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RESEARCH PERSPECTIVES ON *Phymatotrichopsis omnivora* AND THE DISEASE IT CAUSES*

PERSPECTIVAS DE LA INVESTIGACIÓN EN *Phymatotrichopsis omnivora* Y LA ENFERMEDAD QUE CAUSA

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RESUMEN

Phymatotrichopsis omnivora continúa siendo un importante patógeno de plantas. El hongo causa pérdidas económicas por millones de dólares en el norte de México y sur de los Estados Unidos de América. Pese a ello, en años recientes la investigación sobre el tema ha sido escasa. *P. omnivora* es un hongo que habita en el suelo y tiene una amplia gama de plantas hospedantes que suman más de 2000 especies, además de poseer una gran capacidad para sobrevivir en el suelo por más de 10 años. Los análisis sobre este hongo podrían ayudar a reducir el efecto negativo sobre la productividad de los cultivos y ayudan al manejo apropiado de otras enfermedades causadas por hongos. En este ensayo se discuten los resultados de algunas investigaciones realizadas hasta la fecha sobre *Phymatotrichopsis omnivora* y se proponen algunas líneas de investigación a futuro.

Palabras clave: Hongos fitopatógenos en suelo, hongos del suelo, pudrición texana.

ABSTRACT

Phymatotrichopsis omnivora continues to be an important plant pathogen. The diseases caused by this fungus result in economic losses reaching millions dollars in northern Mexico and southern United States of America. However, limited research has been done about this pathogen in recent years. *P. omnivora* is a soil-borne fungus with a host range of more than 2000 plant species, and can survive in soil for more than 10 years. Research on this fungus and the diseases it causes would help to reduce the negative impact on crop productivity and to improve the management of other diseases caused by fungi. In this work, the results of some research of *P. omnivora* are discussed, and future lines of research are proposed.

Key words: Soil-borne fungal plant pathogens, soil fungi, cotton root rot.

INTRODUCTION

The first monograph of *Phymatotrichum omnivorum* Dugg was published in 1973 (Streets and Bloss, 1973). That publication contains a review and discussion of the research initiated since 1888, when the disease was first reported. In 1978, the research related to the ecology of this pathogen was reviewed (Lyda, 1978). More, the fungus was renamed as *Phymatotrichopsis omnivora* (Dugg.) Hennebert, and in 2003, this disease was the subject of an entire Symposium (Pan American Plant Disease Conference South Padre Island, Texas, USA. April 6-10). *Phymatotrichopsis*

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omnivora attacks thousands of plant species and is the causal agent of the disease known in Mexico as "Pudrición Texana", and in the United States as "Cotton Root Rot". Until the 60's, in The United States of America, *P. omnivora* was considered as the fungus with the widest range of host plants, and among the reports of different diseases attacking crops, most of them were due to *P. omnivora* (Kommedahl and Windels, 1979). This pathogen attacks agricultural and forest crops, both native and introduced to several regions of The United States of America and Mexico (Cook and White, 1977; Medina y Lagarda, 1979). The fungus attacks weeds as well as agricultural crops in a wide range of soils (Streets and Bloss, 1973; Percy, 1983) and it is an endemic disease in southern United States of America and northern Mexico (Streets and Bloss, 1973). It has been reported that the presence of this pathogen is a limiting factor for the commercial explotation of certain species, such as pistachio and alfalfa, with high production potential in some regions of Coahuila and Texas, respectively (Medina y Lagarda, 1979, Prostko *et al*., 1998). In 1973, it was estimated that the disease caused losses worth 100 million US dollars in Texas alone (Streets and Bloss, 1973). Even now, The United States of America, the disease causes causing losses of millions of dollars (personal communication Dr. Amador). In La Laguna region, Mexico, estimated losses reach up 3% of death and 9% affected pecan trees (*Carya illinoensi*s (Wagenho) K. since 1979 (Tovar y Herrera, 1979).

In 1998 La Laguna, Coahuila region Mexico, approximately one million dollars of annual losses were estimated due only to the reduction of nut yield in affected pecan trees (Samaniego *et al*., 1998). Death tree replanting and infested tree treatment cost adds up to the total losses (Samaniego *et al*., 2002; Samaniego y Herrera, 2003). Currently estimations indicate that there could be about 350 000 pecan trees infected with *Phymatotrichopsis omnivora* in northern Mexico (Samaniego-Gaxiola, unpublished results).

