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Fungi diversity on wild and cultivated common caraway (*Carum carvi* L.) seeds

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Abstract

Micromycete contamination of wild and cultivated common caraway (*Carum carvi* L.) seeds of the 2001–2004 harvest was studied. Ripe seeds were collected in various localities of Biržai, Kaunas, Raseiniai, Šilutė, Ukmergė, Varėna and Vilnius districts in June–July. The blotter method was applied for the detection of micromycetes on common caraway seeds. The fungi were identified according to their morphological and cultural properties. The frequency of occurrence and relative density of identified species were calculated. The qualitative and quantitative similarity of fungal complexes, detected on cultural and wild caraway seeds as well as on the seeds of different harvest years and grown in different localities was compared.

The fungi of 55 species and 41 genera belonging to *Ascomycota* and *Zygomycota* phyla, *Sordariomycetes*, *Dothideomycetes*, *Leotiomycetes*, *Eurotiomycetes* and *Incertae sedis* classes were detected and identified on the common caraway seeds. The micromycetes of genus *Alternaria* dominated in the mycobiota of investigated seeds. They made up 59.8% of the total isolate amount and the frequency of their occurrence amounted to 58.4%. Saprotrophes (*Alternaria* spp., *Aspergillus* spp., *Penicillium* spp., *Cladosporium* spp. and others) dominated on the seeds of common caraway. The potential pathogens (*Alternaria alternata, Ascochyta biforae*, *Phomopsis diachenii*, *Fusarium oxysporum*, *F. avenaceum*, *Cylindrocarpon destructans*, *Botrytis cinerea*) – the agents of spots, wilts and rots, were recorded as well. The fungal complexes, detected on the seeds of wild and cultural caraway, have great qualitative and quantitative similarity; however they significantly vary between harvest years and localities.

Key words: caraway, fungi, seeds, frequency of occurrence, relative density.

Introduction

In recent years, increasingly more interest has been shown in non-traditional agricultural crops, including medicinal and spice plants. The growing of medicinal and spice herbs, their use in pharmaceutical, food and cosmetics processing industry belong to the most significantly developing fields of nowadays.

The common caraway (*Carum carvi* L.) is one of the most well-liked spices in the world as well in Lithuania. *C. carvi* is annual, biennial or perennial plant of *Apiaceae* Lindl. family, spontaneously growing in the meadows and pastures, on the skirts of wood, riversides or hillsides. Apart from the wild caraway, distributed all over Lithuania, various forms and varieties of cultural caraway (‘Rekord’, ‘Gintaras’, ‘Kančevitskij’, ‘Chmelnickij’, ‘Prochana’) are grown. The industrial growing of common caraway was started in Lithuania in 1963 (Dastikaitė, 1997). Its areas increased from year to year and reached 6000 ha in 2003 (Kriščiukaitienė et al., 2003). Caraway is valued for its fruit accumulating essential oils used in pharmaceutical, cosmetics and food industries.

The investigation of common caraway started in Kaunas Botanical Garden in 1924. In 1960, *C. carvi* research was performed at the Institute of Botany, recently at the Lithuanian University of Agriculture. The studies are being focused mainly on biological properties and bio-active compounds of the plant (Venskutonis et al., 1999; Petraitytė et al., 2002; Samuolienė, Duchovskis, 2006; Petraitytė, Dastikaitė, 2007). Diseases of common caraway have been intensively studied in other countries (Bulgaria, Czechia, Poland, Germany, the Netherlands) (Evenhius et al., 1995; Gabler, 2001;

Mazur, Nawrocki, 2004; Rodeva, Gabler, 2004; Odstričilová, 2007; Machowicz-Stefaniak, 2009), but not in Lithuania. There are not any data about micromycetes on the common caraway seeds and their distribution in Lithuania. Seed contamination by fungi is a significant indicator of seed quality. The micromycetes on the seeds influence seed germination and are responsible for the spread of disease agents in crops, as well as for the production of mycotoxins contaminating the seed yield.

The aim of this study was to investigate the fungal contamination of common caraway seeds, to identify the species diversity of micromycetes occurring on the seeds, to evaluate their distribution and to compare fungal complexes on the cultural and wild common caraway seeds as well as on the seeds of different harvest years and various localities.

Materials and methods

Micromycete contamination of cultivated ('Gintaras', 'Kančevitskij', 'Rekord') and wild common caraway (*Carum carvi* L.) seeds of the 2001–2004 harvest was studied. Ripe seeds were sampled in various localities of Biržai, Kaunas, Raseiniai, Šilutė, Ukmergė, Varėna and Vilnius districts in June–July. A total of 21 seed samples were tested.

The blotter method was applied for detection of micromycetes on the seeds (Mathur, Kongsdal, 2003). The seeds were plated in aseptic environment in sterile Petri dishes on water-soaked filter paper and incubated for seven days at 24ºC in the dark. The analysis of each seed sample was performed in four replications (100 seeds per replication). After incubation, fungi developed on each seed were estimated. They were identified based on their morphological and cultural characteristics according to Ellis (1971, 1976), Nelson et al. (1983), Arx et al. (1986), Melnik (2000), Markevičius, Treigienė (2003). The frequency of occurrence (FO) of separate species (percent ratio of number of seeds where the species was detected to the total number of tested seeds) and the species relative density (RD) (percent ratio of particular species isolate number to the total number of isolates) in tested common caraway seeds were calculated (González et al., 1995). The FO indicates the distribution of particular species in tested object as the RD – its abundance against other fungus species detected there. The SPSS 17 statistical package was used to analyze the obtained data. The qualitative and quantitative similarity of fungal complexes, ascertained on the seeds of cultural and wild caraway as well as on the seeds of different harvest years and localities was compared by calculating Sorenson's index (SI). The similarity of fungal complexes is small if SI amounts to 39.0%; moderate if SI makes up from 40.0 to 49.0%; high if SI makes up from 50.0 to 59.0%; and very high if SI amounts to more than 60.0% (Maguran, 1988). The classification of fungi was based on "Dictionary of Fungi" (Kirk et al., 2008) and Index Fungorum (http://www.indexfungorum.org). The pure isolates have been deposited in the collection (BILAS) of NRC, Institute of Botany, Vilnius, Lithuania.

