Alternaria Genus and the Diseases Caused to Agricultural and Horticultural Plants

Antonia FLOREA[1]*, Carmen PUIA[1]

[1] *Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Calea Mănăştur 3-5, 400372 Cluj-Napoca, Romania*
**corresponding author: antonia-luminita.florea@usamvcluj.ro*

Bulletin UASVM series Agriculture 77(2) / 2020
Print ISSN 1843-5246; Electronic ISSN 1843-5386
DOI:10.15835/buasvmcn-agr: 2020.0034

Abstract

This work is a bibliographic approach to the historical and most recent taxonomy on *Alternaria* genus. The genus *Alternaria* consists largely of species of saprophytic, endophytic and parasitic fungi. The United States Fungal host index ranks the genus Alternaria on the 10th place based on the number of host plants, with over 4,000 species. Govind *et al*. (2016) tells us that most species of this genus are missing the sexual form, with the exception of a few species, which have, in addition to the anamorphic form, the telemorphic form. With the discovery of several species and due to the superficiality of past research, the inclusion of this genus in the taxonomy has become problematic. At the beginning, the taxonomic classification was performed according to the morphology of the species. This bibliographic approach wants to clarify some of the aspects concerning the old and actual taxonomy ambiguities of *Alternaria* genus. The method used is consulting the scientific literature. The present reclassification of the species was performed by analysing the DNA of each species in 2013 by Woudenberg *et al.* and fit the *Alternaria* species in 25 sections. In 2016 Lawrence *et al.* added 2 other sections and in 2019 Ghafri *et al.* forms a new section based on the new species *Alternaria omanensis*. In conclusion *Alternaria* genus is now divided in 28 sections, each section contains species that are genetically related. Even though most of the ambiguities have been clarified at present, there are still ambiguities regarding the species within and between sections.

Keywords: *Alternaria*, ambiguities, taxonomy

INTRODUCTION

The genus *Alternaria* is largely composed of species of saprophytic, endophytic and parasitic fungi (Lawrence *et al*., 2016; Singh *et al*., 2016). According to the taxonomic classification, it belongs to the kingdom of Fungi, the Ascomycota branch, the *Pezizomycotina* sub-branch, the class *Dothideomycetes*, the subclass *Pleosporales* and the family *Pleosporaceae* (Stuart *et al*., 2009; Lawrence *et al*., 2016, Ghafri *et al*., 2019). The database of the United States of America Fungal host index ranks the genus *Alternaria* on the 10th position based on the number of host plants, with over 4000 species (Singh *et al*., 2016). Most species of this genus are devoid of the sexual form (except for a few species, which have in addition the telemorphic form) (Lawrence *et al*., 2016). With the discovery of several species and due to the superficiality of past research, the inclusion of this genus in taxonomy has become problematic. At the beginning, the taxonomic classification was performed according to the morphology of the species and currently, the reclassification of the species was performed by analysing the DNA of each species (Lawrence

et al., 2016; Tralamazza *et al*., 2018; Woudenberg *et al*., 2013). The damages produced on the crops are significant, with tomatoes registering losses between 50-86%. In addition to crop losses, the spores produce pneumonia, asthma, or sinus irritation (Cruz *et al*., 2016; Lawrence *et al*., 2016; Shyama and Somnath, 2015). Some species of the genus *Alternaria* release mycotoxins in the organs of the attacked plants. Mycotoxins are toxic substances that result due to the pathogen's metabolism. The main mycotoxins produced are: alternariol, alternariol monomethyl ether, altertoxins I, II, III and tenuazonic acid (Pinto and Patriarca, 2017; Tralamazza *et al*., 2018; Van de Perre *et al*., 2015). These mycotoxins were found both in raw products (apples, citrus, wheat, tomatoes, sunflower seeds) and in processed products, which come from infected plants. Mycotoxins have a negative effect on human health. They can contribute to chromosomal mutations and affect the integrity of DNA in colon cells (Ostry, 2008; Pinto and Patriarch, 2017; Tralamazza *et al*., 2018).

The history of the taxonomic classification and the current classification of the *Alternaria* genus

The history of taxonomic classification has gone through five main stages since 1816, the last revision being made between 2003 and 2015. The first stage was between 1816 and 1850 and includes the description of the *Alternaria tenuis* (Lawrence *et al*., 2016; Pryor and Gilbertson, 2000; Ghafri *et al*., 2019). During this period, a connection was observed between the anamorphic forms of four genera: *Ulocladium*, *Macrosporium*, *Alternaria* and *Brachycladium*. In 1833 the genus *Stemphylium* was added. Because of the ambiguity of the first four genera, they were always confused. Few of the species investigated had been validated. Meanwhile, the genera *Brachycladium* and *Ulocladium* had been forgotten (Lawrence *et al*., 2016, 2013).