The pathogen has the capability to adapt to a wide range of environmental conditions. The sclerotia and strands of the fungus can survive, reproduce and attack plants in a wide range of soil conditions including: temperature, moisture, organic matter, pH, texture, salinity, and O_2 and CO_2 concentrations (Taubenhaus *et al*., 1931; Lyda and Burnett, 1970; Lyda and Burnett, 1971; Lyda and Burnett, 1971; Wheeler and Hine, 1972; Streets and Bloss, 1973; Alderman and Hine, 1982; Mueller *at al*., 1983; Percy, 1983; Borunda y Herrera 1984; Medina, 1984; Rush *et al*., 1984; Rush, *et al*., 1984; Stapper *et al*., 1984; Galván, 1986; White amd Kenerley, 1986; Smith and Hallmark, 1987; Samaniego *et al*., 1988; Sameniego *et al*., 1989; Kenerley and Jeger, 1990; Pérez *et al*., 1991; Samaniego, 1991; Samaniego, 1992; Samaniego y Rivera, 1992; Samaniego, 1994; Matocha and Hopper, 1995). Sclerotia have been found at various depths, sometimes deeper than two meters and it is known that can survive more than ten years in the soil.

Cotton plants are susceptible to the attack of the fungus 60 or more days after planting (Rush *et al*., 1984). In young pecan trees, the incidence and severity of the disease is higher than in older trees (Galván, 1986, Herrera y Samaniego, 2002). There is evidence that sclerotia can survive and reproduce in certain unsusceptible plants (Rush *et al*., 1984).

So far, no fully successful control methods have been developed based on chemical (Hine *et al*., 1969; Lyda and Burnett, 1970; Perches y López, 1971; Streets and Bloss, 1973; Herrera, 1974; Herrera, 1975; Valle, 1977; Rush an Lyda, 1982; Rush, 1984; Galván, 1985; Galván, 1986; Whitson and Hine, 1986; Olsen *et al*., 1988; Galván, 1990, Herrera y Samaniego, 2002), biological (Lazo *et al*., 1983; Perusquía *et al*., 1986; Cook *et al*., 1987; Samaniego *et al*., 1989; Pérez *et al*., 1991; Yuan and Crawford, 1995), and cultural practices (Chavez *et al*., 1976; Bell, 1989; Herrera, 1989; Herrera *et al*., 1989; Rush and Gerik, 1989). Even the breeding of resistant varieties of cotton (Bird *et al*., 1984; Percy and Rush, 1985) had failed to yield satisfactory results. Therefore, so far the best recommendation is to avoid susceptible crops in areas where the disease has caused significant losses in the past (Samaniego *et al*., 1998).

As stated, of this paper is to discuss current research perspectives and propose future lines of work aimed at a better understanding of the behavior of the fungus. Moreover, it is emphasized that the generation of basic knowledge will be helpful to understand the biology of other fungi, particularly those with sclerotia that inhabit the soil under a wide range of plant hosts such as the species of *Macrophomina*, *Sclerotium*, *Rhizoctonia* and *Verticillium*, and can contribute to the design of improved methods for the control of soil-born pathogens.

DISCUSSION

Genetics

There is a limited amount of published information about the genetics of *P. omnivora* (Thorn, 2000; Lyon and Lopez, 2000). The sexual stage of the fungus is not well known, neither is the precise number of species, races or pathogenic variants. It is essential to achieve a basic genetic knowledge of the fungus in order to identify pathogenic differences. This would allow future research to demarcate high and low risk areas to grow crops with different degree of susceptibility. Also it would help to select tolerant or resistant cultivars at least to the less pathogenic forms of the fungus. In addition, a deeper genetic knowledge would facilitate the understanding of the soil suppressive factors to some pathogenic variants of *P. omnivora*.

