SUNFLOWER DISEASES RESEARCH PROGRESS AND MANAGEMENT

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ABSTRACT

Sunflower diseases have been and remained a major limiting factor in successful sunflower production in the world. From the history point of view, in last several years new disease agents did not occur, however, new races or pathotypes emerged in some diseases. The exception is *Phomopsis/Diaporthe complex* in which appeared several new species of the genus *Phomopsis*. Broomrape should be added to this, but as it will be discussed in another text, we shall restrict ourselves only to diseases. Many disease agents are present throughout sunflower producing regions and some of them, despite high turnover and migration of seeds in the world remained present in some of them. Their spread is evident just due to seed turnover. Considering all sunflower pathogens, it should be noted that 13 of them are significant to a greater extent for sunflower production, in terms of yield and oil quality reduction, although in the world history of this significant oil crop, much higher number of them have been described. Significant progress has been made in better comparison of certain parasite races in the world and some regions due to new research techniques at molecular level. Good international cooperation in the use of a series of isogenic lines in determination of the intensity of the appearance of certain disease inducing races, above all of downy mildew, rust, *Verticillum* wilting and others has contributed to this. As a new parasite races emerge, pesticides that have remained one of the more significant tools in control of disease agents, in addition to the other control measure evolved resistance. This requires joint effort of researches in plant protection, breeding, and others in the struggle for reduction of losses caused by disease agents. It is, therefore, important to organize periodic surveys that would uncover their exact distribution and harmfulness in certain regions to sunflower crops.

Key words: Sunflower diseases,pathogen identification, host resistance.

INTRODUCTION

Sunflower diseases have been and remained a major limiting factor in successful sunflower production in the world. From the historical point of view, in several last years, new disease agents did not emerge, expect several exceptions. However, “virulent pathotypes”, usually called pathogenic races occurred in some diseases. Many disease agents have been present in the whole sunflower production region in the world, and despite great marketing of seeds in the world, they have persisted in some regions. Their spread is evident, mainly due to seed marketing on a global scale (Gulya et al, 1997).

Diseases are far the most important factor in yield reduction, although they emerge in different intensity per years and growing regions. (Chattopadhyay et al, 2015; Artokhin and Ignatova2013;Vear 2016)For example, in 2015 in the U.S, the most important diseases were sunflower rust, *Phomopsis* and *Rhizopus* head rot (Kandel and Gulya, 2016). Contrary to the period 2001 - 2011 with incidences (occurrence) of *Sclerotinia* head rot, followed by sunflower rust and then *Phomopsis* were the most important in relation to incidence and severity in U.S.

***Plasmopara halstedii* (Farlow) Berlese and Toni – Downy Mildew**.The oldest and sometimes the most devastating disease is downy mildew of sunflower (*Plasmoparahalstedii*) for which in 80s of the last century only two races were known(Viranyi, 2008). Since then the exact ″invasion″ of races has occurred, and nowadays in the world over 38 races are recorded. In regard to Europe, the greatest number of new races, 13 was established in the last decade and previously 14. In other countries, such as Italy and Germany, there are 9 new races. In last decade in Hungary, Italy and Romania 7 new races were established. In the U.S. 21 new races have been registered and in Canada 18. As a great sunflower producer Argentina in last decade established the presence of 5 new races (Viranyi et al, 2015).

In the Czech Republic, Trojanova et al. (2013) reported that downy mildew races 700, 704, 710, 714, 730 and 770 were found in the last decade and there are no new reports about races composition earlier and after. In Hungary, new race 704 was found in 2011 and race 714 was found in 2013 (Ban et al,2014).According to Viranyi (2015), race 700 and 730 are predominant.

Pacureanu (2010) reported that 310 and 710 as new races in Romania. Older ones 100, 300, 330 and 730 have been previously described. Among all races 100 and 300 are predominant. Interesting data is that in Turkey changes of the population has not been established after 2007, and since then, 9 downy mildew races have been recorded. In Italy race 704 (Tossi and Beccare, 2007) has been found in last decade and no more new races.

In Serbia races 100, 700, 730 have been found earlier, and in last decade race 730 has become dominant. Based on latest researches, in Serbia, some new races with a race composition similar as in neighboring countries are to be expected. (Masirević, unpublished). This disease has not been established in Australia.

Seed treatment by fungicides and use of resistant genotypes is widely accepted measure against this oomycete. The problem, in this case, is wide genetic variability of pathogens. It seems that winning combination are resistant hybridsand fungicide seed treatment. This measure has the best perspective, and in contemporary conditions, its duration should be the longest until the discovery of some new indicators. After all, this measure is the most used measure in Europe, Russia, Ukraine and the efficacy of this combination has been proven and downy mildew is not such a big problem.