The second stage was between 1850 and 1930. This period was marked by the discovery of new species. About 400 species had been classified, most of them were placed in *Macrosporium* genus (Singh *et al*., 2016; Lawrence *et al*., 2016). After this period, the first taxonomic hierarchy was known by the name of *Alternaria* and *Macrosporium*. Most species were distributed according to the morphological characteristics of the conidia like: shape, form, size, colour etc. (Nabahat *et al*., 2020) and six main groups were formed (Lawrence *et al*., 2016).

The third stage was between 1930 and 1960. During this period, an attempt was made to separate the two genera to determine the classification of the genus *Stemphylium*. The year 1933 was a decisive one, because the researchers came to the conclusion that the genus *Macrosporium* should be called "*nomen ambiguum*" (Singh *et al*., 2016; Lawrence *et al*., 2016, 2013). This decision was based on the fact that problems occurred because of the numerous taxons that were superficially investigated, and more than 400 fake species were described (Nishikawa and Nakishima, 2020). This conclusion was not immediately accepted. Thus, in 1945, Neergaard (Singh *et al*., 2016; Lawrence *et al*., 2016) tried to redistribute them, based on the morphological characteristics of the conidia formation. This classification does not follow the rules of nomenclature and it is not used (Lawrence *et al*., 2016; 2013).

The fourth stage was between 1960-2000. This stage was dedicated to the researcher Enoy Guy Simmons, who put together all the known information about the *Alternaria* genus (Lawrence et al., 2016; Pryor B.M. and L. Gilbertson, 2000). During this period, the genus *Alternaria* and other similar species were called "*phaeodictyosporic hypfomycetes*", trying to name species with berry shape conidia appearance and dark brown spores imperfect fungi. This category includes the genera *Alternaria*, *Macrosporium* and *Stemphylium* until 1970. Meanwhile, the genus *Ulocladium* was forgotten and the differentiation between the other three genera was confusing (Lawrence *et al*., 2016; Pryor and Gilbertson, 2000). The genus *Macrosporium* was forgotten mainly through the declaration of the species *Macrosporium* cheiranthi belonging to the *Alternaria* genus. Later, other genera emerged from the *Alternaria* genus, such as *Alternaria*ster, *Chalastospora, Embellisia, Nimbya* and *Teretispora* (Singh *et al*., 2016; Lawrence *et al*., 2016; 2013).

The fifth stage was between 2003-2015, when the reclassification of the genus *Alternaria* and other related species, through DNA analysis was elaborated. The first approach of this was performed on the genus *Stemphylium* and *Ulocladium*. Studies have revealed a very close relationship between these genera and the *Alternaria* genus. Due to

the multitude of morphological characters, DNA sequencing was a good approach to solve some phylogenetic problems by reducing the number of allied genera under Alternaria name (Gannibal and Lawrence, 2018; Lawrence *et al*., 2016, Nishikawa and Nakishima, 2020). Even though these methods have advanced a lot in the research of this genus, the discrepancy, the relationship between species and the relationship between taxonomy and plant parasitism has not been sufficient to help the practical recognition of species (Nishikawa and Nakishima, 2020). Currently, 28 sections have been formed within the genus based on phylogenetic relationships (Gannibal, 2018; Gannibal and Lawrence, 2018; 2016; Lawrence *et al*., 2016; Tralamazza *et al*., 2018; Singh *et al*., 2016).

Causes of *Alternaria* ambiguities: morphology of the genus *Alternaria*, biological cycle and the lack of sexual reproduction

One of the main reasons for *Alternaria* genus ambiguities is the similarity between the morphological characteristics of the species. The mycelium of the *Alternaria* genus is composed of conidiophores and conidia (Singh *et al*., 2016; Lawrence *et al*., 2016). The conidiophores can be simple or branched, pale brown, grey, dark brown or olive and can be either solitary or grouped in bundles. The surface of the conidia can be smooth or rough, with or without septa. The mycelium is found on the plant on the necrotic lesion (Singh *et al*., 2016; Stuart *et al*., 2009, Hu *et al*., 2015; Lawrence *et al*., 2016; Melo *et al*., 2009; Pinto and Patriarca, 2017; Tralamazza *et al*., 2018).

