as in 2008, pathogens began to compete to occupy the undamaged leaf areas. The pathogen causing powdery mildew could occupy only the leaf surface areas left free by the Septoria leaf blotch, which erupted earlier. The common root rot damages spring wheat less, and with lower intensity, than spring barley.

Table 3. Effect of sowing time on severity (%) of foliar diseases and common root rot on spring wheat (c. Manu`) in 2006–2008 at Kuusiku and grain yield (dry mass).

Precrop	Sowing time, year	Severity (%) of Septoria leaf blotch*+ powdery mildew**			Severity (%) of common root rot			Yield kg ha^{-1}
Red clover	26.04.2006 A1)- 1. time	12.06- GS 32 3.0	26.06- GS 59 2.0	11.07- GS 77 4.3	12.06- GS 32 0	26.06- GS 59 0	11.07- GS 77 1.5	1752
Red clover	09.05.2006 A2)- later	12.06- GS 29 2.0	26.06- GS 39 4.4	11.07- GS 71 5.0	12.06- GS 29 0.0	26.06- GS 39 0.0	11.07- GS 71 1.8	1456
$LSD_{0.05}$		0.3	2.8	1.0	0.0	0.0	0.4	230.9
Red clover/ timothy	12.04.2007 A1)- 1. time	30.05- GS 31 2.1	13.06- GS 37 2.4	16.07- GS 77 38.2	30.05- GS 31 0.0	13.06- GS 37 0.0	16.07- GS 77 11.4	2259
Red clover / timothy	26.04.2007 A2)- later	30.05- GS 29 0.3	13.06- GS 35 2.0	16.07- GS 75 33.4	30.05- GS 29 0.0	13.06- GS 35 0.0	16.07- GS 75 21.5	2084
$LSD_{0.05}$		1.1	0.2	0.9	0.0	0.0	7.9	93.0
Red clover/ timothy	16.04.2008 A1)- 1. time	27.05- GS 21 0.1	17.06- GS 50 0.6	11.07- GS 71 16.9+11.4	27.05- GS 21 0.6	17.06- GS 50 0.7	11.07- GS 71 1.3	1619
Red clover/ timothy	04.05.2008 A2)- later	27.05- GS 20 0.0	17.06- GS 47 0.1	11.07- GS 69 6.0+15.6	27.05- GS 20 0.3	17.06- GS 47 0.3	11.07- GS 69 0.3	1758
$LSD_{0.05}$		0.3	0.3	2.3+3.4	0.9	1.0	1.1	170.4

*Septoria leaf blotch (*Leptosphaeria nodorum*, *Mycosphaerella graminicola*
**Powdery mildew *(Blumeria graminis*)

In more moist conditions during the growth period (2008), the occurrence and severity of common root rot may increase also in wheat. The severity of common root rot in both sowing variants may be evaluated as practically equal throughout the whole growth period, especially in 2006 and 2008. So it may be concluded that the infection in the case of late sowing takes place with a small shift if compared to the early sowing but by the end of the growth period the severity in both sowing variants will equalize.

The higher yield level of early sowing is caused by more favourable natural conditions, not by lower harmful impact of diseases. In 2008 the early sown wheat was damaged by *Phyllotreta* spp.; the early sown crop was too sparse and the yield remained lower than in the case of late sowing when the pest was not active.

Effect of tillage system in spring barley

By autumn ploughing carried out at the optimum time it is possible to move the plant debris together with pathogen inoculum 18–25 cm into the soil and to achieve their full or partial inactivation. With reduced tillage there is a greater opportunity for preservation of the pathogen inoculum and subsequent distribution to the next crop. Also of great importance are the pathogens of the pre-crop which are able to infect the new crop. Due to their root excretions, crucifers prohibit the development of many pathogens considered to be a good pre-crop for cereals. Cereals and crucifers have few mutual pathogens (*Pythium, Rhizoctonia* spp.). Distribution of cereal diseases takes place with seed, soil infection or with wind from nearby cereals. Spring turnip rape and pea are not known to have pathogens mutual with the cereals. When using disease-free seed, one must consider mainly the air-born infection from nearby cereals in foliar disease distribution.

With reduced tillage, after using spring turnip rape as a pre-crop (Table 4) the infection of barley with foliar diseases and common root rot in 2006 was more severe. Also the pea had root disease creating pathogens mutual with cereals such as *Pythium, Rhizoctonia, Fusarium* spp. In reduced tillage compared to autumn ploughing, the infection of barley after pea as pre-crop in 2007, both with common root rot and foliar diseases, was more severe throughout the whole growth period. In 2008 the severity of foliar diseases in barley with pea as a pre-crop was almost equal using both tillage methods but the severity of common root rot was higher with reduced tillage, starting from GS 37 (emergence of flag leaf).

Thus the tendency is toward an increase of both common root rot and foliar diseases in autumn reduced tillage compared to autumn ploughing. Similar results were obtained by Malecka, Blecharzcyk (2008): compared to conventional tillage (ploughing), a significantly higher incidence of *Gaeumannomyces graminis* and *Fusarium* spp. was observed in spring barley with reduced tillage. The yield in all three test years was significantly better in favour of autumn ploughing (Table 4). However, differences in infection by tillage variants are very small and may not be the cause of the established yield differences.

Table 4. Effect of tillage system B1)-reduced and B2)-ploughing on severity (%) of foliar diseases and common root rot on spring barley (c. `Baronesse`, `Leeni`) in 2006–2008 at Kuusiku and grain yield (dry mass).

