MANAGEMENT OF BROWN ROT (*Monilinia fructicola*) OF PEACH BY PRODUCERS FROM THE SIERRA NEVADA IN PUEBLA

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Citation: Huilotl-Luna ML, Gil-Muñoz A, Hernández-RomeroE, López PA, Martínez-Carrera DC. 2024. Management of brown rot (*Monilinia fructicola*) of peach by producers from the Sierra Nevada in Puebla. Agricultura, Sociedad y Desarrollo https://doi.org/10.22231/asyd.v21i4.1679

ASyD 21(4): 582-600

Editor in Chief:
Dr. Benito Ramírez Valverde

Received: January 19, 2024.
Approved: March 7, 2024.

Estimated publication date:
September 27, 2024.

ABSTRACT

Globally, brown rot of peach is considered the most important and destructive disease for the crop because of the losses it causes. Even though the literature reports several strategies for its control, there are no studies that document how the farmer faces this phytosanitary problem. Therefore, the objective of this study was to determine the range of management practices that producers carry out to control the disease, to assess how adequate those practices are, and to identify aspects to address. The study was conducted in the Sierra Nevada region, in Puebla, an important peach producing region. Through a randomized stratified sampling, 52 questionnaires were applied in three municipalities of the region. The questionnaires included questions about the management and control of brown rot. The results indicated that this disease is the second most important recognized by producers; 96% of the producers has identified the disease in their orchards, but not all of them perform practices for its control. Of the interviewees, 59% use fungicides to control brown rot, 79% also carry out sanitary pruning, and 40% eliminate inoculum sources. All of them (100%) fertilize and 55% control insect pests. Harvest losses reach more than 30%. The conclusion is that the set of practices that are carried out are not enough to control the disease. The recommendation is to strengthen the knowledge of producers about the disease and its management, to improve their control practices, and to integrate those practices.

Key words: disease control, farmers' knowledge, Integrated Pest Management, *Monilinia* spp, peach.

INTRODUCTION

Peach production in the country occupies a very important place in productive and economic terms. For the year 2022, Mexico was the 10th producer in the world, with an annual volume of 239,133 tons and a total commercial value that exceeded 2,674 million pesos. Its production is distributed in different states, such as Zacatecas, Michoacán, Chihuahua, and Puebla. The latter, in the year 2022, occupied the third place as peach producer in the country, with 24,059.83 tons (Servicio de Información Agroalimentaria y Pesquera-SIAP, 2022). However, peach production is affected by various problems that reduce its yield and quality, such as frosts, winds, hail, pests and diseases (Fernández *et al*., 2010; García-Figueroa *et al*., 2013). Among the latter, brown rot stands out, a disease caused by the fungus *Monilinia fructicola* (G. Winter) Honey (Luo *et al*., 2022; Zegbe *et al*., 2005), which is considered the most destructive for the crop (Luo, 2017). In addition, it is one of the greatest concerns for peach producers, because of the high pre- and post-harvest losses that it causes (Pavanello *et al*., 2015). For that reason, multiple studies have been conducted, directed at understanding the etiology of the disease (Rungjindamai *et* *al*., 2014), detecting the pathogen (Iqbal *et al*., 2022) and, in particular, exploring options for control (Keske *et al*., 2011; Adaskaveg and Förster, 2002).

In the specific case of Puebla, Mendoza *et al*. (2011) reported that brown rot is a latent problem in the production of peach in the Sierra Nevada region, since there are difficulties for its management. The theory suggests that an efficient management of the disease depends on the use of resistant varieties and the practices carried out before, during and after the harvest (Dini *et al*., 2021; Rivas, 2015; Zehr, 1982), as well as the epidemiologic knowledge and the early detection of the disease (Gort and Marín, 2011; Larena *et al*., 2005). However, to date, there are no studies in Mexico that have documented the management that producers make before and during the presence of the disease; that is, of the preventive and control practices of the disease. For this reason, this study was proposed. It was conducted in one of the main peach producing regions in Puebla, the Sierra Nevada region, under the hypothesis that producers of the region carry out different management practices to prevent and control brown rot that affects the peach tree, although these are neither sufficient nor adequate to control the disease. The objective was to determine the different management practices that producers perform to prevent and control the disease, to assess how adequate those practices are, and to identify phytosanitary aspects that must be addressed. This will make possible the design and the implementation of strategies directed at the prevention and control of diseases, under an integrated pest management (IPM) approach.