Another reason behind these ambiguities is the biological cycle and sexual reproduction. The species of the genus can be parasitic, saprophytic and endophytic. The main categories that cause significant damage are parasites and saprophytes (Lawrence *et al*., 2016). In order for pathogens to produce infections, the climate must be alternately humid and dry. The optimum temperature of development is between 25-31°C and the relative humidity between 70-80%. In case of favourable climatic conditions, the infection occurs within 5-18 hours while the first symptoms appear in 4-6 days (Mamgain *et al*., 2013; Singh *et al*., 2016). The penetration occurs through the stomata or healthy tissue and it is favoured by the presence of existing lesions. Once the infection is present, the pathogen releases in plant toxins that can sensitize healthy tissues. The pathogenic mycelium is found mainly on the surface of the affected tissue, along with the conidia. Conidia are usually transported by wind, water, animals, machinery, insects, etc. Spores, which reach other plants or other organs, cause secondary infections. Asexual reproduction is predominant, but there are species that also have a sexual form. Sexual reproduction occurs after 1-2 cycles of asexual reproduction. However, the sexual form was performed only in laboratory conditions because it is hard to reproduce the weather conditions for a long period of time (Meng *et al*., 2015). The main causes for the lack of sexual multiplication are the changes of the heterothallic system in the homothallic system or the beginning or non-completion of the sexual multiplication cycle (Lawrence *et al*., 2016; Meng *et al*., 2015).

Current branching of the *Alternaria* genus

The *Alternaria* genus is divided into 28 sections. Each section includes the species based on morphological and DNA analysis (Table 1).

The main diseases caused by *Alternaria* spp. to agricultural and horticultural crops

Early blight of potato caused by *Alternaria solani, Alternaria protenta, Alternaria linariae, Alternaria grandis*

Main symptoms appear on the main organs of the plant: leaves, stem and tuber. The attack on the foliar system is highlighted by the appearance of brown-blackish, circular spots, small at the beginning of the infection but which can increase over time (Fig. 1).

Figure 1. Early blight of potato (http://omafra.gov.on.ca/IPM/english/potatoes/diseases-and-disorders/alternaria.html)

Table 1. The sections and species of *Alternaria* genus based on pylogenetic and morphological analysis.

Section of *Alternaria* genus	Species	Author
Alternantherae	*Alternaria alternantherae,* *Alternaria celosiicola* *Alternaria gonphenae* *Alternaria perpunctulata*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Alternaria	*Alternaria arborescens* *Alternaria angustiovoidea* *Alternaria gaisen* *Alternaria alternata* *Alternaria burnsii* *Alternaria cerealis* *Alternaria citriarbusti* *Alternaria alstroemeriae* *Alternaria betae-kenyensis* *Alternaria gossypina* *Alternaria iridiaustralis* *Alternaria citrimacularis* *Alternaria colombiana* *Alternaria destruens* *Alternaria dumosa* *Alternaria herbiphorbicola* *Alternaria daucifolli* *Alternaria limoniasperae* *Alternaria longipes* *Alternaria perangusta* *Alternaria postmessia* *Alternaria tangelonis* *Alternaria tomato* *Alternaria toxicogenica* *Alternaria turkisafria*	Paul *et al*., 2015 Woudenberg *et al*., 2013,2014, 2015
Brassicicola	*Alternaria brassicicola* *Alternaria conoidea* *Alternaria mimicula* *Alternaria septorioides* *Alternaria solidaccana*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Chalatospora	*Alternaria abundans* *Alternaria armoraciae* *Alternaria breviramosa* *Alternaria malorum* *Alternaria cetera* *Alternaria obclavata*	Woudenberg *et al*., 2013
Cheiranthus	*Alternaria indefessa* *Alternaria cheiranthi*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Crivellia	*Alternaria papavericola* *Alternaria penicillata*	Woudenberg *et al*., 2013
Dianthicola	*Alternaria elegans* *Alternaria simsimi* *Alternaria dianthicola*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Embellisa	*Alternaria embellisa* *Alternaria tellustris* *Alternaria chlamydosporigena.*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013

