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Bibliographic review

Powdery mildew in pumpkin: identification and management under the conditions of Tehuacán, Puebla, México

El mildiu polvoriento en calabaza: identificación y manejo bajo las condiciones de Tehuacán, México

Jorge Francisco León-de La Rocha[1*], Yusimy Reyes-Duque[2], Ernesto Días-López[1], Nazario Francisco-Francisco[1], Juan Antonio Juárez-Cortez[1]

[1]Universidad Tecnológica de Tehuacán (UTT), prolongación de la 1 no. 1101, San Pablo Tepetzingo, Tehuacán, Puebla, México, C.P. 75859

[2]Universidad Agraria de La Habana "Fructuoso Rodríguez Pérez", (UNAH), carretera a Tapaste y Autopista Nacional, San José de las Lajas, Mayabeque, Cuba, CP 32 700

ABSTRACT: The pumpkin (*Cucurbita pepo* L.), of American origin, represents one of the most used species today. Mexico is an important center of origin, domestication and diversification of the genus *Cucurbita*. Pumpkin production in Mexico places it in sixth place. This crop has as main limitation for its production the incidence of different harmful organisms, where foliar diseases of fungal origin are the most important, where powdery mildew stands out with economic losses of 50 to 100 %. For proper management, an important element is the correct identification of the causal agent, since two different genera and species are associated with the disease. Worldwide, the identified species that infect the Cucurbitaceae family are *Podosphaera fusca* (Fr.) Braun &. Shishkoff (syn.: Sphaerotheca fusca (Fr), *Podosphaera xanthii* (Castagne) U. Braun & Shishkoff) or *Golovinomyces cichoracearum* (DC.) V.P. Heluta. The control of the pathogen has been carried out mainly with the use of fungicides. However, its use causes negative effects on the biodiversity of agroecosystems, which can cause irreversible damage to the environment, increase production costs and enhance *fungus resistance*. Hence the importance of seeking new alternatives for its management, such as the use of oils, salts and biological control agents. This paper presents a review related to the updated identification of pumpkin powdery mildew, as well as trends in its management.

Key words: control methods, biologic control, Podosphaera xanthii, oils.

RESUMEN: La calabaza (*Cucurbita pepo L.*), de origen americano, es una de las especies más utilizadas en la actualidad. México es un importante centro de origen, domesticación y diversificación del género *Cucurbita*. La producción de calabaza en México lo coloca en el sexto lugar, a nivel mundial. Este cultivo tiene como principal limitante para su producción la incidencia de diferentes organismos nocivos, donde las enfermedades foliares de origen fungoso resultan las más importantes, y se destaca el mildiu polvoriento con pérdidas económicas de 50 a 100 %. Para un manejo adecuado, un elemento importante es la correcta identificación del agente causal, ya que a la enfermedad están asociados dos géneros y especies diferentes. A nivel mundial, las especies identificados que infectan a la familia Cucurbitaceae son *Podosphaera fusca* (Fr.) Braun &. Shishkoff (sin. *Sphaerotheca fusca* (Fr), *Podosphaera xanthii* (Castagne) U. Braun & Shishkoff) o *Golovinomyces cichoracearum (*DC.) V.P. Heluta. El control del patógeno se ha realizado, mayormente, con el uso de fungicidas. Sin embargo, su empleo causa efectos negativos sobre la biodiversidad de los agroecosistemas, lo cual llega a provocar daños irreversibles sobre el medio ambiente, incrementan los costos de producción y favorecen la fungo resistencia. De ahí, la importancia de buscar nuevas alternativas para su manejo, como es el uso de aceites, sales y agentes

*Author for correspondence: jfrleeon@gmail.com

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de control biológico. En este trabajo se presenta una revisión bibliográfica relacionada con la actualización de la identificación de las cenicillas en calabaza, así como las tendencias actuales para su manejo.

Palabras clave: aceites, control biológico, métodos de control, Podosphaera xanthii.

