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Carrot (*Daucus sativus* Röhl.) colonization by *Alternaria* spp. and effect of fungicide spray on their population

Elena Survilienė,

Alma Valiuškaitė

Plant Protection Laboratory,
Lithuanian Institute of Horticulture,
LT-54333 Babtai, Kaunas district,
Lithuania.
E-mail: e.surviliene@lsdi.lt

In 2003–2005, at the Lithuanian Institute of Horticulture research was carried out to establish *Alternaria dauci* incidence in carrots (*Daucus sativus* Röhl.) during vegetation, and root damage by *Alternaria radicina* during storage. Resistance of 21 carrot cultivars to alternaria leaf blight (*A. dauci*) was established in natural infection conditions. In stored roots black rot (*A. radicina*) made up to 12% of all identified rots. The biological efficiency of fungicides Amistar 250 SC (azoxystrobin 250), Signum 334 WG (boscalid 267, pyraclostrobin 67), Folicur 250 EW (tebuconazol 250), Dithane NT 75 WG (mancozeb 750), Euparen M 50 WG (tolylfluanid 500) and Rovral FLO 255 SC (iprodione 250) to control alternaria leaf blight was established in the medium resistant variety *Samson* by spraying 2–3 times during the development of harvestable vegetative plant parts (BBCH 43–47). All the fungicides tested reduced the population of micromycetes *A. dauci.* The efficiency of fungicides averaged to 61.44–79.65%. Fungicide sprayings during vegetation reduced root damage by *A. radicina* up to 82%.

Key words: *Alternaria radicina, Alternaria dauci,* carrot, diseases, fungicides

INTRODUCTION

Carrot (*Daucus sativus* Röhl.) is one of the most popular and commonly consumed vegetables (Rubatsky, 2002). Commercial carrot production is an economically important industry worldwide. In Lithuania, nearly 120 thou. tons of carrots are produced annually on over 6 thou. ha (Statistics Lithuania, 2005).

Two pathogenic species of the genus *Alternaria* Nees, *Alternaria radicina* and *Alternaria dauci*, are isolated from diseased carrot plants in all growing stages. Alternaria leaf blight is caused by fungus *A. dauci* (Kühn) Groves & Skolko and alternaria black rot by fungus *A. radicina* Meier, Drechsler & Eddy (Stranberg, 1992). Alternaria diseases decrease the nutritive value of vegetables, their storability and resistance to rots (Coles, Wicks, 2003; Farrar et al., 2004; Survilienė et al., 2006; Šidlauskienė, Survilienė, 2002). Their polyphagous nature and ability to produce mycotoxins and other toxic metabolites mean that they are potentially dangerous food spoilage agents (Solfrizzo et al., 2005).

Control of alternaria leaf blight is necessary to prevent destruction of the photosynthetic surface area of plants and to allow efficient mechanical harvest. Healthy leaves are necessary for harvest since leaves weakened by blight will break, leaving the root in the soil. Modern carrot production utilizes self-propelled multi-row mechanical harvesters which undercut and lift carrots from the ground by their tops using a system of gripper belts. This is followed by removal of the foliage which is discarded, while the roots are conveyed and collected in large containers or wagons. Obviously, strong and healthy foliage is an important feature for this type of mechanical harvesting (Rubatsky, 2002; Farrar et al., 2004). Black rot has been reported from all major carrot-growing regions of the world. Surveys conducted in Europe and Asia showed the average incidence of black rot on storage carrots to range from 1 to 50% (Geeson et al., 1988; Vlasova, 1986).

Alternaria diseases are controlled through integrated use of clean seeds, sanitation, crop rotation, cultivar selection, and fungicides (Soteros, 1979; Farrar et al., 2004). In most carrot production areas, routine applications of fungicides are necessary to adequately control alternaria leaf blight. Under high disease pressure, no single control measure is sufficient to manage the disease adequately. Multiple applications of fungicides are required to achieve economic yield and acceptable quality in infected crops, but there is always a possibility to obtain pathogens resistance to pesticides.