Embellisioides	*Alternaria botryospora* *Alternaria planifunda* *Alternaria tumida* *Alternaria proteae* *Alternaria lolii* *Alternaria hyacinthi*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Euphorbiicola	*Alternaria limicola* *Alternaria euphorbicola.*	Woudenberg *et al*., 2014
Eureka	*Alternaria cucumi* *Alternaria trigochinicola* *Alternaria anigozanthi* *Alternaria geniostomatis* *Alternaria leptinellae* *Alternaria eureka*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Gypsophilae	*Alternaria ellipsoidea* *Alternaria vaccariae,* *Alternaria vaccariicola* *Alternaria nobilis* *Alternaria saponariae,* *Alternaria axiaeriisporifera* *Alternaria juxtiseptata* *Alternaria gypsophylae*	Lawrence *et al*., 2016, 2013 Woudenberg *et al*., 2013
Infectoriae	*Alternaria grsminicola* *Alternaria arbusti* *Alternaria caespitose* *Alternaria californica* *Alternaria conjuncta* *Alternaria daucicaulis* *Alternaria ethzedia* *Alternaria fumenti* *Alternaria graminicola* *Alternaria hordeiaustralica* *Alternaria hordeicola* *Alternaria humuli* *Alternaria incomplexa* *Alternaria alternarina* *Alternaria triticina* *Alternaria metachromatica* *Alternaria infectoria* *Alternaria intercpta* *Alternaria merytae* *Alternaria novae-zelandiae* *Alternaria oregonensis* *Alternaria slovaca* *Alternaria triticimaculans* *Alternaria ventricosa* *Alternaria viburni*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Japonicae	*Alternaria nepalensis* *Alternaria japonica* *Alternaria telliensis*	
Nimbya	*Alternaria caricis* *Alternaria juncicola* *Alternaria heteroschemos* *Alternaria scirpivora* *Alternaria scirpinfestans* *Alternaria scirpicola*	Lawrence *et al*., 2012, 2016 Woudenberg *et al*., 2013 Gannibal, 2018
Omanenses	*Alternaria omanenses*	Ghafri *et al*., 2019

Panax	*Alternaria araliae* *Alternaria avenicola* *Alternaria hedjaroudei* *Alternaria calycipyricola* *Alternaria dendropanacis* *Alternaria photistica* *Alternaria eryngii* *Alternaria panacis*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013 Hashemlou *et al*., 2020
Phragmosporeae	*Alternaria chlamydospora* *Alternaria didymospora* *Alternaria limaciformis* *Alternaria molesta* *Alternaria mouchaccae* *Alternaria phragmospora*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Porri	*Alternaria capsici* *Alternaria agerati* *Alternaria acalyphicola* *Alternaria anagallidis* *Alternaria aragakii* *Alternaria argyroxiphii* *Alternaria bataticola* *Alternaria blumeae* *Alternaria calendulae* *Alternaria carthami* *Alternaria cassia* *Alternaria cichorii* *Alternaria cirsinoxia* *Alternaria crassa* *Alternaria cretica* *Alternaria cyphomandrae* *Alternaria cucumerina* *Alternaria dauci* *Alternaria danida* *Alternaria dichondrae* *Alternaria grandis* *Alternaria hawaiiensis* *Alternaria solani* *Alternaria linariae* *Alternaria limicola* *Alternaria linicola* *Alternaria macrospora* *Alternaria multirostrata* *Alternaria passiflorae* *Alternaria poonensis* *Alternaria porri* *Alternaria protenta* *Alternaria pseudorostrata* *Alternaria pseudorostrata* *Alternaria rahapontici* *Alternaria scorzonerae* *Alternaria sesame* *Alternaria solani-nigri* *Alternaria steviae* *Alternaria subcylindrica* *Alternaria zinnia*	Barreto *et al*., 2008 Gannibal, 2015 Lawrence *et al*., 2016 Soylu *et al*., 2005 Woudenberg *et al*., 2013,2014 Gannibal, 2018
Pseudoalternaria	*Alternaria arrhenatheri* *Alternaria rose*	Gannibal and Lawrence, 2016 Lawrence *et al*., 2016

Pseudoulocladium	*Alternaria aspera* *Alternaria septospora* *Alternaria lanuginose* *Alternaria sylvestris* *Alternaria concatenata* *Alternaria chartarum*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Radicina	*Alternaria selini* *Alternaria petroselini* *Alternaria smyrnii* *Alternaria carotiiniculatae* *Alternaria radicina*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Soda	*Alternaria petuchovskii* *Alternaria shukurtzii* *Alternaria kulundii.*	Lawrence *et al*., 2016
Sonchi	*Alternaria sonchi* *Alternaria cinerariae*	Woudenberg *et al*., 2013
Teretispora	*Alternaria leucanthemi*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013
Ulocladioides	*Alternaria cucurbitae* *Alternaria alii-tuberosi* *Alternaria castaneae* *Alternaria gpagarwalii* *Alternaria microspore* *Alternaria oblongo-obovoidea* *Alternaria populicola* *Alternaria preussii* *Alternaria pseudobotrytis* *Alternaria sorghi* *Alternaria zantedeschiae* *Alternaria brassicae-pekinensis* *Alternaria cantlous* *Alternaria consortialis* *Alternaria heterospora* *Alternaria obovoidea* *Alternaria subcucurbitae* *Alternaria multiforimis* *Alternaria terricola* *Alternaria atra*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013 Gannibal *et al*., 2018
Ulocladium	*Alternaria capsici-annui* *Alternaria botrytis* *Alternaria alternariae* *Alternaria manihoticola* *Altenaria oudemansii*	Lawrence *et al*., 2016 Woudenberg *et al*., 2013 Gannibal *et al*., 2018
Undifilum	*Alternaria bornmuelleri* *Alternaria cinerea* *Alternaria fulva* *Alternaria oxytropis*	Woudenberg *et al*., 2013