THEORETICAL FRAMEWORK

Diseases in crops, as well as pests, seriously limit global food production. Therefore, the lack of knowledge about them by producers can become an important problem (Abang *et al*., 2014). Consequently, understanding the knowledge, perceptions and practices that farmers carry out is an indispensable requirement to establish a program for effective control of any phytosanitary problem. This is because it opens the possibility of optimizing the knowledge of farmers, and also of retaking successful management practices (Mudde *et al*., 2017). According to Abang *et al*. (2014), another aspect that should also be evaluated in order to establish adequate control programs, is the knowledge that farmers have about the etiology and epidemiology of the disease.

Studies carried out by Palwasha *et al*. (2022) in Pakistan revealed that among peach producers there is a lack of important knowledge about pests and diseases of the fruit tree, and that there is also ignorance about phytosanitary good practices. Therefore, the authors conclude that it is necessary to train the producers, with the aim of improving and increasing their technical knowledge about the control of pests and diseases, situation that could contribute to improvements in production.

Currently, there are various strategies for the management of pests and diseases in crops; however, management practices have changed from being cultural and mechanical to the virtually exclusive use of pesticides (Owen *et al*., 2014). The dependency on this type of products for the protection of crops is associated with undesirable effects on the environment, health, and the continuous efficacy of their use. On the other hand, the indiscriminate use of such products has simplified the cropping systems, which implies desisting from more specialized protection strategies. This simplification, the excessive dependency on chemical controls, and the continuous use of few modes of action, have led to a generalized resistance of insects and diseases, so the future of crop protection is threatened (Barzman *et al*., 2015; Busi *et al*., 2013).

The aforementioned has led to propose and develop control strategies under an integrated pest management (IPM) plan, which involves the combination of alternative techniques and treatments, with the purpose of preventing and avoiding their propagation in a satisfactory manner (Gort and Marín, 2011; Rungjindamai *et al*., 2014; Usall *et al*., 2010). In contrast with traditional pest management, IPM stands out for integrating different biological, cultural, physical and chemical tools, directed at reducing the state of the pests to tolerable thresholds, under economic and ecologically acceptable criteria (Stenberg, 2017; Zaccagnini and Canavelli, 1998) and with the objective of identifying, managing and reducing the economic, health and environmental risk (United States Department of Agriculture- USDA- Agricultural Research Service-ARS, 2018). The set of these tools includes both preventive (such as cultural and genetic resistance methods) and corrective tactics, which involve the use of mechanical, physical and chemical methods, although in the case of the latter, at low levels (Kogan, 1998). Hashemi and Damalas (2010) pointed out that understanding the knowledge, perceptions, preferences and beliefs of farmers and their decision-making processes are fundamental requirements for a better adoption of integrated pest management practices.

METHODOLOGY

Study area

The study was conducted in three municipalities of the Sierra Nevada region in Puebla: San Felipe Teotlalcingo (19º 11’ 24” to 19º 15’ 36” N, 98º 28’ 06” to 98º 33’ 18” W, altitude: 2,340 to 3,500 m), Chiautzingo (19º 10’ 24” to 19º 13’ 42” N, 98º 26’ 24” to 98º 33’ 36” W, altitude: 2,300 to 3,500 m), and Huejotzingo (19º 13’ 32” to 19º 06’ 36” N, 98º 20’ 18” to 98º 39’ 00” W, altitude: 2,180 to 5,100 m), because they are the municipalities that concentrate the largest surface planted with peach in the region. These municipalities are located in the central-west part of the state of Puebla and northwest of the Rural Development District (RDD) 05 Cholula (Instituto Nacional de Estadística y Geografía -INEGI, 2010). The predominant climate in the three municipalities is sub-humid temperate with summer rains, with annual precipitation of 900-1,100 mm and annual average temperature of 16.5 °C (INEGI, 2010).

Study population and sample size

To determine the study population, we used the census of producers who are assisted by the Plant Health State Committee in the State of Puebla (*Comité Estatal de Sanidad Vegetal del Estado de Puebla*, CESAVEP) in the three municipalities, which included 288 peach producers. In each municipality and locality, key informants were contacted to validate the census of producers. The localities where peach production was not found were ruled out, as well as the producers who did not produce that fruit tree or only had a few trees. Once the refining was done, a register of 99 producers was obtained, distributed in the following way: 13 in San Felipe Teotlalcingo, 45 in Chiautzingo, and 41 in Huejotzingo. Based on these data, a randomized stratified sampling scheme was applied with Neyman allocation, and the equations described by Singh and Mangat (1996) were used:

a) Equation to determine the total size of the sample:

$$n = \frac{\left(\sum_{i=1}^{k} N_i S_i\right)^2}{\left(N^2 V + \sum_{i=1}^{k} N_i S_i^2\right)}$$

where n: final size of the sample; N: study population, N_i: number of producers from stratum i (each municipality was considered a stratum); S_i: standard deviation of stratum i (calculated for the surface planted with peach); V: ratio between precision and reliability, calculated as:

$$v = \frac{d^2}{z_{\alpha/2}^2}$$

where d: precision (fixed in 10% of the general mean; that is, 0.145); $Z_{\alpha/2}$: reliability (value of z of tables with α=0.90; that is, z=1.64).

