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Identification of taxa of microscopic fungi occurring on selected herbal plants and possible methods of their elimination

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ABSTRACT

The study was conducted in 2014 at the West Pomeranian University of Technology in Szczecin. Its aim was to identify the taxa of microscopic fungi present on selected herbal plants and to propose methods of their elimination. Research material included leaves and stems of affected plants. The material was collected at the end of the growing season (in September). The study identified 11 taxa belonging to two types of fungi: *Ascomycetes* and *Basidiomycetes*. Most identified taxa (98.2%) belonged to *Ascomycetes.* Three species rarely found in Poland were recognized: *Ascochyta levistici*, *Septoria melissae* and *Phragmidium sanguisorbae*. Diseases of herbal plants should preferably be eliminated by using biological methods and appropriate agrotechnical treatments.

Keywords**:** medicinal plants, pathogenic fungi, *Ascochyta*, *Puccinia*, *Ramularia*

1. INTRODUCTION

The word ‘herb’, a translation of Latin word *herba*, has multiple meanings. According to the World Health Organization, herbal plant is any plant that administered in any form to humans or animals exerts a detectable physiological effect. Phytotherapy, also called herbal medicine, is based on herbal materials understood as fresh or dried plant parts containing active ingredients. Usually one plant is used to obtain one type of herbal material with the highest content of beneficial substances.

Herbal materials used in phytotherapy include: tuber (*tuber*), bulb (*bulbus*), rhizome (*rhizoma*), cortex (*cortex*), root (*radix*), flower head (*anthodium*), flower (*flos*), inflorescence (*inflorescentia*), leaf (*folium*), seed (*semen*), fruit (*fructus*), buds (*gemma*), cone (*strobilus*), herb (*herba*), and stigma (*stigma*).

Considering their medicinal use, herbal plants should be cultivated on plantations with minimal use of chemical plant protection products. The use of chemicals deteriorates biological value of the herbal materials and may also negatively affect the health of people undergoing herbal therapy. Therefore, appropriate selection of plant protection products and the use of agents based on natural substances are crucial in these types of crops. Diseases and pests that attack herbal plants cause economic loss and reduce their commercial value. Prolonged or massive infestation may even render the herbal material completely useless for medicinal applications.

Herbal plants are mainly attacked by fungal pathogens that adversely affect their development and curative properties. The most common fungal diseases of medical plants include: rust (caused e.g. by fungi of *Puccinia* genus), powdery mildew, gray mold (*Botrytis cirenea* Pers.), Cercospora (*Cercospora* spp.), Alternaria (*Alternaria* spp.), Septoria (*Septoria* spp.) or seedling blight. Only well developed and robust plants are more resistant to harmful environmental factors. Therefore, crucial aspects of fighting herbal plant pests and diseases include prevention and integrated cultivation. Careful observation and quick reaction to any disease symptoms result in good quality yield.

The aim of the study was to identify the taxa of microscopic fungi present in selected herbal plants commonly used in phytotherapy and to discuss the methods or their elimination.

2. MATERIAL AND METHODS

2. 1. Date and place of the study

The study was conducted in 2014 at the West Pomeranian University of Technology in Szczecin. The plant material was collected at the end of the growing season (in September). The material belonged to the collection of medicinal and seasoning plants at the Department of Horticulture, grown in the university plant house. The collection plants were cultivated on five beds separated with 0.5 m wide communication routes.

The plants were cultivated according to type and designed use and were appropriately spaced. The area where the collection was grown was a short distance from other plant collections, and it was neither enclosed nor isolated from them.

2. 2. Plant material

The plant material consisted of leaves and stems of herbal plants with disease symptoms and etiological signs. The following species were investigated: pricklyburr (*Datura inoxia* Mill.), perforate St John's-wort (*Hypericum perforatum* L.), greater celandine (*Chelidonium majus* L.), catnip (*Nepata cataria* L.), salad burnet (*Sanguisorba minor* Scop.), oregano (*Origanum vulgare* L.), lovage (*Levisticum officinale* L.), lemon balm (*Melissa officinalis* L.), cardus marianus (*Silybum marianum* L.), common sage (*Salvia officinalis* L.), and common mallow (*Malva sylvestris* L.).