The aims of the present investigation were to establish the incidence of *Alternaria dauci* and *Alternaria* *radicina* on carrots and to evaluate the influence of fungicides with different active ingredients on the prevalence of alternaria diseases.

MATERIALS AND METHODS

Field experiments were established at the Lithuanian Institute of Horticulture in 2003 to evaluate 21 carrot cultivars for resistance to alternaria leaf blight in natural infection conditions. The assessment was carried out during the development of harvestable vegetative plant parts (growth stage by BBCH 45–47, when 50% of the expected root diameter has been reached) on 25 plants from 5 places, and disease severity was rated using the 0–4 scale system. Ratings were converted to percent foliage infection.

Fungicide spray trials. Investigations of the efficiency of fungicide treatment to control alternaria leaf blight on the variety *Samson* were carried out in 2003–2005. Medium late carrot *Samson* was grown according to the carrot growing technology accepted at Lithuanian Institute of Horticulture (Table 1).

Table 1. **General technology elements of carrot *Samson* growing**

Previous crop	Onion
Fertilization	Before sowing and at the beginning of growing: Cropcare 6-11-24 500 kg ha^{-1} and 300 kg ha^{-1}; supplementary fertilization: calcium nitrate 200 kg ha^{-1} and Boramin Ca 3 l ha^{-1} (2 times);
Soil	Sod gleyic light loam pH 6.7
Humus	2.06-2.7%
Sowing time	May 20–22
Seed rate	1.2 million ha^{-1}
Weed control	After sowing Stomp 33 EC 4.0 l ha^{-1}; hoed inter-rows at the depth of 5-8 cm and weeded
Pest control	Spraying with insecticide Decis 2.5 EC 0.3 l ha^{-1}, Fastac 10 EC 0.1 l ha^{-1}
Harvesting	End of September

The fungicide efficiency trials were carried out observing the requirements of Good Experimental Practice (GEP certificate No 2, confirmed on May 21, 2001) by using the method of randomly chosen blocks in four replications, with the area of a record plot 11.13 m^2. When the first symptoms of disease were observed, two or three fungicide applications every 10–14 days were made on carrot *Samson* (BBCH 43–47) with fungicides according to the trial scheme (Table 2). The last application was made 28 days before crop harvest. Water volume was 700 l ha^{-1}.

Assessments of diseases were made on 25 plants from 3 places of replications before application and 7–14 days after applications. Diseases prevalence, intensity and the biological efficiency of fungicides were determined according to the generally accepted methods of investigation (Žemės ūkio augalų kenkėjai…, 2002).

Storage experiments. Yield samples were stored in plastic bags in batches of 30 carrot units from each replication in a climatic chamber. Samples from different experimental sites were stored in the same conditions: temperature 0–1 ˚C, relative humidity 90–95%. Injuries on roots were analysed four times during storage between December and March.

Statistical processing of the data was carried out by the method of dispersion analysis according to Duncan's test (P = 0.05).

Meteorological conditions for carrot growing, maturing and diseases were diverse during vegetation in 2003–2005 (Table 3). The beginning of the summer of 2003 was chilly. Frosts occurred in June, the temperature at the beginning of July was changeable and in the middle of July it suddenly rose and remained the same up till the beginning of August. The average

Table 2. **Fungicide trial scheme**

Treatments	Active ingredient, rate g kg^{-1}, l^{-1}	Rate, kg, l ha^{-1}	Application number
Untreated	-	–	–
Amistar 250 SC	Azoxystrobin 250	0.8	2
Signum 334 WG	Boscalid 267, pyraclostrobin 67	1.0	2
Folicur 250 EW	Tebuconazol 250	1.0	2
Dithane NT 75 WG	Mancozeb 750	2.5	3
Euparen M 50 WG	Tolylfluanid 500	1.2	3
Rovral FLO 255 SC	Iprodione 250	2.0	3

Table 3. **Mean air temperature and the amount of precipitation in carrot growing season**