Biology

More precise understanding of the effect of soil moisture on disease prevalence is needed. Under laboratory conditions, sclerotia are formed in smaller quantities in soil subjected to wet and dry cycles, compared to continuously wet soil or soil that dries up slowly (Kenerley and Jeger, 1990). Soil wetting and drying cycles are known to influence the survival of fungi that produce sclerotia; several cycles accelerate the loss of viability and break fungistasis of the soil, which prevents germination of sclerotia. (Coley-Smith, 1979). When some fungi that produce sclerotia are subjected to several wet and dry soil cycles, they accelerate the loss of reserves (excrete), then lose weight, and finally die. The soil microorganisms mineralize most organic matter, and they increase its activity when dry soil is moistened (Birh, 1958). It is imperative to study the survival of the mycelium and strands of the fungus in soils subjected to cycles of wetting and drying throughout the year. This would help to explain some apparently contradictory results. For example, some studies report evidence that the disease is less frequent in soils with higher water retention capacity (Smith and Hallmark, 1987), whereas other studies found that the disease was more prevalent in soils with higher moisture content due to irrigation or rainfall (Jeger and Lyda, 1984). Frequent watering or better water holding capacity in soil seems not to favor the expression of symptoms of the disease in some crops (Medina y Lagarda, 1979; Medina, 1984; Medina y Aguilar, 1985; Galván, 1986; Smith and Hallmark, 1987; Samaniego *et al*., 2001).

Do all soils have the same affinity towards *P. omnivora*?. It is not very likely; for instance, in a pecan orchard in Tierra Blanca, Coahuila, Mexico, with more than 2000 trees, (some of them more than 50 years old), the disease attack had been restricted to 35 trees in the last 15 years. In soil samples from that orchard there were recovered thousands of unviable sclerotia, all invaded by *Trichoderma* spp. (Chew *et al*., 2001). In La Laguna, Coahuila, Mexico, there are some pecan orchards with low incidence of the disease, one of them has only three pecan trees with symptoms of the disease out of 5000 (unpublished data). It is also known that orchards counting of 1000 to 5000 trees without any single tree showing symptoms (Samaniego *et al*., 1998; Samaniego *et al*., 1999).

Soil microecology

This is an important and promising research line to study the factors associated with the ability of other microorganisms to suppress *P. omnivora*. Although promising, it is expected that this research line will face major challenges because of the absence of methods to evaluate the suppressive factors in the soil.

There is insufficient information on the effects that other soil microorganisms may have on the sclerotia, strands, and hyphae of *P. omnivora*, especially those microorganisms that increase in population after incorporating organic amendments in the soil. Streets and Bloss (Streets and Bloss, 1973) wrote "Several theories have been advanced for the marked reduction of *Phymatotrichopsis* root rot in cotton after incorporation of green manures in infected soil. These are: (i) Organic acids from decomposing manure may increase acidity of the soil, rendering it less favorable for the fungus, (ii) evolution of ammonia and other toxic substances may have an inhibitory effect on the fungus, (iii) new roots may be stimulated by nutriments from the amendments and (iv) increase in populations of antagonic microorganism.

The lack of clarity on the role that soil microorganisms play on *P. omnivora* makes it difficult to explain results of some research reports. It has been reported a decrease of the disease upon incorporating crop residues (Chavez *et al*., 1976), in contrast, the opposite has been reported (Rush and Gerik, 1989).

Future research should focus on distinguishing between the effects that added organic amendments have on root development and the microorganisms, particularly in perennial crops such as pecan. It is also important to determine the role that the metabolic activity of the soil microorganisms play to induce lower pathogenic activity, due possibly to the decrease in the viability of the mycelium, strands or sclerotia of *Phymatotrichopsis omnivora*. It is possible that soil conditions improve upon adding organic amendments as green manure, and favor the recovery and proliferation of roots. The antagonistic effects of the indigenous microorganisms of the soil against *P. omnivora* have been studied *in vitro* and *in situ* (Perusquía *et al*., 1986; Cook *et al*., 1987; Samaniego *et al*., 1989; Samaniego, 1991); however, there are no results that enable satisfactory control of the disease.