2. 3. Protective treatments

Due to the nature of the collection and intended use of the plants (medicinal and seasoning), the area was not treated with chemical plant protection products, except for ad hoc elimination of often aphid occurrences. Agricultural treatments included regular manual weeding, fertilization, soil aeration, and watering.

2. 4. Plant storage

The material harvested from the collection of herbal plants was placed in individual paper bags and dried. Each plant organ intended for storage (leaves and stems of individual species) was separately spread flat between newspaper sheets and pressed with books. The sheets were replaced every day until the plants were completely dry. Dried material was placed in paper envelopes labeled with plant species and harvest date and subjected to further analyses.

2. 5. Laboratory tests

2. 5. 1. Species determination

The species were determined using the vascular plant identification key developed by Rutkowski (2004). The analyzed traits included morphological features of leaves, stems and flowers.

2. 5. 2. Preparation of specimens

Leaves with disease or etiological symptoms were used to prepare a series of sliced or scrapped preparations according to the rules set out in available literature (Błaszkowski et al. 1999).

2. 5. 2. 1. Preparation of sliced specimens

Rectangular pieces (1 x 2 cm) of leaf tissue were cut out with a razor and then cut into small strips. A drop of lactic acid was applied on a microscopic slide and the strips were suspended in it. Then the tissues submerged in the lactic acid were covered with a cover slip. The preparations were left in a dark and dry place, at room temperature, for about three weeks to achieve proper discoloration of plant tissues necessary for microscopic observations. The final step included microscopic analysis of the slides.

2. 5. 2. 2. Preparation of scrapped specimens

A drop of lactic acid was placed on a microscopic slide and the coating scrapped from a leaf surface with a dissecting needle was transferred into the acid. The material submerged in lactic acid was then covered with a cover slip. The preparations were left in a dark and dry place, at room temperature, for about three weeks to achieve proper discoloration of plant tissues necessary for microscopic observations. The final step included microscopic analysis of the slides.

2. 6. Local disease symptoms observed in the research material during laboratory analysis

This chapter was prepared based on the information outlined in a publication on plant pathogenic fungi (Marcinkowska 2003).

Blights Blights appear as a result of sudden and rapid shrinking of dying plant tissues affecting large sections of a plant. Affected parts of a plant turn different shades of brown depending on the fungal species.

Leaf spots Leaf spots are usually due to necrosis of a small group of cells. Sometimes the affected tissue does not die but its color is changed due to the presence of a pathogen. The spots have variable morphology but in the beginning they are always brighter than the healthy tissue, and after the cells die, they turn into necrotic spots. Leaf spots are cause by multiple fungal species. Sometimes they are surrounded by a clear ring. Leaf spots also include leaf holes, i.e. the changes visible after removal of necrotic spots within the leaf tissue.

Distortions They involve outgrowths developing due to developmental disorders in the affected plants. Leaf or fruit distortions are due to non-uniform growth caused by the pathogenic fungi.

Powdery mildews These are diseases characterized by the presence of mycelium coating the surface of affected plant organs. Downy mildews produce coating usually visible on the bottom side of the leaves, while the top side is covered with brown spots. The coating develops particularly intensively on alive parts of a plant, i.e. on the border of necrotic spots. Powdery mildews are the only etiological symptoms of the pathogen manifested by surface mycelium that produces both conidia and spores.

Rusts Rusts produce dusty clusters on leaves and/or buds. They are usually yellow, orange, reddish-brown or brown. The color of the clusters varies depending on the season and is associated with the production of different kinds of spores.

2. 7. Identification of fungal taxa

The taxa of fungi occurring in the collected material were identified based on morphological features of the structures they produced (fruiting bodies, spores, stems). The analyzed parameters included size (length, width or diameter), color, structure and shape of individual traits. The identification was based on the information provided in guides and identification keys for fungi (Majewski 1977, 1979; Branderburger 1985; Braun 1987, 1998).

Photographs of the fungi presented in the study belong to the collection of the Department of Ecology and Environmental Protection and Management. They were taken by professor Janusz Błaszkowski.