Results and discussion

Fungi of 55 species and 41 genera, belonging to *Ascomycota* and *Zygomycota* phyla, *Sordariomycetes*, *Dothideomycetes*, *Leotiomycetes*, *Eurotiomycetes* and *Incertae sedis* classes were detected and identified on the investigated common caraway seeds (Table 1).

Table 1. Micromycetes on the common caraway seeds

Micromycetes	Number of isolates					FO* %	RD** %
	2001	2002	2003	2004	Total		
1	2	3	4	5	6	7	8
Acremoniella atra (Corda) Sacc.	0	16	6	2	24	1.2	1.2
Acremonium implicatum (J. C. Gilman & E. V. Abbott) W. Gams	0	0	3	0	3	0.2	0.2
A. strictum W. Gams	1	0	2	0	3	0.2	0.2
Alternaria alternata (Fr.) Keissl.	65	61	242	294	662	33.5	34.3
A. chlamydospora Mouch.	0	0	0	6	6	0.3	0.3
A. dauci (J. G. Kühn) J. W. Groves & Skolko	0	0	0	15	15	0.8	0.8
A. macrospora Zimm.	0	17	0	0	17	0.9	0.9
A. radicina Meier, Drechsler & E. D. Eddy	23	18	7	38	86	4.4	4.5
A. tenuissima (Kunze) Wiltshire	53	120	93	102	368	18.6	19.1
Arthrinium phaeospermum (Corda) M. B. Ellis	2	3	19	5	29	1.5	1.5
Ascochyta biforae Bond.-Mont.	0	0	0	6	6	0.3	0.3

Table 1 continued

1	2	3	4	5	6	7	8
Aspergillus spp.	8	0	12	59	79	4.0	4.1
Bispora punctata (Corda) G. Arnaud	0	7	0	0	7	0.4	0.4
Botrytis cinerea Pers.	10	3	0	6	19	1.0	1.0
Chaetomium bostrychodes Zopf	0	6	0	0	6	0.3	0.3
C. globosum Kunze	0	0	5	10	15	0.8	0.8
C. megalocarpum Bainier	0	0	0	3	3	0.2	0.2
Chrysosporium merdarium (Ehrenb.) J. W. Cormich.	1	0	0	0	1	0.05	0.05
Cylindrocarpon destractans (Zinssm.) Scholten (*Neonectria radicicola* (Gerlach & L. Nilsson) Mantiri & Samuels)	0	1	0	0	1	0.05	0.05
C. magnusianum Wollenw.	0	0	2	0	2	0.1	0.1
Cladosporium cladosporioides (Fresen.) G. A. de Vries	0	0	0	41	41	2.1	2.1
C. herbarum (Pers.) Link	2	2	7	56	67	3.4	3.5
Cladosporium sp.	0	0	0	7	7	0.4	0.4
Dendryphion comosum Wallr.	0	0	1	1	2	0.1	0.1
Didymostilbe sp.	1	0	0	0	1	0.05	0.05
Eladia saccula (E. Dale) G. Sm.	0	3	0	0	3	0.2	0.2
Epicoccum neglectum Desm.	0	0	3	0	3	0.2	0.2
E. nigrum Link	0	0	0	1	1	0.05	0.05
Fusarium avenaceum (Fr.) Sacc. (*Gibberella avenacea* R. J. Cook)	0	0	7	1	8	0.4	0.4
F. dimerum Penz. (*Microdochium dimerum* (Penz.) Arx	0	0	0	1	1	0.05	0.05
F. graminum Corda	0	1	0	0	1	0.05	0.05
F. incarnatum (Desm.) Sacc.	0	0	7	2	9	0.5	0.5
F. oxysporum Schltdl.	0	0	1	0	1	0.05	0.05
F. sambucinum Fuckel (*Gibberella pulicaris* (Fr.) Sacc.)	0	0	1	0	1	0.05	0.05
Fusarium sp.	0	0	1	0	1	0.05	0.05
Helminthosporium sp.	6	0	0	0	6	0.3	0.3
Hypomyces chrysospermus Tul. & C. Tul.	0	2	0	2	4	0.2	0.2
Humicola grisea Traaen	0	0	0	4	4	0.2	0.2
Khuskia oryzae H. J. Huds.	0	0	1	3	4	0.2	0.2
Leptosphaeria libanotis (Fuckel) Niessl	0	0	0	1	1	0.05	0.05
Mycelia sterilia	0	0	0	2	2	0.1	0.1
Mucor spp.	5	3	8	5	21	1.1	1.1
Neofusicoccum mangiferae (Syd. & P. Syd.) Crous, Slippers & A. J. L. Phillips	0	14	0	7	21	1.1	1.1
Ochrocladosporium elatum (Harz) Crous & U. Braun	0	0	0	1	1	0.05	0.05
Penicillium spp.	55	0	104	18	177	9.0	9.2
Periconia byssoides Pers.	0	0	0	2	2	0.1	0.1
P. circinata (L. Mangin) Sacc.	0	0	0	2	2	0.1	0.1
P. macrospinosa Lefebre & Aar. G. Johnson	0	1	0	0	1	0.05	0.05
Periconiella sp.	0	0	0	1	1	0.05	0.05
Phoma eupyrena Sacc.	0	0	0	1	1	0.05	0.05
Phoma spp.	0	24	2	8	34	1.7	1.8
Phomopsis diachenii Sacc.	0	0	30	0	30	1.6	1.6