Genetic resistance is most effective and important crop management manner to control the disease. The situation with confectionary sunflower is very bad because no commercial hybrids are yet available with for downy mildew resistance. Recent studies made in the U.S. are encouraging due to finding of some lines for further selection work that is expected to be finished by the beginning of 2017.

Pathogen virulence observed in all of nine differential lines in the U.S. and also on some additional differential candidates with additional resistance genes indicate that that inclusion of supplementarydifferentials is needed. The identification of new lines with resistance to *P. halstedii* is an important action for breeding resistance.

***Phoma macdonaldi* Boerema– Black Spot.** *Phoma macdonaldi* is present in almost all regions of cultivation but the intensity of infection and impact on yield remained on the level from previous years. Kandel and Gulya (2016) reported that *Phoma* black spot has been the most widely observed disease on sunflower across the all U.S. sunflower production area of the central Great Plains. And this was the case until the first occurrence of the disease in 1980. The reason for not so great damages is prescribed to the source of infection which is in America mainly on the stem surface and it does not penetrate deeper into the vascular tissues. The highest damages occurred in cases when *Phoma* is transmitted by seed or when black spots are on the surface level (Maširević 2014).

This fungi is very interesting because it has not been established in the perfect stadium in new regions expect in previously determined localities in Argentina, Former Yugoslavia and the U.S. New in systematics is that now this fungus is named *Plenodomuslindquisti* (Gruyteret.all, 2012). Narrow crop rotation and reduced tillage are highlighted as important factors in spread of the disease in the southwest parts of France (CETIOM, 2012). Many authors reported that the occurrence of black stem is in positive correlation with the increase in nitrogen fertilization (Dedić and Maširević, unpublished).

Although it is an important disease, in France, as well as in the remaining parts of Europe and in the U.S, specific control measures have not been conducted. The epidemic of this disease is possible to reduce and diminish by the disease escape. The significant and efficient way of the control of the disease is increase of resistance toward *Phomamacdonaldi*. Hybrid resistance is efficient, environmentally friendly and fairly inexpensive for sunflower growers. Some agronomic factors and cultivation methods could contribute to the easiest way of control, i.e. reduction of the disease. In the case of heavier infestation, it can be intervened by fungicides in the case of some important selection material, and some larger treatments of commercial crops have lately become rare. Maybe control of *Phomopsis complex* at the same time controls *Phoma*, also reducing the damage caused by this U.S.agent no.1.

***Phomopsis* Brown Stem Canker (*Diaporthe/Phomopsis spp. complex*).**One of the few fungi that are in expansion and a real renaissance in the emergence of new species is *Phomopsis complex* causer ofbrown gray, i.e. sunflower stem canker.

Phomopsis stem canker has become one of the most yield-limiting diseases worldwide on oilseed sunflower (Mathew et al. 2015b) It was described as *Phomopsis helianthi* in 1980, when *D. helianthi*Munt(syn. *Phomopsis helianthi*) was identified as the U.S.agent no.1, first in Yugoslavia, later in Europe and the rest of the world (Marić et al, 1987). This disease became a limiting factor for sunflower production because it not only causes oilseed yield losses but also caused sunflower oil deterioration (Masirević and Gulya, 1992). Several other new species of *Diaporthe*have been identified as stem pathogens of sunflower. Morphologically and symptom-wise they are almost indistinguishable and thus molecular methods are necessary to speciate the U.S.fungus no.1. A total of ten new *Diaporthe*species have thus been added as sunflower pathogens, including *D. Gulya*Shivas, Thompson and Young, *D. Kongii*Shivas, Thompson andYoung, *D. Kochmanii*Shivas, Thompson and Young, *D. Masirevicii*Shivas, Thompson and Tan, *D. Sackstonii*Shivas, Thompson and Tan (Thompson et al, 2015). Of these, *D. gulyae* is the most aggressive, comparable with *D. helianthi*, and the former occurs in Australia, Canada and in the U.S. (Mathew et al, 2015a; Mathew et al, 2015b). No studies have looked into the *Phomopsis*complex on sunflower in other countries.

*Diaporthe/Phomopsishelianthi*has also been recorded in the U.S. and Argentina, but remains exotic to Australia where other newly described *Diaporthe* species are responsible for damaging stem cankers. However in 2010 in Australia, after a period of sustained wet weather, patches of lodged sunflowers were reported from across the growing regions of New South Wales (NSW) and Queensland (Qld).Three new species, *D. gulyae*, *D. kongii* and *D. kochmanii*, were isolated from infected sunflowers in New South Wales and Queensland.