2. 8. Determination of reach of the identified pathogens

Data on the occurrence of the identified fungal species were taken from the most recent mycological publication (Mułenko et al. 2008). Based on the number of reports from different regions of Poland, the fungi were classified into three groups:

1. taxa found in more than three locations around the country, considered common in Poland,

2. taxa reported from 1-3 locations around Poland, rare,
3. taxa never reported in Poland, new.

3. RESULTS

3. 1. Identified fungal species

Plant material collected in the study was inhabited by 11 taxa of fungi (Table 1). They represented two types of the fungi: *Ascomycetes* and *Basidiomycetes*. The greatest number of taxa (98.2% of all identified fungi) belonged to *Ascomycetes*; all were mitomorphic (conidial) stages of ascomycetes (they were previously classified as anamorphic that is mitosporic fungi). The type of *Basidiomycetes* was represented by only two fungal species (1.8%): *Phragmidium sanguisorbae* and *Pucinia malvacearum*. *Cladosporium* spp. was the fungus found on the greatest number of investigated plant species (6).

Table 1. Fungal species inhabiting the plants harvested from the area of herbal plant collection

Plant species	Fungal species
Lemon balm (*Melissa officinalis*)	• *Oidium* spp. • *Septoria melissae*
Catnip (*Nepeta cataria*)	• *Cladosporium* spp. • *Oidium* spp.
Oregano (*Origanum vulgare*)	• *Cladosporium* spp.
Cardus marianus (*Silybum marianum*)	• no fungal spores
Vila-vila (*Solanum sisymbrifolium*)	• *Alternaria alternata* • *Cladosporium* spp.
Common sage (*Salvia officinalis*)	• *Trichothecium roseum*
Greater celandine (*Chelidonium majus*)	• *Cladosporium* spp. • *Septoria chelidonii* • *Trichothecium roseum*
Common mallow (*Malva sylvestris*)	• *Pucinia malvacearum*
Lovage (*Levisticum officinale*)	• *Ascochyta levistici* • *Ramularia heraclei*
Salad burnet (*Sanguisorba minor*)	• *Alternaria alternata* • *Cladosporium* spp. • *Phragmidium sanguisorbae* • *Trichothecium roseum*

Pricklyburr (*Datura inoxia*)	• *Alternaria solani* • *Cladosporium* spp. • *Phoma herbarum*
perforate St John's-wort (*Hyperiucum perforatum*)	• *Trichothecium roseum*

3. 2. Description of the identified fungi and their occurrence in Poland

***Melissa officinalis* (lemon balm)**

Two fungal taxa were identified that caused diseases manifested by symptoms visible on alive leaves. These were *Oidium* spp. (causing powdery mildew) and *Septoria melissae* (causing leaf blotch).

Septoria melissae produced pycnidia (Figure 1) with diameter of 90-110 µm, housing maturing spores 26-32 x 1.5 µm in size.

Occurrence: according to the report on the presence of microscopic fungi in Poland, this fungus is a rare species, as it was reported for only two locations (Mułenko et al. 2008).

Figure 1. Pycnidium with multicellular spores produced by a fungus from *Septoria* genus (photo prof. J. Błaszkowski)

***Nepeta cataria* (catnip)**

Catnip leaves were colonized by two fungal taxa but only one of them (*Oidium* spp.) caused disease symptoms on alive parts of the leaves. This taxon causes powdery mildew (Figure 2).

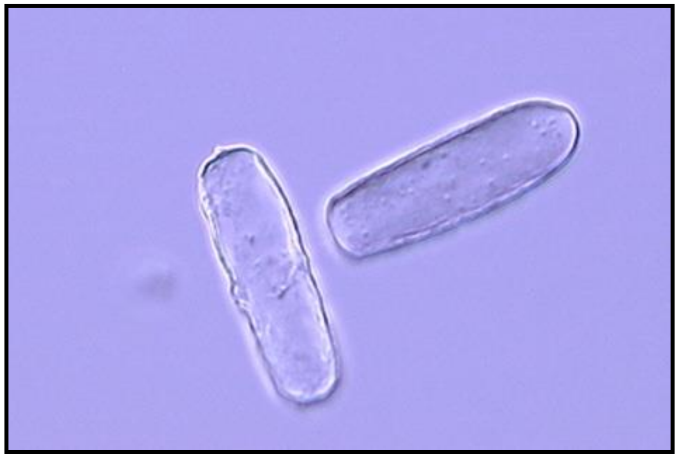

Figure 2. Conidia of a fungus of *Oidium* genus (photo prof. J. Błaszkowski)