b) Equation to distribute the total size of the sample among strata (municipalities):

$$n_i = n\left(\frac{N_i S_i}{\sum_{i=1}^{k} N_i S_i}\right)$$

where n_i: stratum i (municipality 1=San Felipe Teotlalcingo, 2=Chiautzingo, 3 =Huejotzingo); n: final size of the sample; N_i: number of producers of stratum i (municipality 1, 2, 3); S_i: standard deviation of stratum i (calculated for the surface planted with peach).

The final size of the sample was 56 producers, distributed in the following way: 10 in San Felipe Teotlalcingo, 23 in Chiautzingo, and 23 in Huejotzingo. The interviewees were selected randomly from each listing. In each locality, key informants were contacted to ease the approach with the producers selected. Finally, 52 questionnaires were applied, because the conditions were not adequate in one locality.

Technique and instrument

The technique used was the survey and the instrument a questionnaire that included 35 questions (23 closed and 12 open) and was divided into four sections: 1) General data of the producer, 2) Diseases of the peach tree, 3) Importance and knowledge of brown rot, and 4) Management and control of brown rot. As part of the questionnaire, a series of representative photographs of the most common peach tree diseases was included, in order for the farmer to indicate which ones he had detected in his orchards and, then, to order them based on the importance that they represented. The questionnaires were applied from October to December 2022.

Information analysis

Through descriptive analysis techniques (mean, frequency and percentages), we analyzed the variables related to the general characteristics of the production units, as well as the control practices for the disease (cultural, mechanical, genetic, chemical and biological). The statistical program used was SAS® OnDemand for Academics (SAS Institute Inc, 2012-2020).

RESULTS

General characteristics of producers and peach production

Among the peach producers, 98% were over 42 years old (average 60 years old); overall, their average education was six years (minimum 2, maximum 17 years). As to their experience in fruit tree production, 80% of them had 20 or more years of experience at the time of the study.

In the study region, peach is produced primarily in plots where there are other fruit tree species in the same row, interspersed with annual crops (58%) and in lower proportion, in orchards where it is the only species in the row and is interspersed with annual species (23%), or where it is as a sole crop (19%). Production under rainfed conditions predominates (66%) and is followed in lower proportion, by irrigation (34%). In the plots, the use of landraces was common (60%), although orchards with improved varieties were also found. The plantations are, on average, 9.96 years old, and 204 trees (weighted mean) are managed in them. The peach harvest starts in the month of April and extends until the month of August.

Detection and importance of peach tree diseases

It was found that producers have detected different diseases in their peach crop, such as powdery mildew, brown rot, shot hole, and leaf curl, among others. When systematizing the information corresponding to the degree of importance given to each disease, it was found that, for them, the three main ones were powdery mildew, brown rot, and shot hole. Diseases such as crown gall or root rot were the least important among producers, in addition to being the ones least identified. Powdery mildew and brown rot were the most recurrent diseases: 96% of the producers have detected them in their peach crop; brown rot was placed at the second place in importance (Table 1).

Table 1. Detection of peach tree diseases and level of importance assigned by the producers. Sierra Nevada de Puebla, 2022.

Diseases	Identification (%)	Level of importance[†]
Powdery mildew (*Sphaeroteca pannosa*)	96	1
Brown rot (*Monilinia fructicola*)	96	2
Shot hole (*Coryneum beijerinckii*)	75	3
Leaf curl (*Taphrina deformans*)	90	4
Gummosis (*Pseudomonas syringae*)	94	5
Rust or Chahuistle (*Tranzschelia discolor*)	56	6
Crown gall (*Agrobacterium tumefaciens*)	8	7
Root rot (*Armillaria mellea*)	6	8

[†]Where: 1: most important, 8: least important.
Source: prepared by the authors based on survey data.

Symptoms and perception of damage from brown rot

To clarify how the producers recognized the presence of brown rot in their crop, they were asked about the symptoms they related to the disease, as well as the phenological stage in which they had identified those symptoms. It was found that producers related up to five symptoms to the recognition of the disease: fruit rotting (34%), spots on the fruit (31%), organ mummies (22%), wounds and spots in branches (6%), and flower withering (7%) (Figure 1).