Thompson et al.(2011) found that some weed hosts are involved in the epidemiology of three species of*D.gulyae*,*D.kochmanii*and *D. kongii*. During experiments in 2014 and 2015, same author and collaborators found alternative hosts of *Diaporthe* species that can cause sunflower stem canker in Australia. Eight novel species were identified based on GCPSR criteria.The following species have been found: *D. charlesworthii*, *D.goulteri*, *D. macintoshii*, *D.middletonii, D. masirevicii, D. miriciaes, D.sackstonii, D. serafiniae*(Thompson et all. 2015).

According to latest findings, *Phomopsis/Diaporthegulyae* became the main agent of *Diaporthe* stem canker in the U.S. and Canada. Indeed, this situation leads to a possible conclusion on ways of such mass occurrence of new *Diaporthe* species in Australia, and at the same time some of these species have become more present in America. CatheU.S.l agents of *Phomopsis* in Argentina that occurred in a large scale in this 2016 have not been sufficiently studied (Huget 2016). Researches accomplished in Australia and some other countries clearly showed that weeds and their remaining after vegetation are actually brown bridge for *Diaporthe*species that can be harbor for propagation of pathogenic, saprobic or endophytic.

This is all comparable with green bridge with alternative green plants, above all weeds that enable *Diaporthe* species to survive easier cropping phases.

Sowing of hybrids with high levels of resistance to *Phomopsis* stem canker (tolerant genotypes)is a good way of reducing stem canker damage (Škorić, 2012).The disease has proved prevalent in Europe and seed companies have incorporated resistance in some hybrids. Some seed companies rate their hybrids for *Phomopsis* resistance. In regions where the disease has been endemic for 20 years, such as Yugoslavia now Serbia (Masirević and Forgić, 2000), in the cases of heavy infections, an erosion of tolerance was observed, but despite this, farmers in areas with a history of the disease should consider the tolerant. In Australia trials studying hybrids of varying maturities comparing quicker and later maturing hybrids showed that plants with the earlier maturing hybrids developed more damaging lesions and lodged more readily than plants with later maturities.

Lower nitrogen fertilization will in turn minimize the possibility of *Phomopsis* infection (Debaekeet et al, 2003). While *D. helianthi* and other sunflower pathogens were thought to be host specific, recent evidence shows they can infect and survive on weeds and other hosts, both on live and dead plants (Thompson, 2015). Rotation will thus be of limited use, but eliminating weeds and wild sunflowers from the field and margins will potentially cut down on inoculum. Burying plant residue, at least 5 cm deep, will fasten plant decomposition and expose *Diaporthe*to biodegradation.Resistance is widely available in oilseed germplasm.

Winter cereals, sorghum and maize are consideredthe least likely hosts, although Thompson et al. (2015) report four species of *Diaporthe*, including the damaging *D. gulyae*, from asymptomatic maize suggesting that endophytic infection may also play a role in survival of *Diaporthe spp*. in cropping situations (Thompson et al, 2011; Thompson et al, 2015).Complete burial of infected plant residue, at least 5 cm deep, is most thoroughly accomplished by plowing and not disking. This ″strategic tillage″ need only be done after an infected crop. In Europe, it has been found that stalks need to be buried deeper than 15 cm to prevent perithecial maturation. In Australia, early stubble burial trials suggest shallow burial of 5-10 cm leads to rapid stubble breakdown perhaps because of the sustained warmer temperatures in that.

Delayed sowing significantly reduces leaf and stem infection and disease severity. The strategy of delayed sowing is needed to synchronize the most susceptible periods (bud formation) with low-rainfall periods.

Weed control -Thus, eliminating weeds and volunteer sunflowers, from field margins as well as sunflower fields will reduce inoculums (Thompson et al, 2015). However, due to lack of detailed information on the weed host range of *Phomopsis* species, a precaution in weed control is necessary for the purpose of limiting the disease build-up on possible weed hosts. Damaging *D. gulyae* has been isolated from multiple weed hosts in Australia including live Noogoora Burr (*Xanthium pungens*), Bathurst Burr (*X. spinosum*), Saffron Thistle (*Carthamus lanatus*) and Common or Sow Thistle (*Sonchus oleraceus*).

Therefore, creating conditions less favorable to the expression of the disease and damage by the pathogen through reduced stem density, and N-fertilization, increased row width, efficient weed control, reduction in water supply and non-limiting K-nutrition is the necessity. Excessive N supply induces opposite effects on the proportion of infected stems. So a combination of strategic trash burial and rotation will be the most effective strategy in limiting the soil inoculum.

