

ISSN 1392-3196 / e-ISSN 2335-8947

Zemdirbyste-Agriculture, vol. 101, No. 2 (2014), p. 199–204

DOI 10.13080/z-a.2014.101.026

Cultivation technology influences the occurrence of potato early blight (*Alternaria solani*) in an organic farming system

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Abstract

Nowadays, organically produced products have become more popular than ever and interest in them is still growing fast. The early blight causal pathogen *Alternaria solani* has not been considered a great threat to potato in northern climate conditions in the past and has not been routinely sprayed against. During our study early blight was evaluated in 2010 and 2011 on the plants of a potato cultivar 'Reet' in an organic farming experiment. In our study, both growing seasons were very favourable for early blight development. Significant differences between the two cultivation technologies were found ($F_{1,12} = 4.84, p = 0.048$). In 2010, the area under disease progress curve (AUDPC) value was 303 on cover crop (CC) plots and 990 on CC + M (manure) plots that is three times higher, whereas in 2011, the AUDPC value was 967 on CC plots and 1195 on CC + M plots. Our results confirm that potato early blight has become a serious problem in North-East European organic potato fields and thus susceptible potato cultivars cannot be recommended for growing in an organic farming system. However, it is possible to influence the development severity of early blight by selecting the proper growing technology. Since, in the changing climate conditions and in susceptible cultivars, early blight is a potato disease that can cause early defoliation of plants and crop death, there is a need for resistant potato cultivars.

Key words: *Alternaria solani*, disease severity, organic growing system.

Introduction

Potato early blight, caused by the pathogens *Alternaria solani* (Ellis and G. Martin) L.R. Jones and Grout and *A. alternata* (Fr.) Keissl., is one of the most destructive fungal foliar diseases in many potato growing regions (Shtienberg et al., 1990; Leiminger, Hausladen, 2012). In susceptible cultivars, it leads to early defoliation and death of the crop (Pelletier, Fry, 1989). The disease occurs particularly in regions with high temperature and alternating periods of dry weather and high humidity and/or in irrigated potato soils that are light-textured, sandy, and low in organic matter (Gudmestad, Pasche, 2007). By contrast, potato late blight (*Phytophthora infestans*) is the most destructive potato disease in North-East European conditions due to its diverse populations (Runno-Paurson et al., 2010; 2011; 2012; 2014); it is quite difficult to control and needs numerous and consistent applications of fungicides for effective control as in other temperate regions (Cooke et al., 2011; Runno-Paurson et al., 2013).

However, occasionally *Alternaria solani* does cause a severe incidence of early blight in potatoes in the Nordic/Baltic region and application of fungicides is necessary to control it (Salonen et al., 2001). In recent years, early blight has occurred with increasing frequency in potato fields in northern regions, especially on fields with susceptible potato cultivars and damage

has been more serious than before due to changed climate conditions (Kocmánková et al., 2010). Moreover, Jönsson et al. (2013) predict further increase in warmer summers, which could cause greater problems from this pathogen in northern regions. In Latvia, Treikale et al. (2008) have reported increased potato early blight damage in recent years on potatoes grown as a monoculture with a high level of nitrogen. Based on disease frequency monitoring, early blight has become more important as a pathogen in recent years in Germany and in Poland (Latorse et al., 2010). Epidemics caused by *Alternaria* species can cause significant economic damage to potato production if not sufficiently chemically controlled (Kapsa, Osowski, 2004; Leiminger, Hausladen, 2012). For organic potato producers the main challenge is disease management, which is limited by regulations that prohibit the use of synthetic pesticides (EU-regulation 2092/91). Thus, early blight represents a risk to crop production and results in significant yield losses (Rotem, 1994). In conventional cultivation in a warm and dry growing season, early blight susceptible cultivars need to be sprayed against the pathogen; otherwise haulms can be destroyed too early in the growing season (Kapsa, Osowski, 2004; Treikale et al., 2008). Growing more resistant cultivars of potato is considered the most efficient, cost-effective

and environmentally-friendly control method for both conventional and organic growing systems. However, growing early blight resistant cultivars is not widespread (Dita Rodriguez et al., 2006). The locally bred potato cultivar 'Reet' was described by breeders Tsahkna and Tähtjärv (2008) as quite late, blight resistant and medium ripening with potential to form tubers early, and therefore is suitable for growing in an organic farming system. Also the cultivar 'Reet' has good quality characteristics like shallow eyes, regular shape and no darkening which are important for food market requirements and processing factories, all very important qualities for marketing (Tsahkna, Tähtjärv, 2008).