Concentric circles can be seen on the surface of the strains (Waals *et al*., 2001; Bobes, 1983). On the upper part of the spots appears a black brown down composed of the conidiophores and conidia of the pathogen. As the pathogen develops, the spots on the leaf surface increase and unite leading to the necrosis of the tissue (Bobes, 1983). The attack on the potato tubers can be observed by the presence of dark-brown circular spots, hard in texture and slightly deep into tissue. On their surface there is a black rot formed by the conidia on the conidiophores of the fungus. At first, the

attack can be seen on the lower floor of the plant then it gradually develops and takes over the plant (Waals *et al*., 2001; Popescu, 1993).

Alternaria black spot of canola caused *Alternaria brassicae* Saccardo

The pathogen prefers high temperatures, high humidity, but also the presence of precipitation that favours their development. Main symptoms appear on all green organs. Circular or ellipsoidal spots with a diameter between 2-10 mm appear first on the leaves. The spots are yellowish-black, and concentric formations appear inside them (Singh *et al*., 2016; Kumar *et al*., 2014; Bobeş, 1983). On the stem, lesions appear from the top to the base, the spots are elongated in the form of stripes, in the direction of the axis. On the silique, there are a multitude of small spots in size that have the shape of black dots or stripes slightly immersed in the tissue (Singh *et al*., 2016; Bobes, 1983). As the pathogen develops, the spots join together and form irregular spots. The pathogen grows on the surface of the spots, forming a blackish-brown down composed of the conidia and conidiophores of the fungus (Singh *et al*., 2016; Bobeş, 1983; Kumar *et al*. 2015).

Figure 2. Alternariosis in cucurbits (https://pestre.ro/blog/bolile-castravetilor/)

Alternaria leaf spot of cucurbits caused by *Alternaria cucumerina* Ellis & Everhart

The pathogen attacks all the green organs of the plant: leaves, stem and fruits. The spots that appeared at the beginning of the infection are at that moment small in size but with their development can reach up to a diameter of 10 mm (Yacoub, 2003). The shape of the spots is elliptical, they have a yellow-brown colour, and the spots on the fruit have an aqueous appearance (Fig. 2). As the spots grow, they come together and can cover the entire leaves, causing burns on the stems. On stems and shoots, the affected plants show deep spots and the browning of the tissue (Yacoub, 2003; Bobes, 1983).

Black carrot rot caused by *Alternaria radicina* Meier, Drechsler & E.D. Eddy

The disease can occur in all stages of plant development. At the base of leaves, there can be seen an atrophy of the corner that darkens, and the plants wither and fall. The leaves begin to yellow and ultimately suffer drying processes (Scott and Wenham, 1972). In the roots section appear black spots that are deep in the tissue. The edges of the spots can be angular or smooth and are well defined. On the surface of the spots appears the mycelium of the pathogen formed by the conidia and conidiophores of the fungus, with a velvety appearance. It often affects the inside of the root, rarely the top of the root (Farrar *et al*., 2004; Scott and Wenham, 1972).

Alternariosis of carrot leaves caused by *Alternaria dauci* Groves & Skolko

The symptoms of this pathogen can be easily confused with the attack of *Cercospora carotae*. The leaves that are in a very advanced stage of the attack have spots with necrotic appearance of black-brown colour, surrounded by a chlorothic halo (Scott and Wenham, 1972; Boedo *et al*., 2010).

Brown spot leaves, stems and calatidium on sunflower caused by *A. helianthi* Tsubaki and Nisihara, *Alternaria zinnia* Ellis, *A. alternata* Keissler

Favourable climatic factors for the development and spread of the pathogen are high temperatures above 24°C and high humidity. The optimal humidity conditions where the pathogen causes the infection are created after long-term precipitation in the interval of 12-24 hours. The days before the precipitations, in which the temperatures are high and the humidity is low for long periods, stop the development of the disease (Van der Westhuizeni *et al*., 1980; Baicu *et al*., 1996). The symptoms are manifested on all the green organs of the plant. Circular or angular brown-grey spots appear on the foliar apparatus, the edge of the spots being

delimited by a yellow halo. The stains can reach a diameter of 50mm. On the calatidium and bracts, the spots have a circular appearance. The formed achenes are small in size and dry (Udayashankar *et al*., 2012; Baicu *et al*., 1996).