Table 1 continued

1	2	3	4	5	6	7	8
Phomopsis sp.	0	0	0	1	1	0.05	0.05
Rutola graminis (Desm.) J. L. Crane & Schokn.	0	0	0	1	1	0.05	0.05
Scopulariopsis brevicaulis (Sacc.) Bainier (*Microascus brevicaulis* E. V. Abbott)	30	3	2	0	35	1.8	1.8
Scopulariopsis fusca Zach	1	0	0	0	1	0.05	0.05
Sordaria fimicola (Roberge ex Desm.) Ces. & De Not	0	0	0	2	2	0.1	0.1
Stachybotrys chartarum (Ehrenb.) S. Huges	0	0	2	0	2	0.1	0.1
Stemphylium botryosum Sacc.	4	5	0	0	9	0.5	0.5
Taeniolella stilbospora (Corda) S. Huges	1	6	0	9	16	0.8	0.8
Torula expansa Pers.	0	0	3	7	10	0.5	0.5
T. herbarum (Pers.) Link	0	6	0	17	23	1.2	1.2
Trichothecium roseum (Pers.) Link	0	3	0	0	3	0.2	0.2
Truncatella truncata (Lév.) Steyaert	0	0	1	0	1	0.05	0.05
Ulocladium oudemansii E. G. Simmons	0	0	0	1	1	0.05	0.05
Volucrispora graminea Ingold, P. J. McDougall & Dann	0	11	0	4	15	0.5	0.8

Note. * frequency of occurrence, %; ** relative density, %.

Micromycetes from genus *Alternaria* prevailed among them and accounted for 59.8% of the total isolate amount. The relative density of *Penicillium* spp., *Cladosporium* spp. and *Aspergillus* spp. amounted to up to 9.2, 5.6 and 4.1%, accordingly. Fungi of *Phoma* (RD 1.9%), *Phomopsis* (RD 1.7%), *Torula* (RD 1.7%) genera and *Microascus brevicaulis* (RD 1.8%) made up almost two-thirds of the total amount of isolates. The RD of *Arthrinium phaeospermum*, *Acremoniella atra* and fungi of genera *Chaetomium* and *Fusarium* topped one percent and amounted to up to 1.5, 1.2, 1.3 and 1.2%, accordingly (Figure 1).

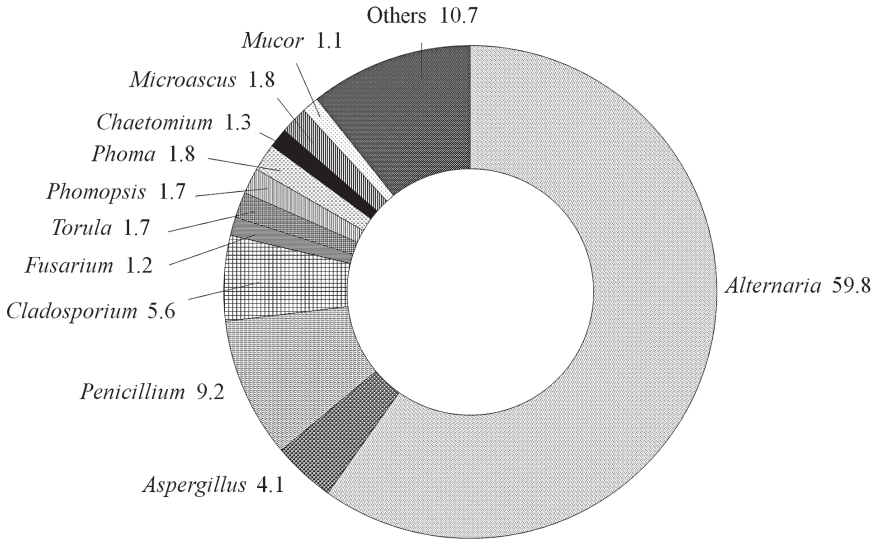


Figure 1. The relative density (%) of some fungal genera on the common caraway seeds

The fungi of genus *Alternaria* were detected in all seed samples collected in various localities and different years (Tables 2–4). Their FO exceeded 58.4%. Six species (*A. alternata*, *A. chlamidospora*, *A. dauci*, *A. macrospora*, *A. radicina* and *A. tenuissima*) of this genus were identified on the common caraway seeds. *A. alternata* predominated among them and made up 57.3% of the total *Alternaria* isolate amount. *A. tenuissima* (RD 31.9% among *Alternaria* isolates) and *A. radicina* (RD 7.5% among *Alternaria* isolates) were frequent occurrence as well (Figure 2 a). These *Alternaria* species were most common in all years of investigation. Their FO depended both on the common caraway growing locality and the harvest year. The fungi of genus *Alternaria* were more common on the seeds of cultural caraway (Mačkinaitė, 2009).

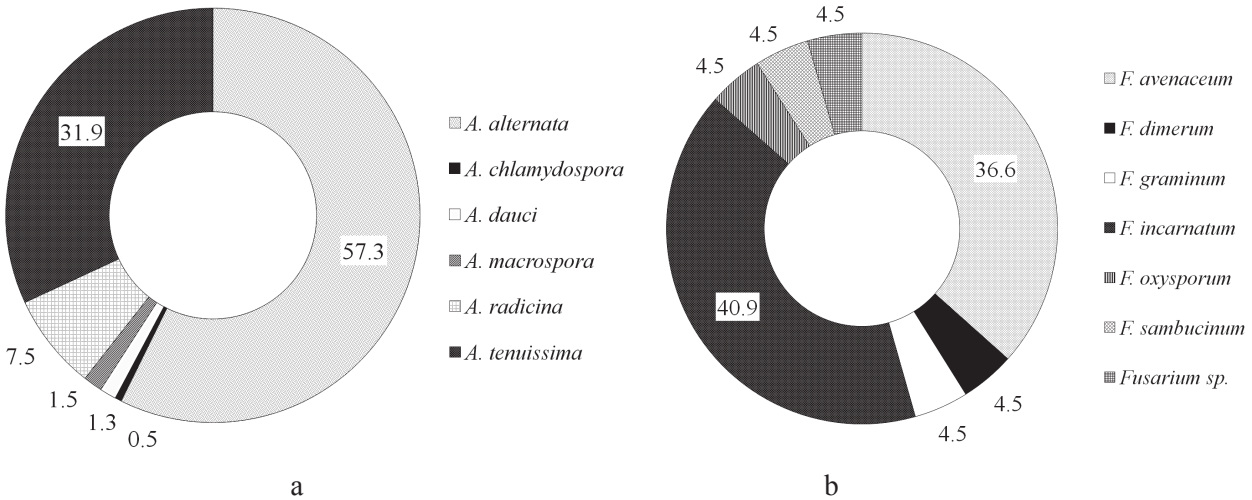
Table 2. Micromycetes on the common caraway seeds of 2001–2002 harvest in various localities