In the organic cultivation system, different alternative fertilizers and cultivation technologies including cattle manure and green manure are used to maintain and enhance soil fertility. Studies have shown that winter oilseed rape as a cover crop has the ability to suppress some soil borne diseases of potato (Larkin et al., 2010). Therefore, the main aim of this research was to test how different organic cultivation technologies influence early blight development in disease-favourable conditions. A further aim was to test the suitability of a locally bred quite late blight resistant cultivar recommended for growing in an organic farming system.

Materials and methods

Field experiment. Early blight (*Alternaria solani*) was evaluated in 2010 and 2011 on the plants of a potato cultivar 'Reet' in an organic farming experiment of the Department of Field Crops and Grassland Husbandry, Estonian University of Life Sciences located at Eerika (58°22' N, 26°40' E), near Tartu. The potato trial is part of a 5-year crop rotation experiment with red clover, winter wheat, peas, potato and barley following each other. The rotation experiment was started in 2008. Different field operations and their timing are shown in Table 1.

Table 1. Different field operations and their timing

Field operation	Experimental year 2010	Experimental year 2011
Cultivar	'Reet'	'Reet'
Planting date	6 May	12 May
Planting rate	3 t ha ⁻¹	3 t ha ⁻¹
	57 000 tubers ha ⁻¹	57 000 tubers ha ⁻¹
Harvest date	30 August	24 August
Fertilization	winter cover crop + composted cattle manure –	winter cover crop + composted cattle manure –
	20 April	27 April
	40 t ha ⁻¹ composted cattle manure	40 t ha ⁻¹ composted cattle manure

Year 2010 was the third year for conversion to organic with 2011 the first fully organic year. Winter oilseed rape was used as a winter cover crop before the potato. The experiment was carried out in two different organic growing systems (treatments). In both, a winter cover crop (CC) for green manure (winter oilseed rape) was used; it was planted in both years in September and ploughed down in April the following year. No cattle manure was added to treatment CC, whereas composted

cattle manure (M) was added to the second treatment CC + M (Table 1). There were four replicates of each treatment. The size of each test plot was 60 m². The distance between seed tubers was 27 cm and the distance between rows was 70 cm. In both years only certified seed potatoes were used. Seed tubers with a diameter of 35–55 mm were used. No fungicides, herbicides or insecticides were applied. The soil was *Stagnic Luvisol* (LVj) by WRB 2006 classification (FAO, 2006), the texture of which is sandy loam with a humus layer of 20–30 cm. No irrigation was used.

Weather conditions. In 2010, spring/summer temperature records (Eerika Weather Station) were similar to the long-term (20-year) average, except in July which was hotter by 4.2°C (Table 2). Rainfall in 2010, was similar to the long-term average in June and August, but, in July, was lower with only 36 mm (20-year average is 69.3 mm). In 2011, May, August and September temperature records were similar to the long-term average, but June was hotter by 1.9°C and July by 2.4°C (Table 2). Rainfall was much lower than the long-term average in June, July and August but in the first ten-day period of September more than the long-term average. In July, the warm (with temperatures over 30°C for more than 10 days) and humid conditions were conducive to early blight infection in the third ten-day period of July.

Early blight assessment. Disease assessments were made from 23 July to 27 August in 2010 (6 observations), and from 29 July to 2 September in 2011 (6 observations). Foliar disease was evaluated in natural infection conditions as a percentage of total foliage once each week, until harvesting. In each of the replications, 25 plants per plot were assessed. Early blight infection was assessed according to the 0–100% scale (Granovsky, Peterson, 1954). The area under the disease progress curve (AUDPC) was calculated from the date of first occurrence of early blight until the last observation of the disease in the trial according to Shaner and Finney (1977) by using the following formula: $\sum_i < n [(R_i + 1 + R_{i+1})/2] (t_{i+1} - t_i)$, where R_i is the disease severity (percentage leaf surface blighted) at the i th observation, t_i – the time in days since the previous rating at the i th observation, and n – the total number of observations. The early blight tuber assessment was made three months after harvest. From each replication, 100 tubers were randomly selected to characterize the total yield. A few days before the assessment the tubers were washed in order to see the lesions better.