***Silybum marianum* (cardus marianus)**

Disease symptoms in the form of small spots creating a marbled pattern were visible on cardus leaves but no spores of the pathological fungi were detected. These changes may indicate a very early stage of a fungal disease, at which the pathogen still cannot be identified, or a bacteria or virus caused disorder. Literature data indicate that marbled leaves are typical for viral diseases (Kryczyński 2010), but a confirmation of virus presence in plant tissues requires advanced and specialist tests.

***Solanum sisymbrifolium* (vila-vila)**

The preparations of vila-vila leaves contained two fungal taxa, of which only one (*Alternaria alternata*) colonized alive tissues. The fungus causes alternariosis. The species produced characteristic, elongated, multicellular, light-brown spores (Figure 3).

Figure 3. *Alternaria alternata* spores (photo prof. J. Błaszkowski)

***Chelidonium majus* (greater celandine)**

The leaves of greater celandine were colonized by three fungal taxa, of which only one caused disease symptoms on alive fragments of the leaves. This fungus was *Septoria chelidonii* (causing leaf blotch). The species produces pycnidia with a diameter of 130-140 µm, where spores 32-36 × 1.5 µm in size are grown.

***Malva sylvestris* (common mallow)**

The leaves of common mallow were inhabited by only one pathogenic fungus causing rust, *Puccinia malvacearum*. The species produced telia with a diameter of 700 µm, where two-celled, 90-100 µm long teliospores were formed (Figure 4). The teliospore stem was 50 µm long and came off easily.

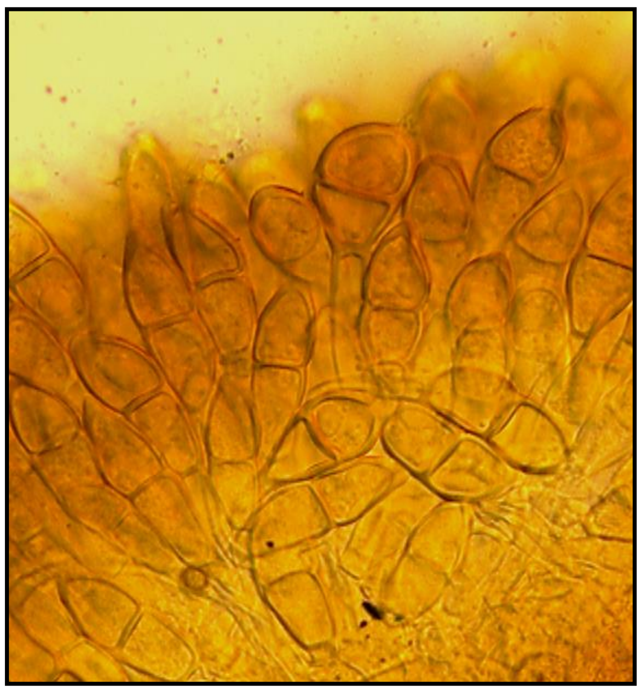

Figure 4. Two-celled teliospores formed by a fungus of *Puccinia* genus (photo prof. J. Błaszkowski)

***Levisticum officinale* (lovage)**

The preparations made from disease spots of lovage plants enabled identification of two fungal taxa. These were *Ramularia heraclei* (causing leaf spots) and *Ascochyta levistici* (causing blight disease). Both fungi were pathogenic for lovage plants.

Ramularia heraclei formed stems (Figure 5) 60-90 × 2-4 µm in size, on which developed one- to four-celled spores with a dimension of 12-24 µm. Two-celled, 20-24 µm spores of *Ascochyta levistici* were formed inside pycnidia.