Systemic strobilurin compounds are likely to be most effective for control combinations of preventive and curative fungicide produce better control. The best disease control is achieved with fungicides on the base of benomyl applied before symptoms occurrence. However some recommended benzidamidazoles have not been registered in the U.S, and should be applied twice, the first time at the beginning of budding, when the crop is no more than 55-60 cm high on average stage and the second at flowering stage (Deaeke and Estragnat, 2003). Later times treatments, or after the occurrence of symptoms are inefficient. Forecasting systems proved to be very important, for effective and economic fungicide control depends on it. These systems include spore traps and weather monitoring to advice grower when it is necessary to apply fungicides. In regions where *Phomopsis* is normally present, a fungicide treatment at the critical plant height for conventional sprayers (50-70 cm) or following the advice of the official Plant Protection Service is generally recommended even when using tolerant genotypes.

Sclerotinia spp. **–Stalk Rot, Head Rot, Wilt and White.** *Sclerotinia sclerotiorum* (Libert) de Bary (1884); Syn.: *Whetzelinia scleotiorum* (Lib.) Korf & Dumont (1972), *Sclerotinia minör* Jagger; Syn. S. *intremedia* Ramsey (1924) (Kohn, 1979).

S. sclerotiorum is global in distribution on various hosts' climates and is found in everysunflower producing country.Most frequently it can be found in temperate climates.

In the U.S. the pathogen is observed most frequently in northern growing areas. *S. minor* is more frequent in hot, dry climates, and is observed on sunflowers in Argentina, Australia, the Indian subcontinent and EU countries bordering the Mediterranean and Black seas. In the U.S. *S. minor* is reported on sunflower only in California and Texas, and is one-six as prevalent as *S. Sclerotiorum* (Gulya et al, 2012).

Sclerotinia-incited stem and head rots are the leading cause of yield losses to sunflower worldwide. Their impact is not only upon the existing crop, but the contamination of soil with long-lived *Sclerotia*, and their wide host range.

Diseases caused by either of the *Sclerotinia* species are very difficult to control, and the best management is aimed at prevention.

Since infected plants can spread *Sclerotina* via root-to-root contact, lower plant densities will minimize wilt incidence (Nelson et al, 1989). To minimize head infection, anything which decreases foliage, increases air movement, including lower nitrogen fertilization, lower plant densities. Many different biocontrol/cultural practices have been shown to be partially effective at decreasing soil populations of *Sclerotia* and thus minimizing both root and head infections.

Deep plowing, with a moldboard plow to completely invert the soil profile to > 15 cm, will bury *Sclerotia* into an aerobic environment where microbes should degrade the *Sclerotia* (Mueller et al, 2002). However, there is conflicting data on this practice, and most experimental trials suggest that shallow burial leads to faster degradation of *Sclerotia* (Cosić et al, 2012; Subbaroa et al, 1996). Planting dense cover crops of cereal grains will produce them microenvironment conducive to the apothecial formation, and if this crop is tilled under just prior to a susceptible crop, the net effect is to sap the *Sclerotia* of energy/biomass sufficient to produce more apothecia (Mueller et al, 2002).

Crop rotation is of minimal use, since there are so many susceptible crops, but if several years of a non-host monocot (grasses or cereals) are planted, this also would hasten lowering the sclerotial soil population (Mueller et al, 2002). Once eitherstem rot or head rot are observed, there are no curative measures to save those plants. The best option at that point isto removephysically affected plants and dispose of them away from the field, thus minimizing soil contamination with more *Sclerotia*.

Many commercial biocontrol products are available, based on fungi such as *Coniothyrium*, *Gliocladium*, and *Trichoderma*, and bacteria such as *Bacillus*, and these applied as soil drenches immediately following a *Sclerotinia* infestation will hasten degradation of this fungi and shorten the interval between planting another susceptible crop (Radujkov et al, 2015).

Biofumigation by planting *Brassica* cover crops, and tilling them under will release isothiocyanates, which are toxic to a range of fungi (Griffiths et al, 2011).

In certain sunflower hybrids, some progress has been made in developing partial (incomplete) resistance or tolerance to *S. sclerotiorum*. There are no hybrids available with complete resistance to either of the two *Sclerotinia* spp.