Data analysis. Statistical analyses were performed with the programme *Statistica 11* (StatSoft Inc., Tulsa, USA). The differences in the severity percentage of early blight between treatments were tested with one-way ANOVA. Kruskal-Wallis ANOVA was used to determine the effects of year and cultivation technology on the early blight tuber infection as the data were not normally distributed. The dependence of AUDPC value and marketable yield of tubers on year and cultivation technology was analysed with type III ANOVA. Both factors such as "year" and "cultivation technology" were treated as fixed categorical variables. Tukey HSD post-hoc tests ($\alpha = 0.05$) were applied to find specific differences between years and cultivation technologies. Interactions between variables were also tested for.

Table 2. Average monthly temperatures and rainfall at Eerika during the vegetation periods of 2010 and 2011 together with long-term averages (according to Eerika Weather Station, Estonia)

Month	Ten-day period	Temperature °C			Rainfall mm		
		Average of 2010	Average of 2011	Average of 1969–2011	Sum of 2010	Sum of 2011	Average sum of 1969–2011
May	I	7.3	8.0	9.7	39.2	0.2	12.9
	II	16.7	11.8	11.4	44.6	46.6	20.9
	III	12.4	13.0	12.8	13.6	11.6	22.8
June	I	13.3	19.7	14.9	41.4	0.0	20.9
	II	13.6	15.9	15.1	17.8	24.8	26.9
	III	15.9	16.2	16.2	38.8	10.4	28.0
July	I	19.9	20.0	17.3	11.6	9.2	19.3
	II	22.9	18.6	17.4	3.0	30.4	24.8
	III	22.4	21.0	17.8	23.8	8.6	26.5
August	I	20.9	16.1	17.6	18.2	16.2	33.3
	II	19.1	15.6	16.2	74.6	17.0	28.5
	III	13.7	15.8	14.6	55.6	21.4	28.0
September	I	10.4	13.0	12.7	32.6	32.2	20.3
	II	12.1	12.2	10.6	46.4	28.4	18.3
May–September	I–III	15.8	14.8	14.6	461.2	257.0	331.5

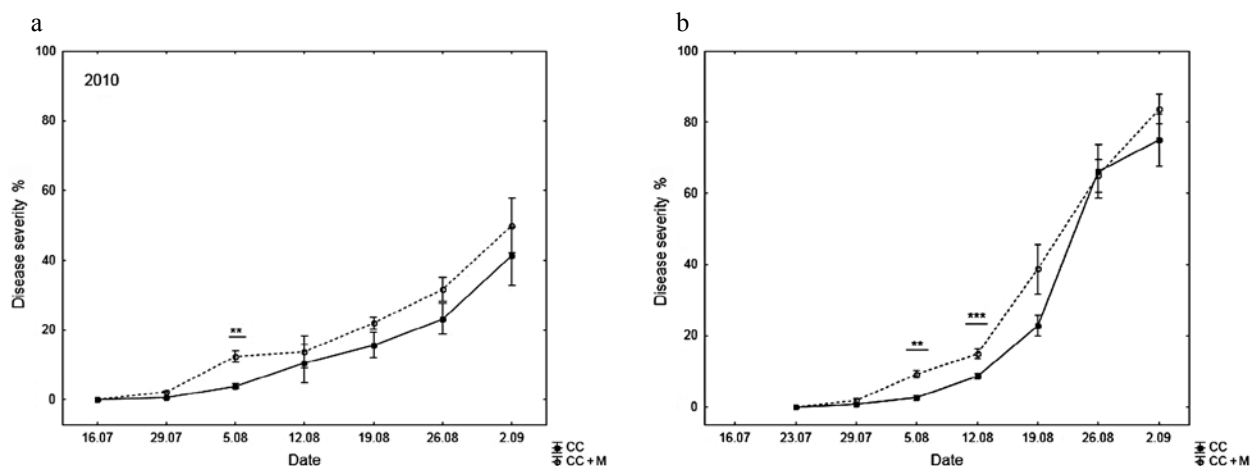
Results

Development of foliar early blight. In both years, early blight was the primary foliar disease on the trial plots. Infection by potato late blight was not recorded in either year. Both growing seasons were very favourable for early blight development and evaluation, with weather conditions even more favourable in 2011 than in 2010. In 2010, the first early blight symptoms were recorded on 23 July, with both treatments infected (Fig. 1 a). The disease-conducive conditions allowed rapid establishment and progression of the disease from the time the first symptoms had been recorded. Winter cover crop (CC) plots had significantly slower progression at the beginning of disease development than the CC + M (manure) plots (29 July, $p = 0.003$; 5 August, $p = 0.66$) (Fig. 1 a) and the disease developed more slowly on the CC plots than on the CC + M plots ($F_{5,18} = 54.70$, $p < 0.0001$, Tukey HSD test $p < 0.05$). By the end of growing season, 50% of foliage was destroyed by early blight on the CC + M plots and 40% on the CC plots. In 2011, the first early blight symptoms were found on 29 July with both CC and CC + M plots infected (Fig. 1 b). Disease developed