Leaf blight on wheat caused by *Alternaria triticina* Prasada & Prabhu

The disease was reported in tropical and subtropical countries, especially in the countries of South and Southeast Asia, by Prasada and Prabhua in 1962 (Vergnes *et al*., 2006). It prefers areas with warm climates and high temperatures. The first symptoms appear in wheat after 7-8 weeks, evolving with the growth of the plant. The attack can be manifested on all the above-ground organs: leaves, stems, ear, jokes, pale and seed. On the leaf surface, ovoid spots appear, irregular at the beginning, of small dimensions, scattered on the entire leaf surface. As the disease progresses the spots increase in diameter and intertwine (Siddiqui, 2007; Vergnes *et al*., 2006).

Black spot on carnations caused by *Alternaria dianthi* Stevens & Hall and *Alternaria dianthicola* Neergard

The organs attacked by the pathogen are: leaves, stems and shoots, but attacks on flowers are rare. On the leaves and nodes brown-grey spots appear, well delimited by a portion of healthy tissue, forming a yellow-green halo. When the humidity is high, the spots are covered by the mycelium of the black fungus (Mehta *et al*., 2007; Popescu, 1993). The attacked leaves fall from the stems and on the shoots the mycelium appears in the form of a ring surrounding the stem. The stems break very easily above the affected area. On the flowers, brown areas are observed on the white petals and discoloration spots on the carnations with red flowers, this symptom being characteristic of the *A. dianthicola* (Popescu, 1993).

Saffron alternariosis caused by *Alternaria carthami* S. Chowdhury

The attack of the pathogen is observed on the foliar apparatus of the plant by the presence of small spots, circular or with irregular edge, brown colour, and on their edges, light green halos are present. As the attack progresses, the spots intertwine and enlarge. On the surface of the spots appears a blackish mycelium consisting of conidiophores and conidia of the pathogen (Ivaşcu *et al*., 2009).

CONCLUSION

Currently, the last attempt to taxonomically reclassify the genus *Alternaria* was made between 2003 and 2015, where due to modern technologies; the species was identified by molecular analysis. However, the differences between the species of the different sections are still unknown. On the territory of Russia, interactions of species from different sections of the genus *Alternaria* have been found on plants from the *Solanacae* family (Kokaeva *et al*., 2017; Lawrence *et al*., 2016).

Acknowledgments. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Armitage AD, Cockerton HM, Sreenivasaprasad S, Woodhall J, Lane CR, Harrison RJ, Clarkson JP (2020). Genomics evolutionary history and diagnostics of the *Alternaria alternata* species group including apple and asian pear pathotypes. Frontiers in Microbiology, 10: 3124.
2. Baicu T, Tatiana Eugenia ŞT (1996). Fitopatologie Agricolă. Ed. Ceres, Bucureşti.
3. Barreto RW, Santin AM, Vieira BS (2008). *Alternaria cichorii* in Brazil on *Cichorium* spp. seeds and cultivated and weedy hosts. Journal of Phytopathology, 156: 425-430.
4. Bobes I (1983). Atlas de fitopatologie şi protecţia agroecosistemelor. Ed.Ceres, Bucureşti.
5. Boedo C, Berruyer R, Lecomte M, Bersihand S, Briard M, Le Clerc V, Simoneaua P, Pouparda P (2010). Evaluation of different methods for the characterization of carrot resistance to the *Alternaria* leaf blight pathogen (*Alternaria dauci*) revealed two qualitatively different resistances. Plant Pathology, 59: 368–375.
6. Comes T, Lazar A, Bobeş I, Hatman M, Drăcea A (1982). Fitopatologie, Ed. Didactică şi Pedagogică. Bucureşti.
7. Cruz CRM, Laforet EP, Oyarzo PV, Silva LC (2016). Identificación de *Alternaria botrytis* (preuss) Woudenberg y Crous. Revista Argentina de Microbiología, 48: 182-183.
8. Farrar JJ, Pryor BM, Davis RM (2004). Alternaria Diseases of Carrot. Plant Disease, 88(8): 776-784.
9. Gannibal PB (2015). Distribution of *Alternaria* species among sections. 1. Section *Porri*. Mycotaxon, 130: 207-213.
10. Gannibal PB (2016). Distribution of *Alternaria* species among sections. 2. Section *Alternaria*. Mycotaxon, 130: 941-949.
11. Gannibal PB (2018). Distribution of *Alternaria* species among sections. 4. Species formerly assigned to genus *Nimbya*. Mycotaxon, 133: 37-43.