Year	Mean air temperature, ˚C				Amount of precipitation, mm			
	June	July	August	September	June	July	August	September
2003	15.4	20.1	17.5	12.8	54.2	118.2	53.4	27.9
2004	13.7	16.1	16.7	11.6	77.4	50.4	123.6	36.2
2005	14.8	19.4	14.7	13.2	66.6	3.8	109.4	45.3
Rate	16.6	17.6	16.3	12.0	50.4	71.8	74.8	56.0

Table 4. **Characteristic of carrot cultivars**

Cultivar	Source	Type[1]	Suitability for storage[2]
Ascania F_1	Agro Tip, Germany	N	3
Bangor F_1	Bejo Zaden, Holland	B/N	1–2
Bersky F_1	Bejo Zaden, Holland	B	3
Bolero F_1	Vilmorin, France	N	1
Cabana RZ F_1	Rijk Zwaan, Holland	N	2
Canada F_1	Bejo Zaden, Holland	C/F	2
Champion F_1	Syngenta Seeds, Holland	N	1
Favor F_1	Clause, France	N	2
Joshi RZ F_1	Rijk Zwaan, Holland	N	2
Maestro F_1	Vilmorin, France	N	2
Magi	Agro Tip, Germany	N	3
Napa F_1	Bejo Zaden, Holland	N/I	1–2
Nigel F_1	Bejo Zaden, Holland	N	1–2
Nimrod F_1	Bejo Zaden, Holland	N	1
Primo F_1	Nickerson-Zwaan, Holland	N/C	3
Riga F_1 RZ	Rijk Zwaan, Holland	B/N	1
Samson	Bejo Zaden, Holland	N	2
Senator F_1	Clause, France	B/N	1
Tempo F_1	Vilmorin, France	N	3
Tito	Nickerson-Zwaan, Holland	N	2
Turbo F_1	Tezier, France	N	3

[1] Type of root-crop: B – Berlikum; C – Chantenay; F – Flakee; I – Imperator; N – Nantes.

[2] Suitability for storage: 1 – very good; 2 – good; 3 – unadvisable.

summer temperature was by 1.2–2.5 °C higher than the multiannual average. Precipitation was distributed unevenly. More abundant rains started at the end of June, and it rained till the middle of July. At the end of August – beginning of September the weather was rainy, but cooler. It was favorable not only for carrot growth and maturing, but also for infection with phytopathogens and the development of diseases.

The weather of the summer of 2004 was variable – cool in the first and warmer in the second half of the season. June was much more humid than usually. There was by 20 mm less precipitation in July, but it was very humid in August – the precipitation exceeded the rate even 1.6 times. June was the coolest and August the warmest month. The air temperature in summer was very similar to the multiannual value. September was warm and in the first half dry, but the third decade was very rainy. In general, the weather was favorable for carrot growth, and the precipitation was sufficient for the infection process.

In 2005, the weather was medium favorable for carrot growing. June was warm and rainy. In July and September the air temperature was higher than the average multiannual value. In July precipitation was scarce, and August was significantly wetter, therefore the first disease symptoms in carrots were detected in August.

RESULTS AND DISCUSSION

In field experiments the resistance of 21 carrot cultivars to alternaria leaf blight was estimated in natural infection conditions at the stage of the development of harvestable vegetative plant parts (BBCH 45–47). Most