moderately until 12 August and thereafter increased abruptly (Fig. 1 b). At the beginning of the observation period, early blight developed significantly more rapidly on the CC + M than on the CC plots. On 26 August, both treatments were similarly infected, but later again the CC treatment developed more slowly than the CC + M (Fig. 1 b). On the CC + M plots more than 80% of the foliage was destroyed by 2 September (Fig. 1 b). Disease severity in the CC + M plots increased from less than 2% at the start to more than 83% within five weeks.

The early blight tuber infection. Infection of tubers by early blight was found in both years. In both 2010 and 2011, it was higher on the CC + M plots than on the CC plots, although not statistically so ($H(1, N = 16) = 0.631$, $p = 0.427$) (Table 3). Data also showed differences between years; tuber infection was higher in 2011 than in 2010, but not statistically significant ($H(1, N = 16) = 2.527$, $p = 0.112$).

Resistance evaluation using area under the disease progress curve (AUDPC). Both growing years were very favourable for early blight foliar resistance



* – $p < 0.05$, ** – $p < 0.01$ (ANOVA)

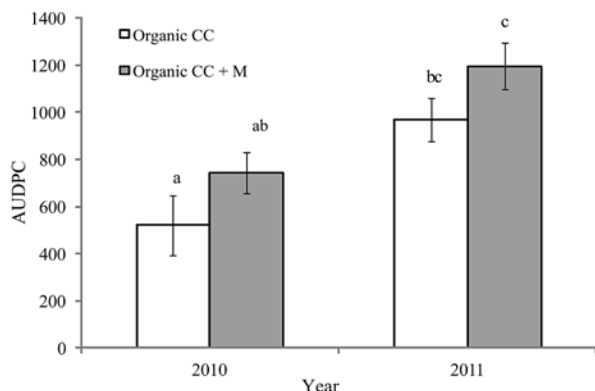
Figure 1. Development of potato early blight on organic plots with previous cover crops (CC) or with cover crops and added cattle manure (CC + M) in 2010 (a) and 2011 (b)

Table 3. Results of the early blight tuber infection (%)

Treatments	Year	
	2010	2011
Organic CC	0.25 a	1 a
Organic CC + M	0.5 a	1.75 a

Note. a – statistically significant differences between treatments not found; CC – winter cover crop, CC + M – winter cover crop + composted cattle manure.

evaluations; still early blight pressure was different in 2010 and 2011. Significant differences were found in AUDPC values between the two years ($F_{1,12} = 19.29$, $p < 0.001$) (Fig. 2). In both years, AUDPC values were very high; the mean AUDPC in 2010 was 632 and, in 2011, even higher – 1081 (Fig. 2). Significant differences between the two cultivation technologies were found ($F_{1,12} = 4.84$, $p = 0.048$). In 2010, the AUDPC value was 303 on CC plots and 990 on CC + M plots, that is three times higher (Fig. 2), whereas in 2011, the AUDPC value was 967 on CC plots 1195 on CC + M plots (Fig. 1). There was no interaction between cultivation technology and year ($F_{1,12} = 0.0008$, $p = 0.978$).



Notes. The boxes indicate the mean value and whiskers the standard error of the mean. Different letters above the boxes indicate statistically significant differences among treatments (ANOVA, Tukey HSD test). Potatoes were grown on plots following a cover crop (CC) of winter oilseed rape and with (CC + M) or without added cattle manure.

Figure 2. Mean area under the disease progress curve (AUDPC) values of foliar early blight in organic potato field trials in 2010–2011

Early blight effect on potato tuber yield. There were significant differences in marketable tuber yield between years ($F_{1,12} = 16.33$, $p = 0.0016$) and treatments ($F_{1,12} = 8.39$, $p = 0.013$) (Fig. 3). In 2010, marketable tuber yield was approximately 9 t ha⁻¹ lower than in 2011 (Fig. 3), although there were no differences in marketable yield between treatments. In 2011, marketable tuber yield was 8 t ha⁻¹ higher on CC + M plots than on CC plots.