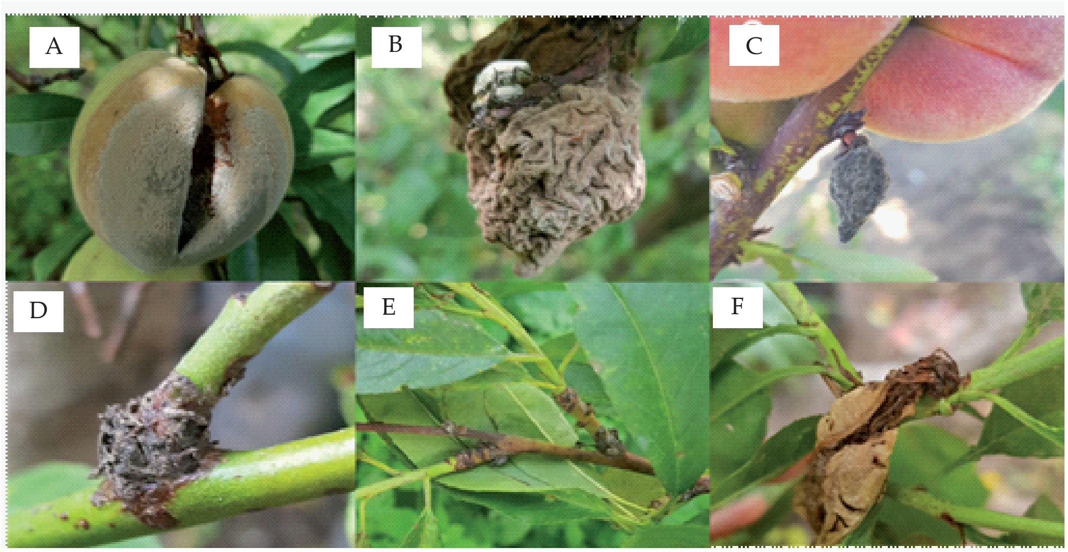
Regarding the phenological stage in which producers identify and perceive a greater damage caused by brown rot, it was found that they detected it primarily in the stages of fruiting, ripening and harvest. These stages were also the ones in which they perceived greater damage. Flowering and budding were the stages where the producer did not perceive damage from the disease (Table 2).

Management of brown rot

Even though 96% of the farmers expressed having detected the presence of the disease in their plots, only 59% said they had taken actions toward its control, which consisted primarily in the application of an agrochemical. Regardless of this, in the questionnaire, producers were asked about other management practices they carry out and which could contribute directly or indirectly to management of brown rot. Based on the information obtained, the practices were grouped into the categories of cultural control, mechanical control, genetic control, chemical control, and biological control. The results are presented next.

Cultural control

It was found that fertilization of peach trees is based primarily on the application of animal manure and fertilizers, particularly nitrogenous and, in lower proportion, compound.



Fruit rotting and spots (A), Organ mummies (B and C), Wounds and pots in branches (D and E), Flower withering (F). Sierra Nevada de Puebla, 2022.
Source: prepared by the authors based on field explorations.
Figure 1. Symptoms of brown rot identified in peach tree.

Composting is very rarely used. In terms of the doses applied, most of the producers exceed the recommended doses (Table 3).

Most of the producers fertilize twice per year (65%) and the rest only once. From the total of interviewees, 76% applies one to two types of products (animal manure and urea), and the rest applies more than two products listed in Table 3. This practice is carried out in different phenological stages of the crop: budding and flowering (41%), fruiting and ripening (40%), and harvest and rest (19%).

Another cultural practice that is commonly performed by the producers, as part of the cultivation tasks, is pruning: 98% of them declared doing this. However, only 79% said they carry out sanitary pruning to prevent brown rot, and from these, none performs

Table 2. Phenological stages where farmers detect the damage from brown rot in peach trees and where they perceive more impact. Sierra Nevada de Puebla, 2022.

Phenological stage of the crop	Stage where the disease is detected (%)	Stage where the greatest damage is perceived (%)
Flowering	1	0
Budding	1	0
Fruiting	32	36
Ripening	29	40
Harvest	24	21
Post-harvest	13	3

Source: prepared by the authors based on the survey data.

Table 3. Use and application of fertilizers and manures in peach tree. Sierra Nevada de Puebla, 2022.