12. Gannibal PB, Lawrence DP (2016). Distribution of *Alternaria* species among sections. 3. Sections *Infectoriae* and *Pseudoalternaria*. Mycotaxon, 131: 781-790.
13. Gannibal PB, Lawrence DP (2018). Distribution of *Alternaria* species among sections. 5. Species producing conidia with many longitudinal septa. Mycotaxon, 133: 285-291.
14. Gannibal PB, Lawrence DP (2018). Distribution of *Alternaria* species among sections. 6. Species formerly assigned to genus *Ulocladium*. Mycotaxon, 133: 293-299.
15. Ghafri AA, Maharachchikumbura SNS, Hyde KD, Al-Saady N, Al-Saady AM (2019). A new section and a new species of *Alternaria* encountered from Oman. Phytotaxa, 405(6): 279-289.
16. Govind SS, Naresh MP, Dayal M (2016). Alternaria diseases of crucifers: biology, ecology and disease management, Springer, DOI 10.1007/978-981-10-0021-8.
17. Hashemlou E, Ghosta Y, Poursafar A, Azizi R (2020). Morphological and molecular identification of *Alternaria hedjaroudei* sp. nov., a new species in section *Panax* from Iran. Phytotaxa, 438 (2): 130-140.
18. Hu W, Ran Y, Zhuang K, Lama J, Zhang C (2015). *Alternaria arborescens* infection in a healthy individual and literature review of cutaneous alternariosis. Mycopathologia, 179: 147-152.
19. Ivaşcu A, Simion J-G, Vasile E (2009). Ghid pentru determinarea rezistenţei la boli şi dăunători. Biroului de calcul al I.S.T.I.S.
20. Kokaeva LY, Belosokhov AF, Doeva LY, Skolotneva ES, Elansky SN (2017). Distribution of *Alternaria* species on blighted potato and tomato leaves in Russia. Journal of Plant Diseases and Protection, 125: 205-212.
21. Kumar D, Maurya N, Bharati YK, Kumar A, Kumar K, Srivastava K, Chand G, Kushwaha C, Singh SK, Mishra RK, Kumar A (2014). *Alternaria* blight of oilseed *Brassicas*: A comprehensive review. African Journal of Microbiology Research, 8 (30): 2816-2829.
22. Lawrence DP, Rotondo F, Gannibal PB (2016). Biodiversity and taxonomy of the pleomorphic genus *Alternaria*. Mycological Progress, 15: 3.
23. Lawrence DP, Park M, Pryor BM (2012). *Nimbya* and *Embellisia* revisited, with nov. comb for *Alternaria celosiae* and *A. perpunctulata*. Mycological Progress, 11: 799-815.
24. Lawrence DP, Gannibal PB, Peever TL, Pryor BM (2013). The sections of *Alternaria*: formalizing species-group concepts. Mycologia, 105: 530-546.
25. Mamgain A, Roychowdhury R, Tah J (2013). Review *Alternaria* pathogenicity and its strategic controls. Research Journal of Biology, 1: 1-9.
26. Mehta R, Sharma S, Nath AK (2007). In vitro selection and biochemical characterization of carnation (*Diathus caryophyllus*) Callus culture tolerant to *Alternaria dianthi.* Indian Journal Plant Physiol., 12 (2):120-126.
27. Melo MP, Soares DJ, Araújo JSP, Tostes GO (2009). *Alternaria* leaf spot, caused by *Alternaria thunbergiae*, recorded for the first time on *Thunbergia alata* from Brazil. Australasian Plant Disease Notes, 4: 23-25.
28. Meng JW, Wen Z, Han HM, Wu EJ, Duan GH, Xie YK, Jin Y, Li N, Shang L, Zhan J (2015). Population genetic analysis reveals cryptic sex in the phytopathogenic fungus *Alternaria alternate*. Scientific Reports, 5:18250.
29. Nabahat B, Bruno H, Simoneau NB, Kihal M, Simoneau P (2020). *Alternaria telliensis* sp. nov., a new species isolated from *Solanaceae* in Algeria. Phytotaxa, 440 (2): 089-100.
30. Nishikawa J, Nakishima C (2020). Japanese species of *Alternaria* and their species boundaries based on host range. Fungal Systematics and Evolution, 5: 197-281.
31. Ostry V (2008). *Alternaria* mycotoxins: an overview of chemical characterization, producers, toxicity, analysis and occurrence in foodstuffs. World Mycotoxin Journal, 1:175-188.
32. Paul NC, Deng JX, Lee HB, Yu SH (2015). Characterization and pathogenicity of *Alternaria burnsii* from seeds of *Cucurbita maxima* (*Cucurbitaceae*) in Bangladesh. Mycobiology, 43: 384-391.
33. Pinto VEF, Patriarca A (2017). *Alternaria* species and their associated mycotoxins, mycotoxigenic fungi: Methods and Protocols, Methods in Molecular Biology. Springer New York, Vol. 1542.
34. Popescu G (1993). Fitopatologie. Ed. Tehnică, Bucureşti
35. Pryor BM, Gilbertson L (2000). Molecular phylogenetic relationships amongst *Alternaria* species and related fungi based upon analysis of nuclear ITS and mt SSU rDNA sequences. Mycological Research, 104 (11): 1312-1321.
36. Scott DJ, Wenham HT (1972). Occurrence of two seed-horne pathogens *Alternaria radicina* and *Alternaria dauci*, on imported carrot seed in New Zealand. New Zealand Journal of Agricultural Research, 16: 247- 250.
37. Shyama S, Somnath K (2015). Evaluation of culture media for growth characteristics of *Alternaria solani,* causing early blight of tomato. Journal of Plant Pathology and Microbiology, 1: 5.
38. Siddiqui ZA (2007). Biocontrol of *Alternaria triticina* by plant growth promoting rhizobacteria on wheat, Archives of Phytopathology and Plant Protection, 40(4): 301 – 308.
39. Singh SG, Mehta N, Meena PD (2016). *Alternaria* diseases of crucifers: biology, ecology and disease management. Springer, Singapore.
40. Soylu S, Kurt S, Soylu EM, Tok FM (2005). First report of *Alternaria* leaf blight caused by *Alternaria dauci* on carrot in Turkey. Plant Pathology, 54: 252-252.
41. Stuart RM, Bastianel M, de Azevedo FA, Machado MA (2009). *Alternaria* Brown Spot. Fitopatologia, 30: 29-44.
42. Tralamazza SM, Piacentini KC, Iwase CHT, Rocha LO (2018). Toxigenic *Alternaria* species: impact in cereals worldwide. Current opinion in food science, 23: 57-63.
43. Udayashankar AC, Chandra NS, Archana B., Anjana G, Niranjana SR, Mortensen CN, Lund OS, Prakash HS (2012). Specific PCR-based detection of *Alternaria helianthi*: the cause of blight and leaf spot in sunflower. Archives of Microbiology, 194: 923–932.
44. Van de Perre E, Jacxsens L, Liu C, Devlieghere F, Meulenaer B (2015). Climate impact on *Alternaria* moulds and their mycotoxins in fresh produce: The case of the tomato chain. Food Research International, 68: 41-46.