Discussion

This study indicates that potato early blight is a great problem for potato growing in an organic farming system, and especially so in years with higher than average temperature. In both our study years, the severe early blight infection caused defoliation, especially in 2011 on the plots with added cattle manure CC + M, where more than 80% of foliage was killed. The direct

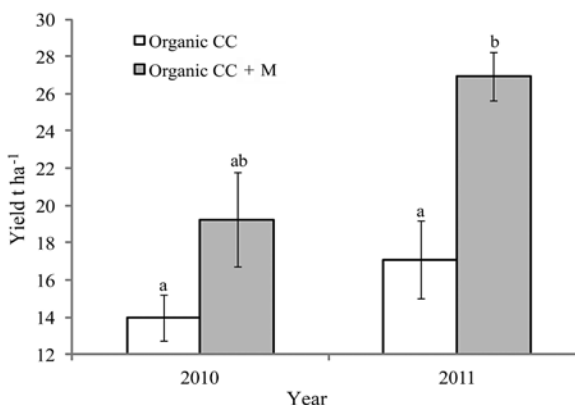


Figure 3. Marketable potato tuber yields in 2010 and 2011 from organically farmed plots with a previous cover crop (CC), winter oilseed rape, some with and without added cattle manure (M)

cause of this was probably the extremely low rainfall in May, June and July in 2011 compared to the long-term average. Drought influences the normal functioning of potato plants; stressed plants are more susceptible to early blight. The early blight pathogens are typical examples of a necrotrophic organism, where a pathogen infects weaker and older plants (Rotem, 1994). The same trend of a recent increase in damage by potato early blight has been reported from other European countries, including some where potato early blight has been problematic for some time, for instance in south-eastern Sweden (Blixt, Andersson, 2010) and in Germany (Leiminger et al., 2010). In Poland, regional losses of up to 45% have been found, mostly associated with cultivars with recognized susceptibility to early blight (Kapsa, Osowski, 2004), and Kapsa and Osowski (2011) have reported a recent increase in the importance of the disease.

In our two year study, the CC + M plots gave higher potato yields than the CC plots despite having more of their foliage destroyed by early blight disease. These results seem quite contrary to the findings in the literature. Early canopy defoliation reduces assimilate accumulation in the tubers (Rotem, 1994) resulting in yield loss (Shtienberg et al., 1990). James et al. (1972) have stated that the tuber-filling process paralyzes when defoliation reaches over 75%. Researchers Campo Arana et al. (2007) have observed even more serious consequences of early blight damage, where, at 50% to 100% defoliation, yield loss was about 55%. Both our cultivation systems had significant differences in AUDPC value, with both levels quite high. Therefore, early blight defoliation apparently did not have as great an effect on marketable yield as fertilization with cattle manure. On the other hand, CC + M plots had a more nutritious soil due to the cattle manure, supplying nutrients earlier and enabling higher tuber yields.

The lower crop yields we obtained in 2010 are quite hard to explain, because disease pressure was lower and overall humidity conditions were more favourable in 2010 than in 2011. Still, after potato plants emerged in June in 2011, it was 3°C warmer than in 2010. Also, in July 2010, there were several days with an air temperature above 28°C. Temperature is a major factor regulating biomass accumulation and tuber development in potatoes. Cao and Tibbitts (1994) have indicated that tuber development of potatoes is optimized by high

temperature during early growth and low temperature during later growth.

AUDPC values were lower on our CC plots than on CC + M plots, even though the former were less fertilized. There is less information available about early blight damage on potato and its relation to obtaining nutrients in an organic growing system. For comparison, in conventional potato growing increased rates of nitrogen fertilizer application reduce the apparent infection rate and the final amount of early blight disease (MacKenzie, 1981). Also, Christ and Haynes (2001) showed that application of more fertilizer and low rainfall in the early part of the season prevented an early blight epidemic. An initial result of our research indicated that manure inhibits the suppressive effect of winter oilseed rape. We could only hypothesize that the suppressive cover crop effect of winter oilseed rape appeared clearer on the treatment without cattle manure.