Fertilizers	Use (%)	Dose applied (g)	Recommended dose (g) †
Animal manure	29	9,000	10,000††
Compost	3	3,660	3,000
Urea	23	350	260
Triple 17	12	630	130
Diammonium phosphate	17	350	100
Potassium sulfate	4	330	240
Ammonium nitrate	4	170	400

†Recommendations based on the formula 120 g N-60 g P_2O_5- 120 g K_2O, balancing N and P_2O_5 when Triple 17 or Diammonium phosphate are used. Source: Hernández-Romero, E. (2023). Lead researcher. Personal communication.
††Apply every other year.
Source: prepared by the authors based on data from the survey, 2022.

burning of the pruning material. Other maintenance activities are weeding, which are done up to four times during the year.

In terms of post-harvest practices, most of the producers select and classify fruits (81%); the rest (19%) does not conduct any activity in this stage. It should be mentioned that 100% of the producers declared not knowing additional practices or treatments for control of brown rot at the post-harvest level.

Regarding the control of mites or pest insects, only 55% of the producers carry out this practice and mostly control the ones that they consider most damaging; for example, red spider mite, grasshopper and American rose chafer; in stages of budding, harvest and ripening, respectively. However, the doses they apply to address each problem are generally higher than the doses recommended by the manufacturer of the product most commonly used (Table 4).

Mechanical control

Different activities were identified among the practices for mechanical control of brown rot. For example, 40% of the producers carried out the elimination of potential sources of inoculum; that is, they withdraw the damaged fruits from the peach tree plot; however, only 8% of the producers bury or burn them. In terms of cleaning of the instruments that are used for peach harvest, only 50% of the producers interviewed do it. Of these, 73% washes them with soap and chlorine and 27% disinfects them with alcohol.

Chemical control

It was found that 59% of the producers control the disease with some type of chemical product. The most frequently used products have as active principle Captan and Benomyl (69%). The producers also use preventive fungicides, such as copper sulfate or sulfur. However, a small fraction of the interviewees (8%) uses products that are not recommended

Table 4. Control of mites and insects that attack the peach tree. Sierra Nevada de Puebla, 2022.

Mites/ Insects	Control (%)	Main stage of control	Main product applied	Dose used (ml L^{-1})	Dose recommended† (ml L^{-1})
Red spider mite (*Tetranychus* spp.)	83	Budding	Cypermethrin	1.54	1.0
Grasshoppers (*Brachystola* spp.)	77	Harvest	Cypermethrin	1.27	1.0
American rose chafer (*Macrodactylus* spp.)	83	Ripening	Cypermethrin	1.40	1.0
Aphids (*Myzus* spp., *Brachycaudus* spp.)	65	Budding	Cypermethrin	1.55	1.0
Borers (*Grapholitha* spp., *Anarsia* spp.)	16	Budding	Cypermethrin	0.75	1.0
Bugs (*Lygus* spp., *Letoglossus* spp., *Thyanta* spp.)	4	Fruiting	Cypermethrin	3.75	1.0

†Dose according to the manufacturer's recommendation.
Source: prepared by the authors based on survey data, 2022.

for brown rot control, such as Carbendazim, Chlorpyrifos ethyl, or the mineral zeolite (Table 5).

Regarding the doses they apply, it was detected that in most of the cases the doses used do not adjust to those recommended by the manufacturer. Concerning the stage of application, it can be seen that the stages when greater control of the disease is exerted are fruiting and ripening of the fruit (Table 5).

Table 5. Chemical control of brown rot by peach tree producers. Sierra Nevada de Puebla, 2022.

Active principle	Use (%)	Dose used (g or ml L^{-1})	Dose recommended (g or ml L^{-1})†	Stages of application
Captan	38	1.31	3.00	Fruiting, Ripening, Harvest
Benomyl	31	1.21	0.50	Fruiting, Ripening, Harvest
Triforine	8	1.25	1.00	Ripening
Copper sulfate	4	1.00	3.50	Flowering
Sulfur	4	5.00	7.50	Ripening
Chlorotalonyl	4	1.25	2.00	Ripening
Carbendazim	4	1.25	-††	Ripening
Chlorpyrifos ethyl	4	0.50	-††	Ripening
Zeolite†††	3	100.00	Not available	Fruiting

†Dose according to the recommendation of the manufacturer of each product (in italics, doses in ml·L^{-1})
††Product not recommended in peach tree.
†††Doses in grams per tree.
Source: prepared by the authors based on survey data, 2022.