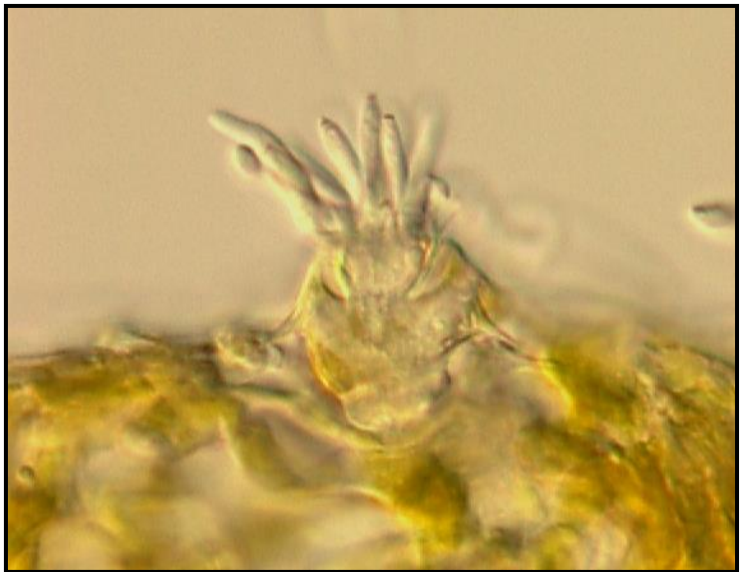

Figure 5. A bundle of stems with spores produced by a fungus of *Ramularia* genus (photo: prof. J. Błaszkowski)

***Sanguisorba minor* (salad burnet)**

Salad burnet leaves were colonized by four taxa of fungi, of which only one triggered disease symptoms on alive parts of the leaves. This was *Phragmidium sanguisorbae* that causes rust disease. The species produces spherical urediniospores (summer spores), with a diameter of 18-24 μm. At the end of the growing season, fungi of this taxon produce characteristic coryneform teliospores (Figure 6).

Figure 6. Multicellular teliospores of a fungus of *Phragmidium* taxon (photo prof. J. Błaszkowski)

***Datura inoxia* (pricklyburr)**

The plant was inhabited by three fungal taxa. Only one of them triggered disease changes in alive leaf tissues. This was *Alternaria solani* that caused rust disease. Its spores are very similar to those of *Alternaria alternata* but the conidia of *A. solani* (Figure 7) are longer and have more cells than the spores of *A. alternata*.

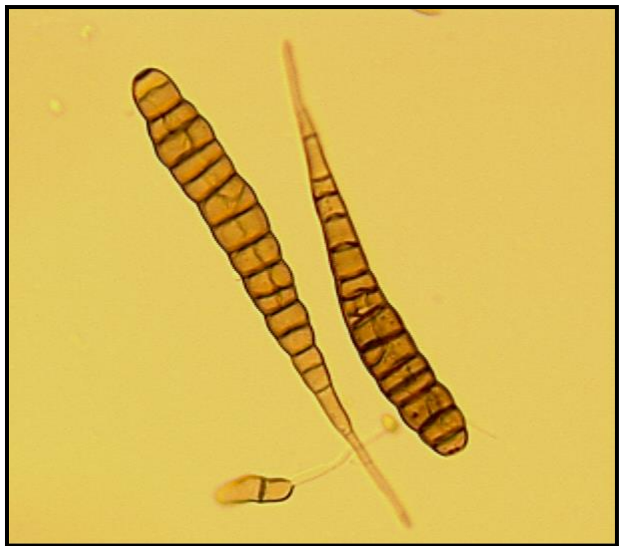

Figure 7. *Alternaria solani* spores (photo. prof. J. Błaszkowski)

***Hyperiucum perforatum* (perforate St John's-wort), *Salvia officinalis* (common sage) and *Origanum vulgare* (oregano)**

Figure 8. Fragments and stems and spores of a fungus of *Cladosporium* taxon (photo prof. J. Błaszkowski)

Plant material of these three species contained only spores of *Alternaria alternata*, *Cladosporium* spp. (Figure 8) and *Trichothecium roseum*. These fungi often colonize dying parts of plants. They are saprotrophic organisms and usually do not trigger disease symptoms in alive and non-weakened leaves.