Genetic resistance of cultivars to pathogens is a major factor for consideration where there is severe pressure from the early blight pathogen (Kapsa, Osowski, 2011). Even the late blight resistant potato cultivar 'Reet' is recommended by breeders for economical cultivation (Tsahkna, Tähtjärv, 2008), although our experience has shown that, in a dry and hot growing season, conditions are favourable for a very severe early blight infection that destroys most of the foliage. The early blight damage evaluation showed that foliage was notably less destroyed by disease in CC plots than in the CC + M plots. As our results have indicated, it is possible to influence the development severity of early blight by selection of growing technology, although further work is necessary. As early blight is not the main foliar disease of potato in Estonia, the extraordinarily heavy early blight infection was not expected. A very severe outbreak of early blight occurred in the organic plots and destroyed most of the canopy. Therefore, from the experience of this two-year trial we can state, that besides the threat from potato late blight, potato early blight can also cause serious infection in Estonia and thus, early blight susceptible potato cultivars cannot be recommended for an organic farming system. From our results, we conclude that for environmentally-friendly farming early blight resistant potato cultivars should be grown in both organic and conventional growing systems. In an organic farming system, chemical control is not allowed and, in conventional systems, the disease requires the application of expensive fungicides.

In changed warmer climatic conditions, new pathogens will give rise to new problems in the future (Jönsson et al., 2013). Our results confirm that potato early blight has already become a more serious problem for North-East European organic potato growers. In the future, we need to investigate what is behind the more serious early blight infections: warmer summers (the global climate change), more susceptible cultivars or even changes in pathogen epidemiology?

Conclusions

1. Potato early blight is a grave problem for potato growing in an organic farming system, and especially in years with higher than average temperatures.

2. In both our study years, early blight infection was more severe in the plots with added cattle manure (CC + M) than in the cover crop (CC) plots.

3. The development severity of early blight can be influenced by selecting appropriate growing technology, but more research on this is needed.

4. In the changed climatic conditions, early blight can cause early defoliation of plants and crop death in susceptible cultivars, indicating the need for resistant potato cultivars.

Acknowledgements

The study was supported by the Estonian Foundation grants Nos. 9432 and 9450; Target Financing SF170057s09, projects RESIST 3.2.0701.11-0003 and TILMAN-ORG.

Received 29 05 2013

Accepted 15 10 2013

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ISSN 1392-3196 / e-ISSN 2335-8947

Zemdirbyste-Agriculture, vol. 101, No. 2 (2014), p. 199–204

DOI 10.13080/z-a.2014.101.026

Auginimo technologijos įtaka bulvių sausligės (*Alternaria solani*) plitimui ekologinėje žemdirbystės sistemoje

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Santrauka

Pastaruoju metu ekologiški produktai tapo itin populiarūs, ir susidomėjimas jais vis didėja. Bulvių sausligės sukėlėjas *Alternaria solani* anksčiau nebuvo laikomas itin grėsmingu bulvėms šiaurinio klimato sąlygomis, todėl nuo šios ligos bulvės nebuvo reguliariai purškiamos. Tyrimo metu bulvių sausligė vertinta 2010 ir 2011 m., vykdant ekologinės žemdirbystės bandymą su veislės 'Reet' bulvėmis. Abiem tyrimų metais bulvių vegetacijos laikotarpis buvo labai palankus bulvių sausligės vystymuisi. Tarp dviejų auginimo technologijų nustatyti esminiai skirtumai ($F_{1,12} = 4,84, p = 0,048$). 2010 m. ligos pažeistų lapų ploto indeksas (AUDPC) buvo 303 antsėlinių augalų laukeliuose ir 990 antsėlinių augalų bei mėšlo laukeliuose, t. y. tris kartus didesnis. 2011 m. AUDPC indeksas buvo 967 antsėlinių augalų laukeliuose ir 1195 antsėlinių augalų bei mėšlo laukeliuose. Tyrimo rezultatai patvirtina, kad sausligė tapo rimta problema Šiaurės Rytų Europoje ekologiškai auginamų bulvių laukuose, todėl ekologinės žemdirbystės sistemoje nerekomenduotina auginėti sausligei jautrių veislių bulvių. Sausligės vystymosi intensyvumui gali turėti įtakos bulvių auginimo technologija. Kintančio klimato sąlygomis auginant sausligei jautrių veislių bulves, dėl šios ligos augalai anksti numeta lapus ir gali žūti, todėl yra poreikis kurti šiai ligai atsparių veislių bulves.

Reikšminiai žodžiai: *Alternaria solani*, ekologinė auginimo sistema, ligos intensyvumas.