Precrop	Tillage system	Severity (%) of foliar diseases***			Severity (%) of common root rot			Yield kg ha^{-1}
Spring turnip rape	Year 2006	12.06-GS 29	26.06-GS 45	11.07-GS 77	12.06-GS 29	26.06-GS 45	11.07-GS 77	
	B1)	5.6	2.4	2.5	0.0	1.2	15.3	1645
	B2)	1.3	3.2	0.9	0.0	0.6	3.4	1956
$LSD_{0.05}$		1.6	0.9	0.3	0.0	1.7	1.1	151,0
Spring turnip rape	Year 2007	30.05-GS 29	13.06-GS 45	16.07-GS 77	30.05-GS 29	13.06-GS 45	16.07-GS 77	
	B1)	1.9	3.4	40.8	6.3	14.0	57.5	1393
	B2)	1.0	2.5	17.9	3.4	11.9	32.5	1570
$LSD_{0.05}$		0.6	0.4	7.1	1.9	1.3	11.2	119,6
Pea	Year 2008	27.05-GS 20	17.06-GS 37	11.07-GS 77	27.05-GS 20	17.06-GS 37	11.07-GS 77	
	B1)	0.6	2.3	50.8	1.5	1.2	2.6	1252
	B2)	0.6	1.7	51.1	4.8	0.7	1.0	1753
$LSD_{0.05}$		0.1	0.1	5.1	0.8	0.5	0.5	102,1

***net blotch (*Pyrenophora teres),* scald *(Rhynchosporium secalis)*

Effect of manure fertilization in spring barley

In autumn reduced tillage (Table 5) the effect of manure on decreasing the severity of foliar diseases as well of common root rot is absent. In variants which did and did not get manure in autumn of 2007 the infection of barley with foliar diseases and common root rot does not differ significantly. Also in the case of autumn ploughing the manure has no established effect to decrease the common root rot severity in 2008 (Table 6), but did decrease the severity of foliar diseases. Thus the positive effect of manure fertilization through the yield increase is caused more by the nutrients inserted into the soil with manure.

Table 5. Effect of manure fertilization on severity (%) of foliar diseases and common root rot on spring barley (c. \`Leeni\`) in 2008 at Kuusiku in reduced tillage system and grain yield (dry mass).

Precrop	Fertilization in autumn 2007	Severity (%) of foliar diseases***			Severity (%) of common root rot			Yield kg ha^{-1}
Pea	C1)- no manure	27.05-GS 20	17.06-GS 37	11.07-GS 77	27.05-GS 20	17.06-GS 37	11.07-GS 77	1269
		0.6	2.2	50.8	1.7	1.3	2.9	
Pea	C2)- manure 30 t ha^{-1}	27.05-GS 20	17.06-GS 37	11.07-GS 77	27.05-GS 20	17.06-GS 37	11.07-GS 77	1527
		0.6	2.3	50.8	1.3	1.0	2.2	
$LSD_{0.05}$		0.1	0.3	7.0	0.3	1.0	1.2	204.3

Table 6. Effect of manure fertilization on severity (%) of foliar diseases and common root rot on spring barley (c. \`Leeni\`) in 2008 at Kuusiku in ploughing tillage system and grain yield (dry mass).

Precrop	Fertilization in autumn 2007	Severity (%) of leaf diseases***			Severity (%) of common root rot			Yield kg ha^{-1}
Pea	C1)- no manure	27.05-GS 20	17.06-GS 37	11.07-GS 77	27.05-GS 20	17.06-GS 37	11.07-GS 77	1280
		0.9	1.5	55.8	4.6	1.0	1.0	
Pea	C2)- manure 30 t ha^{-1}	27.05-GS 20	17.06-GS 37	11.07-GS 77	27.05-GS 20	17.06-GS 37	11.07-GS 77	1641
		0.2	1.7	46.4	4.9	0.3	0.9	
$LSD_{0.05}$		0.2	0.3	4.4	0.8	1.2	0.4	204.3

CONCLUSIONS

1. The infection of diseases (Septoria leaf blotch, powdery mildew, common root rot) in spring wheat, in the case of sowing 2–2.5 weeks after the first sowing opportunity, will take place with a small temporal shift compared to the earlier sowing time but, towards the end of the growth period, the infection severity in different sowing variants equalizes.

2. The severity of powdery mildew on wheat plants infected by Septoria leaf blotch depends on the presence of undamaged foliar surface area. More surface area free of Septoria leaf blotch will enable more intensive development of powdery mildew.
3. Higher wheat yield rate in early sowing depends on more favourable climatic conditions (more soil humidity, better insolation, etc) and not on difference in disease severity.
4. In the case of autumn reduced tillage compared to autumn ploughing, the severity of both common root rot and foliar diseases in barley will increase in the following year.
5. On a background of autumn ploughing the barley yield the following year will be higher than on a background of autumn reduced tillage. However, since the differences in infection by tillage variants are very small, they may not be the cause of the established yield differences.
6. The effect of manure in barley to decrease the severity of both foliar diseases and common root rot is absent in autumn reduced tillage or is rather low in autumn ploughing. The positive effect of manure will be expressed via yield increase in the case of both in autumn reduced tillage and autumn ploughing.
7. The positive effect of manure fertilization through the yield increase is caused by the nutrients and beneficial microflora inserted into the soil with manure.

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