Micromycetes	Frequency of occurrence %					
	2001			2002		
	I	II	III	IV	V	VI
Acremoniella atra	0	0	0	0	0	16.0
Acremonium strictum	0	0	1.0	0	0	0
Alternaria alternata	4.0	41.0	20.0	4.0	44.0	24.0
A. macrospora	0	0	0	8.0	12.0	0
A. radicina	0	19.0	4.0	1.0	13.3	7.0
A. tenuissima	2.0	42.0	9.0	75.0	40.0	15.0
Arthrinium phaeospermum	2.0	0	0	0	0	3.0
Aspergillus spp.	0	0	8.0	0	0	0
Bispora punctata	0	0	0	4.0	4.0	0
Botrytis cinerea	0	0	10.0	0	0	3.0
Chaetomium bostrychodes	0	0	0	0	0	6.0
Chrysosporium merdarium	0	1.0	0	0	0	0
Cylindrocarpon destructans	0	0	0	1.0	0	0
Cladosporium herbarum	1.0	0	1.0	0	0	2.0
Didymostilbe sp.	1.0	0	0	0	0	0
Eladia saccula	0	0	3.0	0	0	0
Fusarium graminum	0	0	0	1.0	0	0
Helminthosporium sp.	0	0	6.0	0	0	0
Hypomyces chrysospermus	0	0	0	0	0	2.0
Scopulariopsis brevicaulis	0	0	30.0	0	2.7	1.0
S. fusca	0	0	1.0	0	0	0
Mucor sp.	3.0	0	2.0	0	0	3.0
Neofusicoccum mangiferae	0	0	0	12.0	2.7	0
Penicillium spp.	5.0	30.0	20.0	0	0	0
Periconia macrospinosa	0	0	0	1.0	0	0
Phoma spp.	0	0	0	0	16.0	12.0
Stemphylium botryosum	0	4.0	0	2.0	4.0	0
Taeniolella stilbospora	0	1.0	0	1.0	6.7	0
Trichothecium roseum	0	0	0	0	0	3.0
Torula herbarum	0	0	0	2.0	0	4.0
Volucrispora graminea	0	0	0	9.0	2.7	0

Note. In 2–6 tables I–XXI – the species, cultivars of common caraway and the localities of their seed sampling: I – *Carum carvi*, Vilnius, Pagubė; II – *C. carvi* 'Rekord', trade company "Sėklos"; III – *C. carvi* 'Rekord', trade company "Agrolitpa"; IV – *C. carvi*, Utena distr., Leliūnai; V – *C. carvi*, Vilnius, Naujininkai; VI – *C. carvi* 'Gintaras', Kaunas distr., Noreikiškės; VII – *C. carvi*, Vilnius, Salininkai; VIII – *C. carvi*, Vilnius distr., Rudamina; IX – *C. carvi*, Varėna distr., Marcinkonys; X – *C. carvi*, Biržai distr., Stačkūnai; XI – *C. carvi*, Vilnius distr., Beržiškės; XII – *C. carvi*, Varėna distr.; XIII – *C. carvi* 'Rekord', Vilnius, Kairėnai; XIV – *C. carvi* 'Rekord', Vilnius, Jeruzalė; XV – *C. carvi* 'Kančevitskij', Ukmergė distr., Juodausiai; XVI – *C. carvi* 'Rekord', Vilnius, Kairėnai; XVII – *C. carvi*, Kaunas distr., Čekiškė; XVIII – *C. carvi*, Šilutė distr.; XIX – *C. carvi*, Vilnius distr., Rykantai; XX – *C. carvi*, Vilnius, Žirmūnai; XXI – *C. carvi*, Raseiniai distr.

Table 3. Micromycetes on the common caraway seeds of the 2003 harvest in various localities

Micromycetes	Frequency of occurrence %								
	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
Acremoniella atra	0	0	0	0	0	0	0	6.0	0
Acremonium implicatum	0	0	0	0	0	3.0	0	0	0
A. strictum	0	0	0	0	0	0	0	2.0	0
Alternaria alternata	0	3.0	1.0	2.0	39.0	58.0	75.0	55.0	9.0
A. tenuissima	0	1.0	0	0	26.0	29.0	13.0	22.0	3.0
A. radicina	0	0	0	0	0	5.0	2.0	0	0
Arthrinium phaeospermum	0	0	0	0	2.0	3.0	14.0	0	0
Aspergillus spp.	0	3.0	6.0	2.0	1.0	0	0	0	0
Chaetomium globosum	3.0	0	1.0	1.0	0	0	0	0	0
Cylindrocarpon magnusianum	0	0	0	0	0	0	0	2.0	0
Cladosporium herbarum	1.0	0	1.0	0	0	0	2.0	1.0	2.0
Dendryphion comosum	0	0	0	0	1.0	0	0	0	0
Epicoccum neglectum	0	0	0	0	3.0	0	0	0	0
Fusarium avenaceum	0	0	0	0	0	0	0	7.0	0
F. incarnatum	0	0	0	0	0	0	0	7.0	0
F. oxysporum	0	0	0	0	0	0	0	1.0	0
F. sambucinum	0	0	0	0	0	0	0	1.0	0
Fusarium sp.	0	0	0	0	0	0	0	1.0	0
Khuskia oryzae	0	1.0	0	0	0	0	0	0	0
Mucor spp.	2.0	0	3.0	0	0	0	0	0	3.0
Penicillium spp.	13.0	13.0	5.0	11.0	11.0	28.0	18.0	1.0	4.0
Phoma sp.	0	0	0	0	0	0	2.0	0	0
Phomopsis diachenii	0	0	0	0	0	0	0	29.0	1.0
Scopulariopsis brevicaulis	0	1.0	1.0	0	0	0	0	0	0
Stachybotrys chartarum	0	1.0	1.0	0	0	0	0	0	0
Torula expansa	0	0	0	0	0	0	3.0	0	0
Truncatella truncata	0	1.0	0	0	0	0	0	0	0



a b

Figure 2. The occurrence of *Alternaria* (a) and *Fusarium* (b) species on the common caraway seeds (relative density, % among *Alternaria* and *Fusarium* isolates)