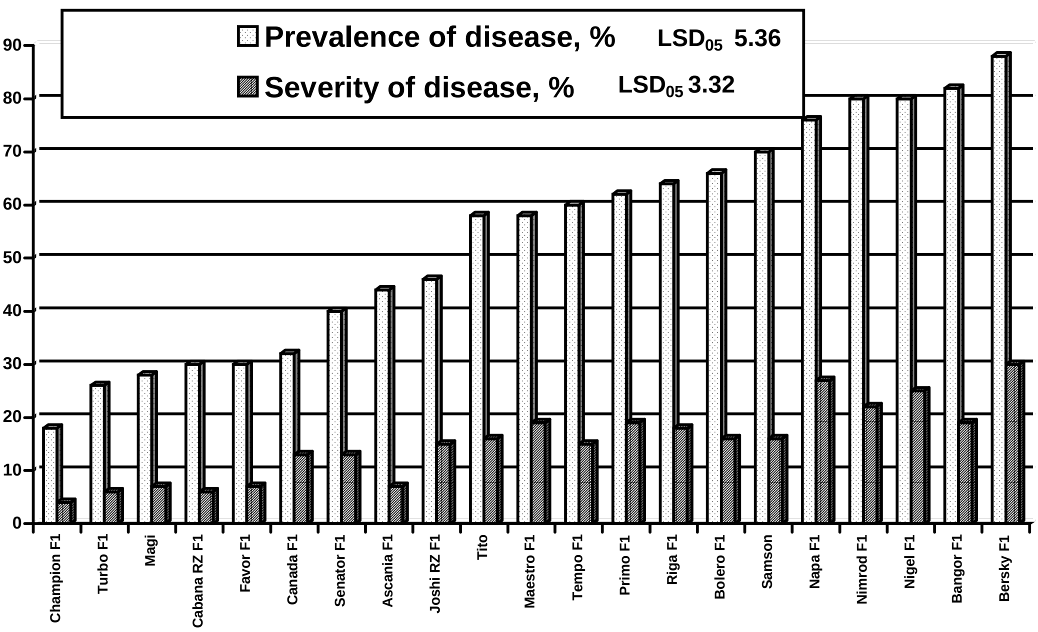

Fig. 1. Resistance of carrot cultivars to natural infection of leaf blight (*Alternaria dauci*).
Severity of leaf blight symptoms was rated as follows: 0 – no infection; 1 – easy infection (1–10% of leaves are infected); 2 – medium infection (11–25% of leaves infected); 3 – strong infection (26–50% of leaves infected); 4 – very strong infection (>50% of leaves infected). Ratings were converted to foliage infection percentage.

Table 5. **Effect of fungicides alternaria leaf blight infection of in carrot *Samson,* 2003–2005**

Fungicide trial (application number)	Rate, ha^{-1}	Foliage infection by alternaria leaf blight, %				
		before application	after the first application		after the last application	
			7 days	14 days	7 days	14 days
Untreated (control)	-	2.62 a	9.11 a	14.12 a	33,06 a	67.83 a
Amistar 250 SC (2)	0.8 l	1.35 b	2.11 c	2.52 d	3.83 d	5.24 e
Signum 334 WG (2)	1.0 kg	3.29 a	4.34 b	4.53 c	4.14 d	9,21 c
Folicur 250 EW (2)	1.0 l	2.09 ab	1.71 cd	3.03 d	4.38 d	7.78 d
Dithane NT 75 WG (3)	2.0 kg	2.07 a	2.83 c	5.51 c	9.52 b	15.58 b
Euparen M 50 WG (3)	1.2 kg	2.42 a	4.08 b	7.02 b	7.99 c	14.57 b
Rovral FLO 255 SC (3)	2.0 l	1.66 b	2.13 c	3.97 cd	7.23 c	10.81 c

Note. Values in columns followed by the same letters are not significantly different at P = 0.05 in Duncan's test.