Eaton and Rigler (1946), emphasized that maize root is immune to *Phymatotrichopsis*. Moreover, their findings indicated that the microorganisms were associated with the roots which are known to excrete abundant carbohydrates, but little is known of the mechanism of *Phymatotrichopsis* and other soil born plant fungi to tolerate, escape or resist to antagonic microorganisms present in the fungus-infected roots, the rhizosphere, and in the (Henis and Chet, 1968; Lyda, 1978; Balis and Kouyeas, 1979; Filonow and Lockwood, 1979; Griffin and Roth, 1979; Henis, 1979; Lockwood, 1979; Tsao and Zentmyer, 1979; Henis and Papavizas, 1983; Hyakurnachi *et al*., 1987; Hyakurnachi and Lockwood, 1989; Mondal and Hyakurnachi; 1998) modified fungistasis or biostasis of the soil, so that the microorganisms will become antagonic to soil born plant fungi including *P. omnivora*: that is to say, it will be induced the proliferation of millions of indigenous soil microorganism or their toxic metabolites and the defenses that have *Phymatotrichopsis* will be broken (Samaniego, 1991; Samaniego, 1992, Samaniego, 1994).

P. omnivora and other fungi, seems to have a latency, the kind that can be broken by biological, physical and chemical means (Chet *et al*., 1977; Coley-Smith, 1979; Griffin and Roth, 1979; Samaniego y Rivera, 1992; Samaniego y Herrera, 2001): there is evidence that upon breaking of the latency of some fungi sclerotia, its metabolic activity increase causing a net loss of reserves and finally the fungus loses its viability (Henis and Papavizas, 1983; Hyakurnachi *et al*., 1987; Hyakurnachi and Lockwood, 1989; Samaniego, 1994; Mondal and Hyakurnachi, 1998). Also upon losing the latency, the sclerotia can germinate excreting carbohydrates, something that is recognized by microorganism of the soil, including *Trichoderma spp*. (Henis, 1979; Samaniego y Rivera, 1992). All this outlines the need to investigate towards the development of practical field treatments against soil born plant fungi: (i) mechanism that *Phymatotrichopsis* has to avoid to be detected and attack by indigenous microorganisms of the soil, (ii) how to break biostasis of the soil, in order to increase the metabolic activity of the indigenous micro biota and, (iii) how to make susceptible the strands, sclerotia, and mycelium to the attack of the micro biota already increased in the soil.

It is evident that exists spontaneous recovery of some crops attacked by pathogens (Streets and Bloss, 1973; Tarango y Herrera, 1997; Samaniego *et al.*, 2003) and fungus, without showing visual symptoms of the disease (Streets and Bloss, 1973; Rush, *et al*., 1984; Watson *et al*., 2000). Also, had been reported recolonization of the soil by alfalfa plants where *Phymatotrichopsis* had previously killed those plants (Streets and Bloss, 1973).

These phenomena have been reported and they have been explained in function of the native micro biota and pathogens population (Baker and Cook, 1974). Nevertheless, it continues to be unknown under what natural micro ecological conditions the soil micro biota restricts the development of the fungus. Therefore, it is relevant to investigate these recovery mechanisms. The knowledge of the micro ecological conditions that brings antagonic effect to native soil micro biota against strands and sclerotia of *P. omnivora* would permit to manipulate soil and crops to favor or induce the elimination of the inoculums.

There are strong differences within and between regions in terms of severity and incidence of the disease. For example, in several regions of Mexico there are different degrees of incidence: At La Laguna region Coahuila, there are approximately 10% of affected pecan trees: in the north of Coahuila, 15%; in Chihuahua 5% and in Nuevo Leon, less than 1% (Samaniego-Gaxiola, unpublished data). Knowledge about the differences in quantities and location of the inoculum of the fungi have helped to explain the behavior of the disease in annual crops (Lyda and Burnett, 1970; Rush *et al*., 1984; Koch *et al*., 1987; Kenerly and Jeger, 1990), but not in perennial crops. Also, there are differences in the methodology to isolate the fungi; in Mexico, it was necessary to develop a specific culture media for the satisfactory reproduction of the sclerotia (Castrejón, 1985). In addition, it has been noted that the quantity of roots killed by the fungi is related to the severity of the symptoms observed in the canopy of infected pecan trees (Herrera y Santamaría, 1991). When the fungus reaches and kills the main root then the pecan dies; nevertheless, adult pecan trees without principal root but still alive had been observed (not published information). This suggests that soil has a strong influence on root development and consequently, on the symptoms expression of the disease in pecan trees. Also it is possible that a significant genetic variation among the pecan trees brings in certain tolerance to the attack of the fungus (Stein, 2001).