INTRODUCTION

Pumpkin cultivation. Origin and generalities

Pumpkin (*Cucurbita pepo* L.), of American origin, is one of the most widely used species today (1). Mexico is an important center of origin, domestication and diversification of the *Cucurbita* genus (2). Records indicate that seeds were found in the Guilá Naquitz cave, in Oaxaca, between 6.000 and 8.000 BC. In the Romero and Valenzuela caves, in Tamaulipas, seeds of *C. pepo* corresponding to 2 000 B.C were also found. In Tehuacán, Puebla, a region from which much of the information on the domestication of plants in Mesoamerica comes from, remains corresponding to 5 200 B.C were found (3).

Within the gourd group, the genus *Cucurbita* is one of the most abundant, with 27 species. The species of this genus form the group known as pumpkins, of which five have been domesticated: *C. pepo* (Indian pumpkin), *Cucurbita ficifolia* Bouché (chilacayote), *Cucurbita moschata* (Duchesne ex Lam.) Duchesne ex Poiret (castilla pumpkin); *Cucurbita maxima* Duchesne ex Lam (kabosha pumpkin) and *Cucurbita argyrosperma* Huber (pipiana pumpkin) (4).

Pumpkin production in Mexico places it in sixth place. Production is mainly destined for the international markets of Japan, Canada and the United States. Therefore, in recent years, production is increasing, where more than 18 thousand hectares are cultivated and a production of 550 409.74 tons per year is obtained, where Sonora stands out, followed by Puebla, Sinaloa, Tlaxcala, Hidalgo and Morelos. In Puebla, in 2019, 1.500 hectares were planted and 21.911 tons were harvested, which represents a source of employment and economic for the regions where it is grown (5).

Pumpkin is a warm climate vegetable that does not tolerate frost, the temperature for germination must be higher than 15 °C, being the optimal range of 22 to 25 °C; the temperature for its development has a range of 18 to 35 °C, with cool temperatures and short days there is greater formation of female flowers. It develops in any type of soil, preferably deep soils rich in organic matter. It is classified as a vegetable moderately tolerant to acidity, its optimum pH ranges from 5.5 to 6.8 (6).

Powdery mildew, general aspects. Causal agent

Powdery mildew, also known as powdery mildew, is caused by a group of diverse fungi, complex in their form, reproductive structures, host range and geographic distribution (7). They belong to the family Erysiphaceae of the order Erysiphales; they are obligate parasites (biotrophs) and parasitize about 9838 species of plants belonging to angiosperms (8). They occur on succulent tissue of the host in shady and cool environments. The life of the conidia is short and they favor enhance levels of relative humidity, but they are not favored by heavy rain and immersion in water (9,10).

Powdery mildew is one of the most important diseases for cucurbit crops (11). Powdery mildew of cucurbits is one of the main diseases affecting cucurbits worldwide, with serious losses, both in field and greenhouse conditions (12).

Worldwide, the species identified as infecting the Cucurbitaceae family are *Podosphaera fusca* (Fr.) Braun &. Shishkoff (syn.: *Sphaerotheca fusca* (Fr), Podosphaera xanthii (Castagne) U. Braun & Shishkoff) or *Golovinomyces cichoracearum* (DC.) V.P. Heluta (13). In congruence with this, (14), in the Culiacan, Valley of Sinaloa, Mexico, identified *G. cichoracearum* as the causal agent of cucurbit ash by observing only the asexual characteristics. However, years later, through the use of molecular techniques, only *P. xanthii* was corroborated as the causal agent of powdery mildew in cucurbits in Mexico (15,16). In this sense, in Tehuacán, Puebla, this pathogen was recently confirmed as the causal agent of powdery mildew in pumpkin (17).

Symptomatology

The development of the disease requires a compatible interaction between the pathogen and the host plant. This interaction depends on conidial arrival, adherence, recognition, penetration, proliferation, nutrition and suppression of host defenses (18).