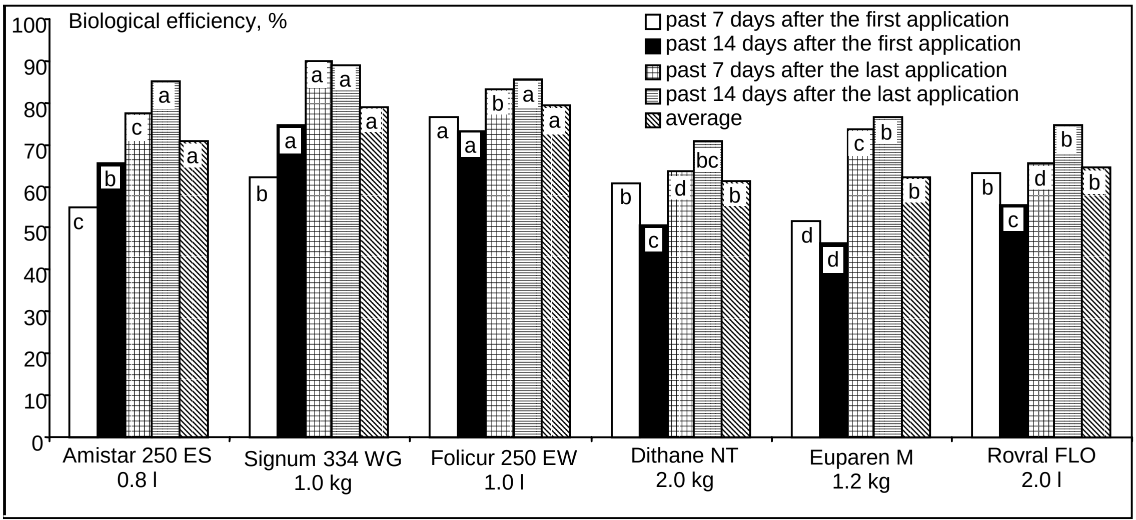

Fig. 2. Biological efficiency of fungicides to control alternaria leaf blight on carrot *Samson,* 2003–2005
Note. Values in the same columns followed by the same letters are not significantly different at P = 0.05 in Duncan's test.

carrots were of Nantes and Berlikum types and differed by suitability for storage (Table 4).

Carrot leaves were injured by alternaria leaf blight at a different level. Foliage infection varied from 18 to 88%. Foliar symptoms of disease appear as small, greenish-brown, water-soaked lesions. The lesions enlarge and the infected tissue becomes dark brown to black and may be surrounded by a chlorotic halo. Under favorable conditions, lesions coalesce and may cause the entire leaf to collapse. Older leaves are infected first. Lesions are more common on the margins of the leaflets, but may occur on any part of the leaf blade or petiole. Lesions on the petioles are similar to lesions on the leaf blades, except that they often become elongated. Numerous or large petiole lesions can kill the entire leaf, and heavy infestations may cause complete defoliation.

Carrot cultivars differ in their resistance to infection by *A. dauci.* During the development of harvestable vegetative plant parts (BBCH 45–47) it was detected that cultivars *Champion* F_1, *Turbo* F_1, *Magi*, *Cabana* F_1, *Favor* F_1 and *Ascania* F_1 were slightly injured by alternaria leaf blight, the severity of infection not exceeding 10% of infected leaves (Fig. 1). The cultivars *Canada* F_1 and *Senator* F_1 were resistant too, but no statistically reliable difference was obtained.

Medium infection of alternaria leaf blight was detected on cultivars *Tempo* F_1, *Joshi* RZ F_1, *Bolero* F_1, *Samson*, *Tito*, *Riga* F_1, *Bangor* F_1, *Primo* F_1 and *Maestro* F_1, the severity of infection not exceeding 25% of infected leaves. Cultivars *Nimrod* F_1 and *Nigel* F_1 did not reveal statistical difference for resistance. The data suggest that the aforementioned carrot cultivars could be grown commercially without fungicides or with a reduced fungicide application program.

Most severely injured by leaf blight were carrots *Bersky* F_1 and *Napa* F_1, the severity of disease exceeding 25% of infected leaf.