Table 4. Micromycetes on the common caraway seeds of the 2004 harvest in various localities

Micromycetes	Frequency of occurrence %					
	XVI	XVII	XVIII	XIX	XX	XXI
Acremoniella atra	0	0	0	4.0	0	0
Alternaria alternata	92.0	14.0	68.0	54.0	92.0	47.0
A. chlamydospora	0	0	6.0	0	0	0
A. dauci	8.0	0	6.0	0	0	1.0
A. tenuissima	34.0	0	17.0	12.0	12.0	5.0
A. radicina	12.0	0	11.0	4.0	8.0	10.0
Arthrinium phaeospermum	0	0	3.0	2.0	2.0	0
Ascochyta biforae	0	0	6.0	0	0	0
Aspergillus spp.	0	53.0	0	0	0	6.0
Botrytis cinerea	6.0	0	0	0	0	0
Chaetomium globosum	9.0	0	1.0	0	0	0
C. megalocarpum	0	0	0	0	0	3.0
Cladosporium cladosporioides	13.0	0	15.0	26.0	0	0
C. herbarum	0	0	41.0	14.0	16.0	0
Cladosporium sp.	0	0	0	0	0	7.0
Dendryphion comosum	0	0	0	2.0	0	0
Epicoccum nigrum	0	0	1.0	0	0	0
Fusarium avenaceum	0	0	0	2.0	0	0
F. dimerum	0	0	0	0	0	1.0
F. incarnatum	2.0	0	0	0	0	0
Hypomyces chrysospermus	2.0	0	0	0	0	0
Humicola grisea	0	0	1.0	2.0	0	0
Khuskia oryzae	0	0	2.0	2.0	0	0
Leptosphaeria libanotis	0	0	0	0	0	1.0
Mycelia sterilia	0	2.0	0	0	0	0
Mucor spp.	0	3.0	2.0	0	0	0
Neofusicoccum mangiferae	0	0	7.0	0	0	0
Ochrocladosporium elatum	0	0	1.0	0	0	0
Penicillium spp.	3.0	2.0	0	0	0	13.0
Phoma eupyrena	0	0	1.0	0	2.0	0
Phoma sp.	0	0	6.0	2.0	0	0
Phomopsis sp.	0	0	0	2.0	0	0
Periconia byssoides	1.0	0	1.0	0	0	0
P. circinata	2.0	0	0	0	0	0
Periconiella sp.	0	0	0	0	0	1.0
Rutola graminis	1.0	0	0	0	0	0
Sordaria fimicola	0	0	1.0	0	0	1.0
Taeniolella stilbospora	0	0	0	18.0	0	0
Torula expansa	0	0	6.0	2.0	0	0
T. herbarum	5.0	0	11.0	2.0	0	0
Ulocladium oudemansii	1.0	0	0	0	0	0
Volucrispora graminea	4.0	0	0	0	0	0

The fungi of genus *Cladosporium* were recorded in all years of investigation almost in two-thirds of common caraway seed samples. Their FO in different localities ranged from 1.0% to 57.0% and made up 5.5% in average. The seeds of the 2004 harvest were most strongly contaminated by fungi of this genus (Tables 2–4, Figure 3). Three species of genus *Cladosporium* were identified, predominantly *C. herbarum* (57.8% of the total *Cladosporium* isolate amount). This fungus was detected in the seed samples of all harvest years and its FO amounted to up to 3.4% in average. It was the most common in the seed samples, collected in Šilutė district (FO 41.0%). *C. cladosporioides* was common as well. The FO of this fungus on the common caraway seeds amounted to up to 2.1%, RD among *Cladosporium* isolates 35.3%. It prevailed on the seeds sampled in Vilnius district, Rykantai (FO 26.0%) (Tables 1–4).

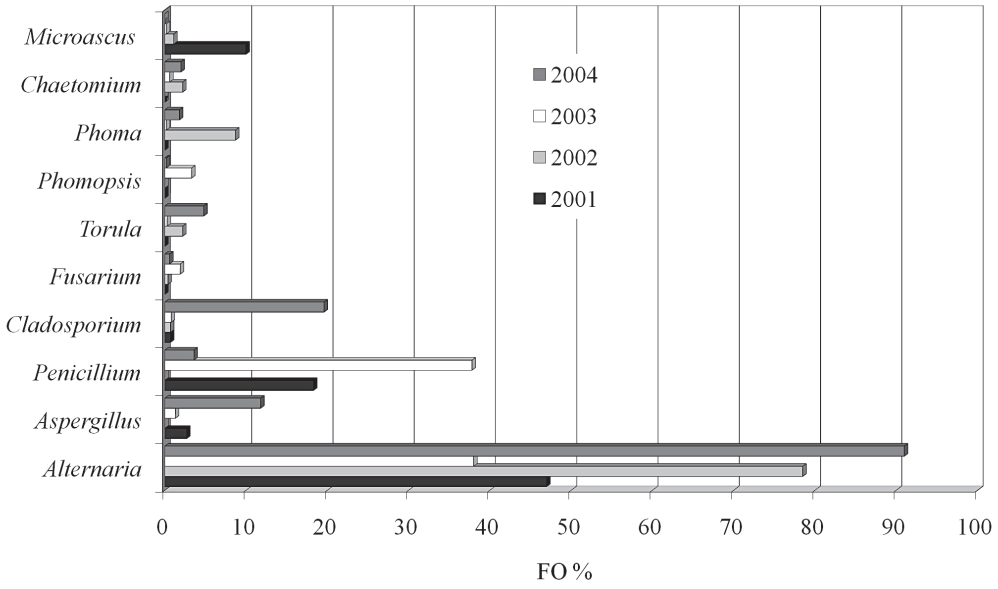


Figure 3. The occurrence of some fungal genera on the common caraway seeds in different years

More than 70% of investigated seed samples were contaminated by fungi of genus *Penicillium*. They were observed on seeds of all harvest years, except for 2002. Their FO ranged from 1.0% to 30.0% and made up 9.0% in average. The wild caraway seeds of the 2003 harvest year, sampled in Varėna district and cultural caraway 'Rekord' seeds of the 2001 harvest year distributed by the trade company "Sėklos" were most contaminated by fungi of genus *Penicillium* (FO 28.0% and 30.0%, respectively) (Tables 1–4).