Symptoms are easy to distinguish due to the abundant production of conidia with an ashy appearance, characteristic by which its common name was originated, as already mentioned (19). Initial symptoms are observed whitish colored and as it progresses they acquire a yellow-creamy coloration which can cover the surface of the upper and lower side of leaves, petioles, stems, buds and flowers (20,21), rarely fruits can be affected (15).

The incidence of the disease is favored by a warm and dry climate, conditions that favor positively the colonization, sporulation and dispersion of the pathogen (9). Average temperatures for powdery mildew development range between 20 and 27 ºC, although infection can occur between 10 and 32 ºC. The optimum relative humidity for germination of conidia is 100 %, and as the relative humidity decreases, the germination rate also decreases (22). Powdery mildew conidia can germinate at values below 20 % relative humidity and can even occur in the absence of water (23). The dissemination of the conidia is mainly through the wind, with the slightest movement of air the spores are removed and dispersed towards crops and when falling on the leaves they can germinate, penetrate the epidermis and cause new infections (13).

Disease behavior

The behavior of a disease in the field is related to different factors, such as the sowing dates of the crops, since this factor can influence either increasing or decreasing the percentages of incidence and severity of the disease or sometimes behaving in a similar way (24). The behavior of a disease in relation to sowing dates is mainly determined by environmental conditions, which may or may not favor the appearance of a disease. Prolonged rainfall can have a negative effect on the severity and incidence of foliar pathogens, in the case of ash because it inhibits the germination of conidia (25). In this sense, in the region of Tehuacán, Puebla, it was found that the severity of the causal agent of powdery mildew is favored in late sowings from May to July, but not when sowing begins in February-April (26).

Management alternatives for powdery mildew

In pest management, it is important to integrate several measures, since no single practice is totally adequate; the integration of these measures contributes to successful management. In this integration we can contemplate chemical, cultural and biological control practices, among others (11).

Chemical control

Chemical control of powdery mildew is the most widely used worldwide (27). There are several types of contact and systemic fungicides that show effectiveness against the disease. In Mexico, fungicides such as tebuconazole and azoxystrobin have been evaluated and have been able to inhibit mycelial development (28). Chemical control as an alternative for foliar diseases is undoubtedly efficient; however, its use has a negative impact on the biodiversity of agroecosystems, which can cause irreversible damage to the environment (27).

Biological control

Biological control is presented as an alternative in the management of diseases caused mainly by soil-dwelling microorganisms (29). Saprophytic bacteria, yeasts and filamentous fungi are common inhabitants of plant surfaces. They possess several mechanisms by which they can alter the growth of pathogens and reduce the diseases they cause (30).

For the treatment of diseases affecting the aerial part of plants, biocontrol agents need specific environmental conditions (31).

Bacillus: One of the entomopathogens used for powdery mildew control is the bacterium *Bacillus subtilis* (Ehrenberg) Cohn 1872 (32). Strains of *B. subtilis* have been described as capable of arresting the growth of *P. xanthii* by producing iturin A or bacillomycin, fengycin and surfactin, of which strain UMAF6639 is a very promising biological control agent as an antagonist and inducer of systemic resistance in plants infected by powdery mildew in cucurbits (31).

Trichoderma: Among the most important antagonistic fungi for disease management, *Trichoderma Persoon* ex Gray stands out, however, its use for many years was directed mainly to soil pathogens and to a lesser extent on foliar diseases. However, in the last years increased the studies in this sense (11) For powdery mildew are relevant the results obtained with *Trichoderma viride* Pers ex S. F Gray and *Trichoderma harzianum* Rifai, with which reference is made to an inhibition of the conidial germination superior to 70 % (33). Among some commercial products, Trichodex® is a preparation based on spores of the fungus *T. harzianum* T-39, which acts causing a competitive displacement for nutrients and space on plant surfaces (11). Some authors (34) reported an efficacy of *T. harzianum* (*Tricho D*) on downy mildew in cucumber (*Cucumis sativus* L.) of 84.24 % when using a dose of 500 g ha^{-1}.