Carrot exhibits a good physiological storability. Provided that carrots are not infected by microbes causing storage diseases, they can be stored for 6–8 months without loss of quality under optimal storage conditions (temperature 0 °C and relative humidity 95%). Carrot has low metabolic activity at low temperatures,

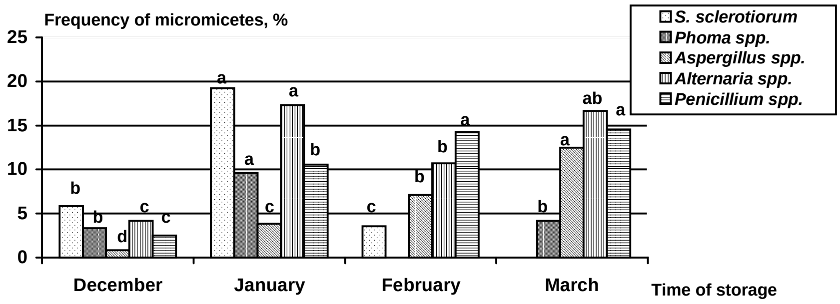

Fig 3. Prevailing micromycetes on carrot by storage time.
Note. Values in the same columns followed by the same letters are not significantly different at P = 0.05 in Duncan's test.

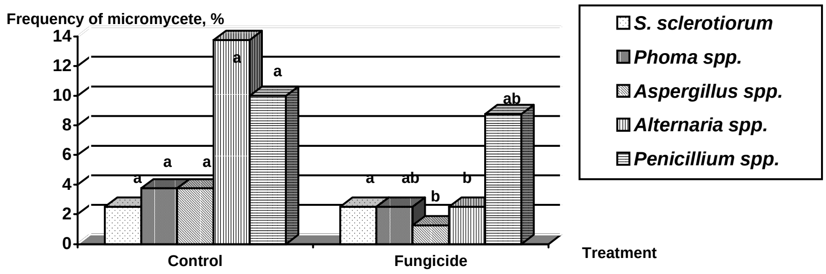

Fig. 4. Dependence of micromycetes distribution in stored carrots on growing conditions.
Note. Values in the same columns followed by the same letters are not significantly different at P = 0.05 in Duncan's test.

as shown by the low respiration rate. However, carrot is sensitive to wilting if not protected from water loss. In commercial refrigerated stores, storage diseases, mainly caused by pathogenic fungi, pose the greatest risk (Stoll, Weichmann, 1987).

In fungicide spray trials, symptoms of alternaria leaf blight on carrot *Samson* were observed at the end of July and the beginning of August. Disease prevalence was from 1.66 to 3.29%. The severity of infection was rated at 1 point (easy infection), and accordingly leaves were infected up to 10%. The obtained results show that two or three applications with the test fungicides inhibited the prevalence of alternaria leaf spot in carrots, and foliage infection was on average 3.58–7.39 times lower than in control (untreated) carrots (Table 5). The severity of disease was rated at 1–2 points (easy and medium infection), and accordingly infection on leaves did not exceed 25%. Meanwhile in the control plot carrots were injured up to 67.83% and the severity of leaf blight reached 3–4 points (strong and very strong infection), more than 50% of leaf surface was infected.

The average biological efficiency to control alternaria leaf blight after two applications with systemic fungicides was reached as follows: Amistar 250 ES at the rate 0.8 l ha^{-1} was 70.74%, Signum 334 WG 1.0 kg ha^{-1} – 78.93%, Folicur 250 EW 1.0 l ha^{-1} – 79.65%. Contact fungicides applied three times were effective to control leaf blight on carrot, and their average biological efficiency was reached as follows: Dithane NT 75 WG at the rate 2.0 kg ha^{-1} – 61.44%, Euparen M 50 WG 1.2 kg ha^{-1} – 62.07%, and Rovral FLO 255 SC 2.0 l ha^{-1} – 64.76% (Fig. 2). Statistical difference was obtained between different input fungicide actions.

Iprodione, chlorothalonil, difenokonazol, imazalil, tolylfluanid, tebuconazol and mancozeb have been the fungicides of choice in European countries and the United States in recent years (Farrar et al., 2004). In the past few years, azoxystrobin, pyraclostrobin and bascolid have shown excellent control in field evaluations and have been labeled for control of alternaria leaf blight in carrots (Soteros, 1979; Survilienė et al., 2006). Azoxystrobin, pyraclostrobin and trifloxystrobin need to be alternated or tank-mixed with fungicides with different modes of action in order to minimize the possibility of selecting for fungicide resistance in populations of *A. dauci*.