The fungi of genus *Aspergillus* (FO 4.0%) were detected in one-third of investigated common caraway seed samples. The most common *Aspergillus* spp. was on wild caraway seeds, sampled in Kaunas district, Čekiškė (FO 53.0%). The FO of these fungi in other seed samples amounted to 1–8% (Tables 1–4).

Microascus brevicaulis (FO 1.8%) was identified only in four common caraway seed samples. It was the most frequent (FO 30.0%) on the common caraway 'Rekord' seeds of the 2001 harvest year, distributed by the trade company "Agrolitpa" (Tables 1–4).

The fungi of genus *Phoma* (FO 1.7%) were detected in six seed samples. They were the most frequent on the wild caraway seeds, sampled in Vilnius, Naujininkai and cultural caraway 'Gintaras' seeds grown in 2002 in Kaunas district, Noreikiškės (FO 16.0% and 12.0%, accordingly) (Tables 1–4).

Phomopsis diachenii (FO 1.6%) was recorded in three seed samples. This fungus was the most frequent in the seeds of cultural caraway 'Rekord', grown in 2003, in Vilnius, Jeruzalė, where its FO made up 29.0% (Tables 1–4).

Two species of genus *Torula* (*T. expansa* and *T. herbarum*) were detected in six samples of the common caraway seeds tested. Their FO in average made up 0.5% and 1.2%, respectively, when in individual seed samples it ranged form 2.0% to 11.0%. These fungi were the most frequent in the seeds of the 2004 harvest year (Tables 1–4, Figure 3).

Arthrinium phaeospermum was observed in all experimental years in eight seed samples. The FO of this fungus ranged from 2.0% to 14.0% and made up 1.5% in average. It was the most common in caraway 'Rekord' seeds of the 2003 harvest year grown in Vilnius, Kairėnai (FO 14.0%) (Tables 1–4).

Acremoniella atra was found in three seed samples. Its FO made up 1.2% in average, however in the most contaminated caraway 'Gintaras' seeds, grown in Kaunas district, Noreikiškės, in 2002 this index amounted to 16.0% (Tables 1, 2).

Botrytis cinerea (FO 1.0%) was identified in three seed samples only of cultural caraway. The FO of this fungus in seeds of *C. carvi* 'Rekord' of 2001 and 2004 harvest year amounted to up to 10.0% and 6.0%, respectively, when in seeds of *C. carvi* 'Gintaras' of the 2002 harvest year – 3.0% (Tables 1–4).

The fungi of genus *Chaetomium* were recorded in one third of investigated common caraway seed samples. Their FO amounted to up to 1.3% in average. Three species of this genus were identified. *C. globosum* (RD 62.5%) prevailed among them. This fungus was most common in seeds of *C. carvi* 'Rekord' grown in 2003 in Vilnius, Kairėnai (FO 9.0%). *C. bostrychodes* (FO 6.0%) was identified only on *C. carvi* 'Gintaras' seeds, grown in 2002 in Kaunas district, Noreikiškės, when *C. megalocarpum* (FO 3.0%) on wild caraway seeds sampled in Raseiniai district (Tables 1–4).

The fungi of genus *Fusarium* were detected in five seed samples and their FO amounted to up to 1.2% in average. The *C. carvi* 'Rekord' seeds of 2003 harvest year, grown in Vilnius, Jeruzalė were most severely contaminated by *Fusarium* spp., whereas on *C. carvi* 'Rekord' seeds of the same harvest year, grown in Vilnius, Kairėnai, these fungi were not found (Tables 1–4). Six *Fusarium* species (*F. avenaceum*, *F. graminum*, *F. dimerum*, *F. incarnatum*, *F. oxysporum*, *F. sambucinum*) were identified on the common caraway seeds. The most common were *F. incarnatum* (FO 0.5%) and *F. avenaceum* (FO 0.4%), accounted for 41.0% and 36.5% of the total *Fusarium* isolates, accordingly (Figure 2 b).

Mucor spp. contaminated almost 40% of investigated common caraway seed samples. Their FO amounted to up to 1.1% in average, when in individual samples 2.0–3.0% (Tables 1–4).

Neofusicoccum magniferae was found only on wild *C. carvi* seeds, sampled in 2002 and 2004. The FO of this fungus amounted to up to 1.1% in average, whereas on the most contaminated seeds, sampled in Utena district, Leliūnai and Šilutė district, it amounted to 12.0% and 7.0%, respectively (Tables 1–4).

The FO of other fungi identified on the seeds of common caraway was below 1.0% (Table 1).

Most of these fungi were found on common caraway seeds by other researches as well. Some of them (*Alternaria* spp., *Aspergillus* spp., *Cladosporium* spp., *Fusarium* spp., *Penicillium* spp., *Phoma* spp., *Phomopsis* spp.) were frequently isolated and named as the most common (Szczeponek, Mazur, 2002; Odstričilová, 2007; Dimić et al., 2008; Machowich-Stefaniak, Zalewska, 2008).

Our research as well as that of other researchers (Kosić-Tanackov et al., 2007; Dimić et al., 2008) indicated that common caraway seeds are heavily contaminated by micromycetes. Fungal complexes identified on the seeds of cultural and wild caraway have great qualitative (Sorenson's index (SI) 51.1%) and quantitative (SI 59.0%) similarity, however, they significantly differ between years and localities. The comparison of similarity of fungal complexes on the common caraway seeds sampled in various localities shows, that most of them (52.4–67.4%) have low both qualitative and quantitative similarity (SI ranged between 0–39.0%). Only 4.8% of fungal complexes on seeds of cultural caraway and 10.9% on seeds of wild caraway were of very high similarity (SI ranged between 60.0–75.0%) (Tables 5–6).