The fungi from *Alternaria*, *Cladosporium* and *Trichothecium* taxa were also present on already infested plants of e.g. catnip, greater celandine, salad burnt and pricklyburr. The fungi found on these plants were accompanying species, i.e. they populated the tissues of plants weakened by other pathogens.

Representatives of *Alternaria*, *Cladosporium* and *Trichothecium* taxa are common all around the world (Marcinkowska, 2003).

Two species of the investigated plants (*Melissa officinalis* and *Nepeta cataria*) were colonized by *Oidium* spp. Representatives of this genus are the mitomorphic stage of the fungi from *Erysiphales* order. The identified pathogen commonly dwells on the plants of *Lamiaceae* family (Braun 1987), and if two investigated hosts are close to each other, the infection may spread easily.

The fungi identified in the study were classified into two groups:

- **Species rarely occurring in Poland:** *Ascochyta levistici*, *Septoria melissae* and *Phragmidium sanguisorbae*.
- **Species commonly occurring in Poland:** *Oidium* spp., *Cladosporium* spp., *Alternaria alternata*, *Alternaria solani*, *Trichothecium roseum, Phoma herbarium*. No taxa new to Poland's area were found in the collected plant material.

3. 3. Methods for pest control in plantation crops (Kochman and Węgorek, 1997)

Damage inflicted by diseases, pests and weeds to plant production may be extremely costly. To achieve higher yield and increase plant production, it is necessary to constantly develop plant protection by means of introducing modern and more advanced methods for pest control. The methods of contemporary plant protection used to fight pests, diseases and weeds may be divided into three major groups. The first two groups include preventive measures.

1. **Plant quarantine**
   The objective of plant quarantine is to protect a plantation from penetration of new pathogens, weeds and pests from other countries (external quarantine) or from nearby areas (internal quarantine).
2. **Agronomic and breeding methods**
   They can be divided into agronomic and hygienic treatments and breeding and selection treatments. The first ones are the least expensive. They allow for extermination of the spots of pest, weed and pathogen propagation and provide the most favorable conditions for crop plant development. The other methods yield varieties characterized by lower or higher resistance to pests.
3. **Direct combat methods**
   The objective of this group of methods is to destroy the existing pests and to prevent their spreading. The treatments are based on three basic methods: biological methods that fight pests using their natural enemies; mechanical and physical methods that rely on the destruction of pathogens by means of physical factors such as temperature or

light and the use of mechanical equipment, various types of baits and traps; and chemical methods that involve the use of chemical agents, adversely affecting the growth of weeds, pathogens and pests.

3. 4. Proposed methods of controlling pests, fungi and weeds in herbal crops

The methods of plant protection against diseases are divided into two major groups. The first involves using plants resistant to diseases and the second is based on using preventive approach in the form of agronomic, chemical and physical treatments that prevent infection, destroy its sources and may curb the disease development when an infection already occurred (Borecki, 1996). Plant protection is one of the most challenging aspects of plant production. It requires data on the production area (soil quality), climatic conditions and local pest pressure (Wolny, 2003). Plant health is determined by many factors, such as variety selection, healthy seeds and plantable material, appropriate crop rotation, proper soil preparation, and timely execution of cultivation treatments. Another important factor is proper harvest method http://www.sosnowica.pl/download/Agroekologia_B.Studzinska.pdf

The most important cultivation treatments on herb plantations are weed control and fighting plant diseases and pests. Cultivation and pest fighting treatments should be carefully considered with environmental protection and intended use of the herbs in mind. The most important aspect when growing herbal plants is prevention understood as creating appropriate conditions, unfavorable for the occurrence and development and weeds, pests or diseases (Kołodziej, 2010). The crop site and plantation location are also very important and they should include soils not contaminated with heavy metals, residues of plant protection products or industrial waste. The plantation should be established on fields free from weeds, particularly stoloniferous weeds, removal of which during the crop growth is difficult and often ineffective (Franz et al., 1999). Appropriate crop rotation and careful soil cultivation are also conducive to weed removal (Kołodziej, 2010). Weeds may be effectively controlled by mulching the soil, and mechanical treatments, and although these methods are more arduous, they allow for reduction or even complete elimination of herbicide use.