Genetic control

It was found that, in the region, the use of landrace cultivars predominates (60%) and, in lower proportion, of improved ones (40%); among them, the ones that stand out are 'Diamante Especial', 'Diamante Mejorado', 'Diamante Supremo', 'Oro Azteca Mejorado', 'Oro de Tlaxcala' and 'Robin'.

Biological control

Producers from the region declare not knowing any treatment of biological origin for control of brown rot.

Harvest losses as a result of brown rot

When producers were asked about the percentage of harvest losses that they have experienced as a result of brown rot, it was found that from the total of interviewees, 88% mentioned having had harvest losses. From these, 37% declared losses lower than 20%, 56% of the producers mentioned having had losses of 20 to 69%, and 7% have experienced harvest losses of more than 70%. On average, losses of 33% are reported.

DISCUSSION

The disease of brown rot is one of the most important globally and is considered a limiting factor in peach production (Obi *et al.*, 2018), since the losses that it causes before and after the harvest represent more than half of those recorded in the world (Iqbal *et al.,* 2022). In Spain, in Valle del Ebro, Usall *et al.* (2010) indicate that the disease is associated with up to 80% of the harvest losses, while in New Zealand, McLaren *et al.* (1996) reported post-harvest losses that reached 50%. It should be highlighted that Emery *et al.* (2000) point out that there are also indirect losses attributable to the cost of the application of fungicides in pre- and post- harvest stages. It was calculated that 10% of the losses from *Monilinia* spp. are equivalent to 1.7 million Euros (Martini and Mari, 2014). Our results show that brown rot disease represents an important problem for peach producers in the Sierra Nevada region in Puebla, since it is recognized as one of the most important diseases that they face. In addition, even though the harvest losses reach 33% on average, there were reports of losses higher than 70%. Despite this, only 59% of the producers (on average), carry out practices for control of the disease: 59% via chemical control, 79% through sanitary pruning, and only 40% via the elimination of affected fruits. This indicates that peach production in the region faces an important phytosanitary challenge with regards to this disease.

About the recognition and symptomatology of the disease

Prusky (1996) and Gell *et al.* (2008) describe that the presence of the pathogen causing brown rot is favored by conditions of high moisture and high precipitations, rainy springs and summers, which promote its growth. Villarino *et al.* (2010) point that the pathogen is capable of infecting at temperatures between 0 and 40 °C and relative humidity of 80 to

100%. Therefore, this implies that the temperate climate present in the region, favorable for the production of peach, also generates optimal environmental conditions that favor the development of the pathogen.

It has been proven that the causal agent of the disease is capable of infecting at any stage of the fruit development (Keske *et al*., 2011); that is why the knowledge of the epidemiology of the disease and its symptoms, as well as the recognition of critical moments, are important aspects to consider for efficient control (Larena *et al*., 2005). Results from our study reveal that even though producers recognize the disease and its symptoms in the different phenological stages of the crop, most of them identify them in stages where the damages and signs of the disease are more evident, such as fruiting and ripening of the fruits, and when the impact is higher.

If there is the intention to implement preventive actions since early stages, it is necessary to strengthen the knowledge of farmers so that they recognize the disease from stages such as budding and flowering, and understand the importance of this.

About cultural and mechanical control

Regarding the management of the disease, the theory suggests that an efficient control of the disease depends on the management practices carried out before, during and after the harvest (Dini *et al*., 2021; Rivas, 2015; Zehr, 1982). Our results show that in the region of the Sierra Nevada in Puebla, producers perform some practices for management of brown rot; however, these practices are insufficient to prevent and avoid its propagation. For example, Gort and Marín (2011) and Obi *et al*. (2018) point out that keeping a balanced fertilization, without exceeding the applications of nitrogenous fertilizers, decreases the incidence of brown rot in the crop. In this sense, in the study area, farmers exceeded the recommended doses of fertilization and, at the same time, they privileged the application of nitrogenous fertilizers with low contribution of other elements, situation that could be favoring the development of this disease. Managing a fertilization program, as suggested by Mondino (2014), would allow attaining a nutritional balance with the objective of decreasing the development of diseases.

Control of insects is also an essential management practice, because they cause wounds in the fruit, which are the entry point of brown rot and other diseases (Rivas, 2015). In this regard, Holb (2008) found that lower levels of the disease are attributed in part to the control of insects that cause wounds. On the other hand, Iqbal *et al*. (2022) and Amiri *et al*. (2010) describe that weeding can decrease the populations of insects, in addition to increasing the air flows to reduce the levels of moisture. In this sense, we found that only 55% of the producers carry out this type of practices, since they control some insects such as American rose chafer (*Macrodactylus* spp.) and grasshoppers (*Sphenarium* spp.), which foster the spread and development of the disease from the damage that they cause in the fruit and foliage. However, the control is based on the application of insecticides, once the pest is found in the crop, so it is more a curative than a preventive practice. In addition to this, farmers use primarily products with the same active ingredient and in doses higher than those recommended by the manufacturer, which could decrease the effectiveness of the product and, at the same time, favor the development of resistance in the insects. Actions such as pest insect monitoring could be useful (Obi *et al.*, 2018).