***Lecanicillium*:** Another fungus used is *L. lecanii*, with which relevant results have been obtained. In this regard, Jeong et al. (35) mentioned that when applying *Lecanicillium lecanii* (Zimm.) Zare and W. Gamssoon highly infected leaves, 11 and 15 days after inoculation with *Sphaerotheca fuliginea* (Schltdl.) Pollacci, the application suppressed the subsequent production of spores in comparison with controls.

***Ampelomyces*:** *Ampelomyces quisqualis* Cesati ex Schlecht (Strain AQ-10) is considered the most specific biological control agent for counteracting powdery mildew fungi on cucurbits (36). One of the best known mechanisms of fungal antagonism is the mycoparasitism of powdery mildew by *Ampelomyces* spp. because its hyphae penetrate the structures of powdery mildew, mainly the conidia, and continue their growth, affecting the functioning and sporulation by intracellular mycoparasitism (37).

This species has been used with good results for the causal agents of powdery mildew in cucurbits (31). With applications of *A. quisaqualis* in a preventive way against powdery mildew in pumpkin, a control of the disease of 80.30 % with respect to the control was achieved (36).

Other management alternatives

Salts

Phytomineral therapy is a practice that consists of the application of salts, called biocompatible compounds, with the purpose of protecting against the attack of some crop diseases (27). Mineral salts work by modifying the growth and reproduction structures of the pathogen (38), or by promoting the phenomenon of systemic resistance against plant diseases. Undoubtedly, the use of mineral salts for the control of powdery mildew has given good results (39), who report that potassium silicate has greater or equal biological effectiveness than chemical treatment based on azoxystrobin in the control of ash scale in cucumber. Authors reported that calcium nitrate and potassium phosphite were the most effective salts to reduce the damage caused by ash scale (*Oidium* sp.) in cucumber plants (40,41), compared to calcium phosphite and potassium sulfate. On the other hand, reasearchers (42) reported that applications of silicon and potassium phosphite reduced the incidence and severity of *Podosphaera pannosa* (Wallr.) de Barya under greenhouse conditions in rose crops. Some investigators reported that the immersion of mandarin fruits (*Citrus reticulate* L.) in solutions based on calcium and potassium phosphite reduced by up to 50 % the incidence of citrus green mold caused by *Penicillium digitatum* Sacc (43).

Bicarbonates

Bicarbonates are mineral salts found in nature, in all living organisms and even in water and soil. They are usually used in agriculture for their antimicrobial activity, among which sodium bicarbonate (CO_3HNa_2) and potassium bicarbonate (CO_3HK_2) stand out (40). The way they act on the different diseases they control is due, to a great extent, to the toxic effects they cause on the structures and activation of the defense mechanisms of plants (27), to the increase of the pH on the leaf surface (44), the collapse of the fungal cells due to the imbalance of the potassium ion and the dehydration of the cell wall of the spores (45).

Phosphites

The terms phosphite and phosphanate are commonly used in the literature to refer to salts derived from phosphorous acid, as well as hydrogen phosphonates, orthophosphites, phosphonic acid compounds or phosphorous acid compounds, compounds that have the ability to control diseases in various crops, acting directly on the pathogen and indirectly by stimulating host defense responses (46).

Oils

Vegetable oils currently represent a viable practice to combat different diseases (47). Authors report that the most used oils for fungal control are olive oil (*Olea europea* L.), jojoba (*Simmondsia chinensis* Schneider), soybean (*Glicine max* L.), sunflower (*Heliantus annus* L.) and neem (*Azadarichata indica* L.) (39), many of these are highly effective in the case of cenicilla (48). Soybean oil (2 %) reduced ashylla severity in roses by 2-5 % in relation to the chemical control (higher than 40 % infection) and to the control, where severity increased to 100 %.

CONCLUSIONS

Powdery mildew is a disease of worldwide importance in the cultivation of cucurbits. In Mexico, in the region of Tehuacán, Puebla, it is one of the main limiting factors for pumpkin production. The integration of biological, salts, oils and cultural management of the crop, are practices that favor the reduction of the severity of the pathogen on the crop and consequently the economic losses.

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