Chemicals used during crop growth accumulate in plant tissues, which is certainly not advisable (Węglarz et al., 2009). As the herbs are intended for therapeutic purposes and their plantations are usually small, there are not many herbicides registered for use in herb crops (Kołodziej, 2010). Any agronomic treatments should allow for specific requirements of individual plant species. Herb crops may be fertilized with organic or mineral fertilizers. However, the organic fertilizers must be free from human faeces and should be thoroughly composted. Mineral fertilizers must be limited to their minimum doses. Water for plant watering is also very important, it should be clean and of good quality (Kołodziej, 2010).

An essential agronomic treatment on herb plantation is soil loosening aimed at improving its structure, reducing evaporation, airing its deeper layers, increasing its water capacity and removing any emerging weeds (Domańska, 1980).

Diseases and pests of herbal plants inflict serious losses, lower the value of herbal material, and may even completely disqualify it as medicinal product (Senderski, 2004). Disease prevention and appropriate protection of herbal plants are integral elements of a cultivation system and are crucial for modern crop cultivation. Effective disease prevention requires a combination of biological, chemical and agronomic strategies, as selective application of individual methods does not provide expected results (Klima, 2006). Only well developed and robust plants are more resistant to adverse factors, which is why prevention is crucial in the fight against plant diseases and pests. The prevention should be understood as creating growth promoting conditions and strict adherence to agronomic recommendations and cultivation treatments (Kołodziej, 2010). Crop rotation is also important as it provides information on the current and past occurrence of pests and diseases on a plantation and nearby fields, and thus facilitates predictions on their future presence. Varieties grown by the farmers should be carefully selected, adapted to the prevailing climatic conditions and resistant to risk-posing pathogens (Kołodziej, 2010). Soil pH is another essential aspect to consider while fighting plant diseases. Crops attacked by the same diseases and similar pest species should not be planted close to each other. Weeds growing on idle lands and areas neighboring the plantation should be removed, as they are the source of diseases and pests attacking the crop plants. Herbal plants should not be grown in monocultures (Rumińska, 1983). Modern plant cultivation approaches pay special attention to biological methods aimed at creating favorable conditions for the development of natural enemies, such as fungi or bacteria, antagonistic to plant pathogens. This is one of the elements of organic cultivation of herbs (Mercik, 2004).

Plantations of herbal plants should be isolated from chemically protected crops, and special precautions should be observed regarding the use of pesticides (Kołodziej, 2010). Integrated methods of production allow the use of chemicals only when the pathogen pressure is so huge that it may inflict serious economic loss. Organic farming is focused on the production of chemically unprocessed agents and it promotes the use of formulations containing living organisms or natural substances produced by them. Plant protection products of this type are called biological preparations. They contain active substances adversely affecting plant pathogens or stimulating plant resistance. The most popular and commonly used active ingredients include e.g. chitosan, garlic extract, garlic mash, grapefruit seed and pulp extract, fungus *Phytium oligandrum*, orange oil, and dry herb extracts. The list the Minister of Agriculture and Rural Development with plant protection products authorized for use in Poland contains about 800 products (as of 29 May 2007). Twelve of them, with active ingredient of biological origin, have been authorized for use in horticulture (Zydlik, 2008).

4. DISCUSSION

The study provided information on the presence of fungal pathogens on selected herbal plants: *Chelidonium majus*, *Datura inoxia*, *Hypericum perforatum*, *Levisticum officinale*, *Malva sylvestris*, *Melissa officinalis*, *Nepata cataria*, *Origanum vulgare*, *Salvia officinalis*, *Sanguisorba minor*, *Silybum marianum* and *Solanum sisymbrifolium*. The plant material showed clear signs of infection caused by fungal pathogens. The most often observed diseases included blights, distortions, necroses, spots, rusts, and mildews. They were present on the leaves and stems of the investigated plants. The herbal material was colonized by a total of 11 taxa representing two types of fungi: Ascomycetes and Basidiomycetes. The greatest number of taxa (98.2% of all identified fungi) belonged to *Ascomycetes* and they were all mitomorphic (conidial) stages of ascomycetes. Two of the detected taxa: *Phragmidium sanguisorbae* and *Puccinia malvacearum* were classified as belonging to *Basidiomycetes* (1.8%). *Cladosporium* spp. was the fungus found on the greatest number of investigated plant species.