Performing fruiting pruning to manage the microclimate, as well as sanitation pruning during winter, significantly reduces the potential sources of inoculum (Dini *et al.*, 2021; Rivas, 2015). In this study, it was found that most of the producers only carry out sanitary pruning and that, after these, they leave the infected residues in the same plot, without burying or burning them. The same happens with the elimination of infected fruits or mummies, which are simply removed from the tree; the percentage of producers that burn or bury them is minimal. This represents a critical point to be addressed, since otherwise, the practice is insufficient and inefficient to reduce or eliminate potential sources of inoculum of the disease.

Another moment when brown rot can cause considerable damage is during post-harvest. To reduce those damages, Emery *et al.* (2000) mentioned that the activities of collection and manipulation of the fruit should be done with the utmost possible care, to avoid mechanical lesions, since the wounds ease the entry of the disease. Cleaning tools and harvest containers is also suggested, in addition to selecting fruits with the objective of removing those with symptoms of the disease, in order to reduce the load of the inoculum and to prevent the spread of the disease during storage and commercialization (Gabilondo and Budde, 2014). Regarding this, we found that farmers do carry out practices such as selection and classification of fruits and cleaning of the instruments they use, practices that, for the time being, could be enough to control the disease in post-harvest, since very few farmers considered that there is important damage during this stage. However, the inclusion of post-harvest treatments, such as preservation in cold, thermal treatments and disinfecting treatments with peracetic acid and chitosan, could be considered (Usall *et al.*, 2010).

About chemical control

Regarding the chemical control of brown rot, it is carried out primarily with fungicides of chemical synthesis, which are highly effective to inhibit the pathogen. Gort and Marín (2011) and Zehr (1982) indicate that something to take into account is that the disease can manifest itself in any stage of development and that there are two critical moments for its control: flowering and ripening. Holmes *et al.* (2011) describe that the application of fungicides should be performed during the flowering stage, to protect the flowers from blight, and they recommend a monthly application to protect fruits during ripening and harvest. Authors such as Li and Yu (2001) suggest the combination of treatments with fungicides of different modes of action, such as benomyl, captan or iprodione, since in this way, a greater effectiveness is ensured, and the risk of resistance in the pathogen is reduced. It has also been recommended to perform just one application of benomyl and, then, to alternate with other fungicides (Zegbe *et al.*, 2005). However, different studies report that *Monilinia fructicola* has shown resistance to benomyl (Chen *et al.*, 2014; Ma *et al.*, 2005). In this regard, it should be mentioned that the Fungicide Resistance Action Committee

(FRAC, 2024), specifies that benzimidazoles (group to which benomyl belongs), started to be used commercially since the late 1960s, but that problems of pathogen resistance emerged shortly after. It adds that among pome and stone fruits, the first field report of *Monilinia* spp. strains resistant to benzimidazol, happened in 1973. What is alarming about it is that according to Penrose (1990), once strains of *M. fructicola* resistant to benomyl are detected, it is very unlikely to be able to make an effective use of fungicides based on benzimidazoles again. Another critical aspect is that, according to Zehr *et al*. (1991), the strains of *M. fructicola* resistant to benomyl present in commercial orchards persist for long periods of time, even after the applications have stopped.

In this study it was found that only 59% of the producers carry out chemical control, although they do not exert a preventive control of the disease, since practically all of those who apply those products carry out aspersions in stages when the damages are mostly perceptible, such as fruiting and ripening. In addition, they apply a single active ingredient in different stages of the crop, and the doses that they usually use exceed those recommended by the manufacturer, and they might even use products that are not useful to control the disease. Based on the literature, regarding the chemical control, it is necessary to modify several practices of the farmers: a) perform preventive applications (in flowering), b) alternate active ingredients, and c) respect the doses recommended by the manufacturers and do not exceed the number of applications allowed in the same cycle, among the most important.