Analyses of stored carrots in December–March of 2003–2005 revealed that on damaged carrots most frequent were micromycetes of *Alternaria, Aspergillus, Phoma, Penicillium* genera and *Sclerotinia sclerotiorum* (Fig. 3). Most often (up to 12%) carrots were injured by black rot (*Alternaria radicina*). More injuries on roots were detected in later storage periods (January–March). Notably more roots were damaged by sclerotinia (*S. sclerotiorum*) and dry rots (*Phoma* spp.) in January. Micromycetes of the genera *Alternaria, Aspergillus, Phoma, Penicillium* are considered as potential mycotoxin producers (Lugauskas, 2005).

Postharvest diseases are the most important limiting factors to long-term storage of carrots and can cause considerable crop losses (Kora et al., 2005). Infection is usually introduced from fields with contaminated produce or stays in contaminated storages and containers. The injured roots are spotted, become black and fur up in various colors (depending on the pathogenic microorganism).

Prevalence analysis of micromycetes on roots during storage has revealed that carrots sprayed with fungicides during vegetation have a lower incidence of *Alternaria* micromycetes. The fungicide inhibition effect on micromycetes of *A. radicina* reached even 82%, *Aspergillus* spp. 67%, *Phoma* spp. 33% (Fig. 4). The effect of fungicide spraying on the fungi of other genera was not so high.

Carrots infected by *A. radicina* later in the growing season may not develop visible lesions until after harvest. In storage, disease development is favoured by a high relative humidity (>92%) and warm storage temperatures. Symptoms of black rot on stored carrots appear as dry, black, sunken lesions which can decay the entire root and spread to adjacent carrots. In the field, black rot symptoms on the carrot crown often become apparent only after the canopy closes, making detection difficult and reducing the effectiveness of fungicide applications. However, fungicides such as chlorothalonil, iprodione and strobilurins can be applied to reduce the damaging effect of *A. radicina* (Farrar et al., 2004; Soteros, 1979; Survilienė et al., 2006).

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Elena Survilienė, Alma Valiuškaitė

VALGOMŲJŲ MORKŲ (*DAUCUS SATIVUS* RÖHL.) UŽSIKRĖTIMAS *ALTERNARIA* SPP. MIKROMICETAIS IR FUNGICIDINIO PURŠKIMO POVEIKIS JŲ POPULIACIJAI

S a n t r a u k a
2003–2005 m. Lietuvos sodininkystės ir daržininkystės institute atlikti tyrimai nustatant *Alternaria dauci* išplitimą morkose (*Daucus sativus* Röhl.) vegetacijos metu bei šakniavaisių pažeidimą *Alternaria radicina* laikymo metu. Įvertintas 21 morkų veislės atsparumas lapų alternariozei natūralios infekcijos fone. Nustatytas fungicidų Amistar 250 SC (v.m. azoksystrobinas 250), Signum 334 WG (boskalidas 267, pyraklostrobinas 67), Folicur 250 EW (tebukonazolas 250), Dithane NT 75 WG (mankocebas 750), Euparen M 50 WG (tolylfluanidas 500) ir Rovral FLO 255 SC (iprodionas 250) biologinis efektyvumas alternariozei ant vidutiniškai atsparios *Samson* veislės, išpurškiant 2–3 kartus derlingųjų vegetatyvinių augalo dalių vystymosi tarpsnyje (BBCH 43–47). Visų tirtų fungicidų efektyvumas siekė vidutiniškai 61,44–79,65%. Sandėliuojamuose šakniavaisiuose juodasis puvinys (*Alternaria radicina*) sudarė iki 12% tarp visų identifikuotų puvinių. Vegetacijos metu purškimas fungicidais mažino šakniavaisių pažeidimą *A. radicina* iki 82%.

Raktažodžiai: *Alternaria radicina, Alternaria dauci,* morkos, ligos, fungicidai