Health status of herbal plants and the effect of plant pathogens on the quality of herbal material have been recorded in Poland for many years. A study by Zimowska and Machowicz-Stefaniak (2004) reported the presence of an array of pathogens infesting perforate St John's-wort (*Hypericum perforatum*). The investigated plant organs were colonized by a number of microorganisms, of which the most important were found to be the fungi of *Fusarium* genus, *Rhizoctonia solani*, *Phoma exiqua* var. *exiqua* and *Botrytis*. Health status record of perforate St John's-wort plants demonstrated that the percent of plants with disease symptoms on two year old plantations ranged from 45.16 to 52.78% and was significantly greater than on one year old plantations. Additionally, significant growth inhibition of all seedlings and the presence of lesions on their stems, leaves and other organs were noticed. Moreover, disintegration and softening of lower sections of the stems infested with mycelium and conidia typical for fungi from *Fusarium* genus were observed. Perforate St John's-wort was also colonized by a pathogen belonging to *Phoma* genus that in our study was identified on the leaves of *Datura inoxia.* This pathogen was *Phoma herbarum.* Fungi of this taxon are commonly found on dying parts of plants (Marcinkowska, 2003).

Rhizoctonia solani isolated from dying plants may also cause diseases in the investigated plants. It was identified in basil (Minuto et al., 1997) and ginseng (Berbeć i Pięta, 1996) crops, where it was described as an extremely persistent pathogen of roots and stems. This common pathogen of many plant species (Kochman, 1986) overwinters in the soil and on the residues of infected plants. Rapid spread of the disease it causes is facilitated by high air and soil humidity (Hołubowicz-Kliza and Korbas, 2012).

The study results indicated the presence of *Alternaria alternata* in the crop environment. This pathogen induces spots on green parts of the plants and secretes toxins that diminish the quality of herbal material and cause economic losses. Moreover, it is capable of rapid colonization of large part of the plantation (Grzybowska and Kapala, 1976).

A study conducted by Kowalik (2013) investigated herbs grown in the Botanical Garden of the Jagiellonian University and the Garden of Medicinal Plants of Collegium Medicum. The aim of this research was to identify fungi inhabiting dead parts of the plants. The plant material was found to contain a number of different pathogens, including *Alternaria alternata*, identified also in the present study. This pathogen was isolated in the studies conducted by Machowicz-Stefaniak and Zalewska (2004), Szczeponek (2006), and Maur and Szczeponek (2005), which indicates its common presence on herbal plants. It is probably so widespread as it is cosmopolitan and polyphagous and it overwinters on dying fragments of different plants. Its optimal developmental conditions require long-time high air humidity (Kochman 1986; Marcinkowska 2003; Kryczyński and Weber 2011, 2012; Hołubowicz-Kliza and Korbas, 2012).

The fungi of *Alternaria* and *Cladosporium* species may cause allergies in humans and animals. They pose a considerable risk to humans exposed to them (Breitenbach and Simon-Nobbe, 2002), and their presence on herbal plants should be considered a reason for disqualification of the plants as herbal material.

Another pathogen commonly found in the investigated species was *Pucinia malvacearum* that causes rust in common mallow and was present on its leaves and stems. The fungi of *Pucinia* species often colonize herbal plants and negatively affect their development. Taxa of this genus were detected e.g. by Mazur and Szczeponek (2006), but so far no negative effects of the fungi from *Uredinales* order on human health have been discovered.

5. CONCLUSIONS

1. Microscopic fungi that colonize investigated herbal plants negatively affect their growth and yield rate.
2. The identified pathogens reduce of completely disqualify usefulness of the plants as herbal material.
3. Some fungal taxa identified during the study may worsen health conditions of particularly susceptible people.
4. Fighting the pathogens that infect herbal plants should include agronomic methods recommended by integrated plant protection and the use of natural products instead of chemical plant protection agents.
5. Special attention should be given to the growing conditions, including the site preparation and the climatic conditions in specific area, as these factors may often be crucial for the health status of the cultivated medicinal plants.

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