Table 5. The qualitative (a) and quantitative (b) similarity of fungal complexes on the seeds of cultural caraway grown in different localities

a)

Locality	Sorenson's index %						
	II	III	VI	XIII	XIV	XV	XVI
II		40.0	28.6	53.3	30.0	46.2	16.7
III	40.0		51.9	47.6	38.5	52.6	20.0
VI	28.6	51.9		**63.6**	29.6	40.0	32.3
XIII	53.3	47.6	**63.6**		38.1	57.1	32.0
XIV	38.5	38.5	29.6	38.1		52.6	13.3
XV	46.2	52.6	40.0	57.1	52.6		17.4
XVI	16.7	20.0	32.3	32.0	13.3	17.4	

b)

Locality	Sorenson's index %						
	II	III	VI	XIII	XIV	XV	XVI
II		41.9	38.5	55.4	46.9	20.0	16.2
III	41.9		37.0	41.0	25.6	27.7	8.4
VI	38.5	37.0		4.6	39.0	27.6	14.8
XIII	55.4	41.0	42.6		53.0	**70.6**	14.8
XIV	46.9	25.6	39.0	53.0		19.1	5.4
XV	20.0	27.7	27.6	**70.6**	19.1		4.6
XVI	16.2	8.4	14.8	14.8	5.4	4.6	

Table 6. The qualitative (a) and quantitative (b) similarity of fungal complexes on the seeds of wild caraway grown in different localities

a)

Locality	Sorenson's index %													
	I	IV	V	VII	VIII	IX	XX	XI	XII	XVII	XVIII	XIX	XX	XXI
I		20.0	22.2	54.5	40.0	53.3	36.4	57.1	**61.5**	50.0	29.4	33.3	**61.5**	31.6
IV	20.0		**75.0**	0	19.0	9.5	11.8	20.0	31.6	11.1	20.0	33.3	31.6	24.0
V	22.2	**75.0**		0	31.6	21.1	13.3	22.2	35.3	12.5	31.6	50.0	35.3	26.1
VII	54.5	0	0		16.7	**66.7**	50.0	18.2	20.0	44.4	19.4	9.5	20.0	12.5
VIII	40.0	19.0	31.6	16.7		**62.5**	50.0	53.3	42.9	46.2	17.1	24.0	28.6	40.0
IX	53.3	9.5	21.1	**66.7**	**62.5**		**66.7**	40.0	28.6	**61.5**	22.9	16.0	28.6	30.0
XX	36.4	11.8	13.3	50.0	50.0	**66.7**		54.5	40.0	**66.7**	12.9	9.5	20.0	37.5
XI	57.1	20.0	22.2	18.2	53.3	40.0	54.5		**61.5**	50.0	17.6	33.3	46.2	42.1
XII	**61.5**	31.6	35.3	20.0	42.9	28.6	40.0	**61.5**		36.4	24.2	34.8	**66.7**	44.4
XVII	50.0	11.1	12.5	44.4	46.2	**61.5**	**66.7**	50.0	36.4		12.5	9.1	18.2	35.3
XVIII	29.4	20.0	31.6	19.4	17.1	22.9	12.9	17.6	24.2	12.5		45.5	36.4	25.6
XIX	33.3	33.3	50.0	9.5	24.0	16.0	9.5	33.3	34.8	9.1	45.5		43.5	20.7
XX	**61.5**	31.6	35.3	20.0	28.6	28.6	20.0	46.2	**66.7**	18.2	36.4	43.5		33.3
XXI	31.6	24.0	26.1	12.5	40.0	30.0	37.5	42.1	44.4	35.3	25.6	20.7	33.3	

b)

Locality	Sorenson's index %													
	I	IV	V	VII	VIII	IX	XX	XI	XII	XVII	XVIII	XIX	XX	XXI
I		8.6	9.3	43.2	42.9	48.6	41.2	25.7	18.1	19.6	9.5	17.2	19.0	19.3
IV	8.6		45.7	0	5.5	1.4	2.9	29.4	27.5	4.1	14.3	13.3	11.8	9.2
V	9.3	45.7		0	7.4	3.1	3.1	**60.8**	56.5	15.1	40.6	44.1	48.6	46.4
VII	43.2	0	0		**60.5**	51.2	**68.6**	21.6	17.9	8.6	4.3	2.1	2.4	22.6
VIII	42.9	5.5	7.4	**60.5**		51.2	**75.0**	29.9	22.7	16.3	4.2	10.1	8.9	33.3
IX	48.6	1.4	3.1	51.2	51.2		51.4	13.7	8.3	25.8	3.4	2.1	2.4	20.9
XX	41.2	2.9	3.1	**68.6**	**75.0**	51.4		28.3	18.3	13.3	2.6	4.4	4.9	26.8
XI	25.7	29.4	**60.8**	21.6	29.9	13.7	28.3		**74.6**	21.7	39.1	44.3	**61.7**	**62.6**
XII	18.1	27.5	15.1	17.9	22.7	8.3	18.3	**74.6**		16.0	48.8	35.8	59.4	**63.1**
XVII	19.6	4.1	15.1	8.6	16.3	25.8	13.3	21.7	16.0		11.1	18.8	20.0	25.9
XVIII	9.5	14.3	40.6	4.3	4.2	3.4	2.6	39.1	48.8	11.1		42.2	47.1	40.6
XIX	17.2	13.3	44.1	2.1	10.1	2.1	4.4	44.3	35.8	18.8	42.2		**61.0**	39.8
XX	19.0	11.8	48.6	2.4	8.9	2.4	4.9	61.7	59.4	20.0	47.1	**61.0**		**67.9**
XXI	19.3	9.2	46.4	22.6	33.3	20.9	26.8	62.6	**63.1**	25.9	40.6	39.8	**67.9**	

It was ascertained that fungal complexes on the common caraway seeds of 2001 and 2004 harvest years had the least similarity both qualitative and quantitative (SI 36.1% and 34.9%, accordingly). The high qualitative and quantitative similarity of fungal complexes was established on common caraway seeds of 2001 and 2002, as well as of 2003 and 2004 harvest years (Table 7). The climatic conditions of the year during seed ripening and the microclimate of the locality where caraway was grown could determinate the similarity of fungal complexes. The formation of fungal complexes on caraway seeds in 2001–2002 could depend on the changeable weather in June of these years, when, according to the data of the Lithuanian Hydrometeorology Station, warm and dry periods alternated with cold and wet ones. The similarity of the second half of June in 2003 and 2004, when cool and rainy weather prevailed, could determine the similarity of fungal complexes on caraway seeds of these years.