Puccinia helianthi **Schwein.–Rust.**Sunflower rust is found worldwide on oilseed, and wild sunflowers (*Helianthus*). During 2013 and 2014 in China sunflower rust was established in many production regions. Using the set of nine international differentials 15 races has been identified. Race 304 was the most prevalent. More virulent races group 700 were less present (Guo et al, 2016).

Since wild sunflower is also a host for rust, removal of any wild sunflower in the vicinity will minimize the production of inoculum. In the future, the problem of rust would probably be greater due to the growth of confectionary sunflower, more susceptible to rust agents and a higher number of races. In Europe situation is under control, for there are not many races established in the U.S. and Canada, and therefore, quarantine measures should be especially followed (Acevedo et al, 2011).

As with many other diseases, genetic resistance is available within oilseed germplasm and this has been obtained from many different annual and perennial *Helianthus* species (Gulya and Brothers 2000). Resistance is specific in order that resistance iseffective. Breeders must know which races are present in the area of interest and use the appropriate single, dominant genes (Gulya and Markell, 2009).Growing a rust resistant hybrid is an important management tool. However, new races of the pathogen can develop and overcome genetic resistance. Wild sunflowers can be ″rust reservoirs″ and provide spores to infect neighboring fields of cultivated sunflower. The presence of early spore stages on wild sunflower, allows more infection cycles to take place. This creates a greater yield loss potential. In addition, sexual recombination occurs when the pathogen completes its life cycle, which enables new races to overcome available resistance. Therefore, removal of wild sunflower populations around fields is strongly recommended. Also, the remaining of infected sunflower by rust must be deeply ploughed and in such a manner destroy inoculum for the following crop, and especially if it is confectionary sunflower.

Fungicides are the main tool for managing rust. Many newer systemic fungicides are effective as both protectants and eradicants against rust (Friskop et al, 2014; Friskop et al, 2015). The timing of fungicide applications is of more impact than the type of fungicide used (Mueller et al, 2004). It is known that products Tebuconazole, Pyraclostrobin and Azoxystrobin, will reduce rust. a fungicide application is most likely economical when average disease severity reaches 1 % on the upper four, fully expanded leaves prior to during bloom. Later applications have not been proven to impact yield positively. High clearance tractors could be used in the control of many diseases that can be combined with rust control (Markell, 2016).

***Alternaria spp.*– Leaf Spot and Blight.** Alternaria leaf blight affects sunflower in many regions of the world. When looking at the whole sunflower growing region it is one of themajor defoliating pathogens in warm, humid climates. There are no reports on the occurrence of new species of Alternaria genus. It means that damages and the intensity of the phenomena are at a level of preceding years and previously published papers.

Symptoms of many *Alternaria* species are similar; making field identification almost impossible.Conidial morphology combined with the genetic analysis is the only sure means to delineate species.

Alternaria helianthi is the primary U.S.agent no.1 and most widespread, also there are eight other species reported on sunflower. Most of them are specific for sunflower (Allen et al, 1983a, 1983b, 1983c; Wu and Wu, 2003).

Removal of wild and volunteer sunflowers, removal or incorporation in the soil of previous sunflower residues, will all reduce disease.

Most growers rely on multiple applications of fungicides containing chlorothalonil, iprodione, porcymidone, or vinclozolin. In the world, protection is carried out according to need in selection material and in cases of extremely convenient weather conditions for disease occurrence. Disease resistance has been found.

Taking into account tendency of soil tillage, i.e. no tillage or minimum tillage, it leads to the fact that many parasites remain on the surface as dry - desiccated or in infected plant residues. They are truly brown bridges for many sunflower parasites. This primarily refers to Argentina, the U.S, part of France, Australia and many other countries. Increased problems in sunflower arise just in such situations. Deep tillage and incorporation of plant residues into deeper layers, and not leaving them on the soil surface eliminates infection pressure of many parasites. In this process, it is most important for *Diaporthe complex*, *Scletotinia*,*Phoma*, *Plasmopara* and some others.

Crop rotation as a system of a combat with diseases does not have such significance if no tillage technology, i.e. crop cultivation is performed.

Weed control - The same situation is with weeds that should be controlled for they are reservoirs for many disease agents including viruses, and therefore, they are to be eliminated from sunflower crops. Wild sunflower plants should be added to this, for wild plants are in fact weedy plants for all cultivated crops, and should be eliminated and destroyed as they often serve to parasites for crossing over and as one kind of a green bridge.

Use of tractors and sprayers with high clearance for other agricultural cultures enables their application for treatment of sunflower crops against diseases. This is a way to obtain particularly high yields, especially in confectionary sunflower type that has a higher price and can serve as a place for propagation of certain parasites because it is generally less resistant to many parasites.

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