Crop management

Several research results indicate that soil characteristics and crop management are related to the symptoms of cotton root rot and pecan nut yield (Galván, 1985, Medina y Aguilar, 1985; Smith and Hallmark, 1987; Matocha and Hopper, 1995; Samaniego *et al*., 2001; Samaniego *et al*., 2002). In a previous survey, the influence of plant separation in relation to the dissemination and dispersion rate of the disease and the number of death plants in a cotton field was studied (Koch *et al*., 1987). In addition, the position of the sclerotia in the soil, relative to the plant, also holds a relationship with the time of plant infection and the number of dead plants (Rush *et al*., 1984). In the case of orchards, the distance between trees could be a factor that affects the symptoms, expression and dissemination of the disease. In sites with an outstanding expression of the disease, physical barriers have not prevented the advance of the pathogen. Consequently, the usefulness of the research on the effect of plant-to-plant distance in perennial crops to avoid the dissemination of *P. omnivora* is evident.

Abundant sclerotia can be found at 90 cm of soil depth, that makes it difficult to manage the disease (Alderman and Hine, 1982; Borunda y Herrera, 1984; Streets and Bloss, 1973). The above justifies the economic evaluation of the use of fungicides in an integrated management program. Street and Bloss (Streets and Bloss, 1973) reported: "Increase knowledge of soil-root ecology and competitive relationships between soil micro biota and the mechanisms fungistasis, is needed". Nevertheless, there are few research reports on this topic. Flooding induces a change in soil potential redox (negative potential), (Ponnamperuma, 1972; Alexander, 1980; Perotti *et al*., 2000). The negative soil redox potentials in flooded soils seems to be associated with the dramatic decrease of the viability of soil-borne plant pathogens, such as *Fusarium*, *Phymatotrichopsis*, *Pyrenochaeta*, *Sclerotium*, *Verticillium*, and probably other fungi (Taubenhaus *et al*., 1931; Stover, 1955; Menzies, 1962; Watson, 1964; Pullman and DeVay, 1982; White and Kenerly, 1986; Hyakurnachi *et al*., 1987; Hyakurnachi and Lockwood, 1989; Crowe and Debons, 1992; Samaniego, 1992; Samaniego, 1994; Mondal and Hyakumachi, 1998; Blok *et al*., 2001). Research on soil potential redox and its effect on viability loss of fungi are necessary.

There is scarce information about the integrated management of *P. omnivora* in agricultural crops. Some pages in the www provide a variety of management tools for the control of this disease (Valle, 1997), but they do not propose an integrated management scheme. Recently, the economic feasibility of some treatments for the control of disease in pecan trees was evaluated at La Laguna, Mexico (Samaniego y Herrera, 2001). Simple practices as tree pruning were economically feasible. In the future, it would be desirable to integrate crop-specific management practices, which must be justified upon: economic analysis, disease incidence and severity, as well as implementation viability of the practices.

CONCLUSION

It would be desirable to exchange information about the disease and the fungus among researchers from different regions and countries. This would lead to a better understanding of the pathogen-host- environment relationship. There is an overall agreement among researchers about some aspects of *P. omnivora*: (i) In some susceptible crops at certain regions, the attack becomes devastating (Streets and Bloss, 1973), (ii) *P. omnivora* is not a disease that can be controlled in susceptible and very susceptible crops, (iii) it is recommended not to grow susceptible crops in soils with previous strong expression of the disease (Salomon *et al*.,) and (iv) the disease causes important economic losses (Wheeler and Hine, 1972; Streets and Bloss, 1973; Herrera y Samaniego, 2002). However, much remains to be learned of this pathogen and the disease it causes continues to be a priority and deserves continuous research. Back in 1888, researchers preceded us with surveys of the cotton root rot. They shared their knowledge, and now we should share our experiences, and develop joining efforts against this disease that is widely distributed in the southern United States of America and northern Mexico.

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