45. Van der Westhuizeni GCA, Holtzhausen MA (1980). *Alternaria helianthi* on sunflower in South Africa. Phytophylactica, 12: 49-52.
46. Vergnes MD, Renard ME, Duveiller E, Maraite H (2006). Identification of *Alternaria* spp. on wheat by pathogenicity assays and sequencing. Plant Pathology, 55: 485–493.
47. Waals der var JE, Korsten L, Aveling TAS (2001). A review of early blight of potato. African Plant Protection, 7(2): 91–102.
48. Woudenberg JHC, Groenewald JZ, Binder M, Crous PW (2013). *Alternaria* redefined. Studies in Mycology, 75: 171-212.
49. Woudenberg JHC, Truter M., Groenewald JZ, Crous PW (2014). Large spored *Alternaria* pathogens in section *Porri* disentangled. Studies in Mycology, 79: 1-47.
50. Woudenberg JHC, Seidl MF, Groenewald JZ, de Vries M, Stielow JB, Thomma BPHJ, Crous PW (2015). *Alternaria* section *Alternaria*: Species, *formae speciales* or pathotypes? Studies in mycology, 82: 1–21.
51. Yacoub B (2003). Alternaria leaf spot disease on Cucumber: Susceptibility and control using leaf disk assay. An-Najah University Journal Research, 17(2): 269-279.
52. ***, http://omafra.gov.on.ca/IPM/english/potatoes/diseases-and-disorders/alternaria.html Accessed 09.11.2020
53. ***, https://pestre.ro/blog/bolile-castravetilor/ Accessed 09.11.2020