Table 7. The qualitative and quantitative similarity of fungal complexes on the common caraway seeds of different harvest years

Harvest year	Qualitative similarity				Quantitative similarity			
	Sorenson's index %							
	2001	2002	2003	2004	2001	2002	2003	2004
2001		**50.7**	46.8	34.9		**51.2**	44.4	36.1
2002	**50.7**		39.6	37.3	**51.2**		40.0	45.5
2003	46.8	39.6		**57.4**	44.4	40.0		**51.7**
2004	34.9	37.3	**57.4**		36.1	45.5	**51.7**	

Our research evidenced that saprotrophes dominated on the common caraway seeds. Most of them (*Aspergillus* spp., *Penicillium* spp., *Fusarium* spp., *Alternaria* spp., *Cladosporium* spp., *Chaetomium* spp. and others) are active producers of secondary metabolites – mycotoxins. The potential pathogens – the agents of plant spots, wilts and rots were detected as well. *Alternaria alternata*, *Ascochyta biforae*, *Phomopsis diachenii*, *Fusarium oxysporum*, *F. avenaceum*, *Cylindrocarpon destructans*, *Botrytis cinerea* could be noted among them. These fungi were named as potential pathogens, the agents of caraway diseases, in many references (Gabler, 2001; Pearse, 2002; Mazur, Nawrocki, 2004; Machowicz-Stefaniak, 2009). They injure plant umbels, leaves, stems, roots and in favourable conditions can intensively spread and cause severe damage in caraway crops by reducing and impairing the seed yield. Caraway seeds, heavily contaminated by micromycetes, can accumulate large amount of secondary metabolites and become unusable (Reddy et al., 2009; Hashem, Alamri, 2010). Therefore, mycological control of seeds prior to processing is an essential task in human health protection.

Conclusions

1. The fungi of 55 species and 41 genera, belonging to *Ascomycota* and *Zygomycota* phyla, *Sordariomycetes*, *Dothideomycetes*, *Leotiomycetes*, *Eurotiomycetes* and *Incertae sedis* classes, were identified on the common caraway seeds. Micromycetes of genus *Alternaria* were most common among them. Their frequency of occurrence amounted to up to 58.4% and they accounted for 59.8% of the total isolate amount.

2. Saprotrophes, active producers of mycotoxins, prevailed on the seeds of common caraway. Potential pathogens (*Alternaria alternata*, *Ascochyta biforae*, *Phomopsis diachenii*, *Fusarium oxysporum*, *F. avenaceum*, *Cylindrocarpon destructans*, *Botrytis cinerea*), the agents of plants spots, wilts and rots, were detected as well.

3. The fungal complexes identified on the seeds of wild and cultural caraway have great qualitative and quantitative similarity, however they significantly vary between harvest years and localities.

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Grybų įvairovė ant laukinio ir kultūrinio paprastojo kmyno (*Carum carvi* L.) sėklų

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Santrauka

Tirtas laukinio ir kultūrinio paprastojo kmyno (*Carum carvi* L.) 2001–2004 m. derliaus sėklų užterštumas mikromicetais. Sėklos surinktos įvairiose augavietėse Biržų, Kauno, Raseinių, Šilutės, Ukmergės, Utenos, Varėnos ir Vilniaus rajonuose joms subrendus, birželio–liepos mėnesiais. Mikromicetams nustatyti taikytas drėgnų kamerų metodas. Aptikti mikromicetai apibūdinti pagal morfologinius bei kultūrinius požymius, apskaičiuotas jų aptikimo dažnis ir santykinis tankis. Palygintas grybų kompleksų, nustatytų laukinių ir kultūrinių kmynų sėklose, taip pat sėklose, augusiose įvairiose augavietėse skirtingais derliaus metais, kokybinis bei kiekybinis panašumas.

Paprastojo kmyno sėklose buvo aptikti ir identifikuoti 55 rūšių bei 41 genties grybai, priklausantys *Ascomycota* ir *Zygomycota* skyriams, *Sordariomycetes*, *Dothideomycetes*, *Leotiomycetes*, *Eurotiomycetes* ir *Incertae sedis* klasėms. Tirtų sėklų mikobiotoje vyravo *Alternaria* genties mikromicetai, kurie sudarė 59,8 % visų izoliatų, o jų aptikimo dažnis siekė 58,4 %. Nustatyta, kad kmynų sėklose vyrauja saprotrofai (*Alternaria* spp., *Aspergillus* spp., *Penicillium* spp., *Cladosporium* spp. ir kt.), tačiau yra ir potencialių patogenų (*Alternaria alternata*, *Ascochyta biforae*, *Phomopsis diachenii*, *Fusarium oxysporum*, *F. avenaceum*, *Cylindrocarpon destructans*, *Botrytis cinerea*) – augalų dėmėtligių, vytulių bei puvinių sukėlėjų. Laukinių ir kultūrinių kmynų sėklose nustatyti grybų kompleksai turi didelį kokybinį bei kiekybinį panašumą, tačiau gerokai skiriasi įvairių augaviečių ir skirtingų derliaus metų kmynų sėklose.

Reikšminiai žodžiai: kmynai, grybai, sėklos, aptikimo dažnis, santykinis tankis.