About other control mechanisms

In Mexico, genetic improvement programs have been developed for the generation of high-yielding varieties, also resistant to powdery mildew and brown rot. Among those obtained, there are the following: 'Oro Azteca', 'Diamante Especial', 'Diamante Supremo', 'Colegio' and 'Robin' (Calderón-Zavala *et al*., 2019; Rodríguez *et al*., 2008). When these materials are related to those found in the study, it is concluded that producers of the region have planted some improved varieties with resistance to brown rot, which undoubtedly can help to decrease the damage from the disease; however, the use of landrace cultivars still predominates. The not so common use of improved varieties could be due to the lack of knowledge from the producer of varieties reported as resistant to the disease, to the low availability of them, or to the early flowering they present, which increases the risk of damage from low temperatures.

Landrace materials present a high susceptibility to various foliage and fruit diseases, brown rot among them, and have the characteristic of presenting intermediate or late ripening, which favors the development of diseases due to the high rainfall frequency during the months of harvest (Fernández *et al*., 2010). This, in addition to the emergence of strains of *M. fructicola* resistant to fungicides, to the efforts to reduce the applications of agrochemicals, and the issue of food safety, suggest the need to adopt other strategies, one of the most important being genetic resistance (Dini *et al*., 2022). In this regard, Obi *et al.* (2018) point out that the use of materials with a certain level of resistance to brown rot is one of the most important, profitable and environmentally safe strategies for disease control. The replacement of landrace materials by improved varieties implies additional advantages to the resistance to the disease, such as higher productivity, fruit quality, and versatility of uses (Calderón-Zavala *et al*., 2019), as long as they are accompanied with an adequate management plan (Mendoza-Robles and Hernández-Romero, 2019).

Finally, in relation to the biological control of the disease, until today, important advances have been achieved which include the use of different microorganisms for the control of brown rot, among them, bacteria such as *Bacillus licheniformis* W10 (Ji *et al*., 2020) and *Pseudomonas synxantha* in post-harvest (Aiello *et al*., 2019), yeasts such as *Saccharomyces delbrueckii* A50, *S. cerevisiae* YE-5 and *S. cerevisiae* A41 (Zhou *et al*., 2008), opportunistic fungi such as *Epicoccum nigrum* (Larena *et al*., 2005), antagonist fungi such as *Trichothecium roseum* (Moreira and May-de Mio, 2007), *Trichoderma harzianum* and *T. viride* (Mitidieri *et al*., 2011), as well as the use of extracts derived from plants such as *Brassica carinata* (Martini and Mari, 2014). This illustrates the range of options available which, if crystallized into commercial products, could be included in the plans for disease control. For the time being, the scarce availability of products of this nature in the market explains, in part, why producers do not know about them and for now limit their use as alternatives to the constant use of fungicides.

From what was exposed, it is deduced that producers do carry out different control practices (cultural, mechanical, chemical, genetic) of the disease, which is convenient, as pointed out by Gort and Marín (2011), Rungjindamai *et al*. (2014) and Usall *et al*. (2010). However, to be able to control the pathogen satisfactorily, several of them require a broader use or adjustments, in addition to their complementation with other practices such as a higher incorporation of materials resistant to brown rot and, eventually, the use of products of biological origin that reduce the impact caused by the disease. In consequence, the hypothesis suggested in this study was not rejected.

Recapitulation

The disease of brown rot represents an important limiting factor for the production of peach in the Sierra Nevada region in Puebla, problem that is recognized by the farmers who cultivate that fruit tree. As a consequence of this, almost 60% carry out several practices that can help to have some control of the disease, such as fertilization, weeding, pest control, sanitary pruning, elimination of sources of inoculum, selection and classification of fruits, cleaning of instruments, application of fungicides and, in some cases, use of improved varieties. However, for them to be truly effective as measures to prevent and avoid propagation of the disease, in some cases, it is required to promote a more extensive use of these, and in others, to make diverse modifications. Thus, regarding the contribution of nutrients, activity that they all carry out, it is advisable to respect a mineral or organic fertilization program, balanced and timely. Weeding, for its part, represents an activity to keep. When it comes to pest control, it is necessary for it to be a more extended practice, which could have a more preventive than curative nature with the support of monitoring, and include the diversification of active ingredients used. With regards to sanitary pruning and the elimination of sources of inoculum, these should be promoted as practices of common use, which need to be associated to the adequate disposal of the material (burning or burying). Likewise, in the case of the practices of selection and classification of fruits, as well as cleaning of instruments, it is convenient to foster their generalized use. In those cases where there is the need to resort to the use of fungicides, the use of the correct products should be promoted, in the recommended doses and frequency, with a program of preventive applications that includes the rotation of active ingredients. Lastly, when it comes to genetic control, the use of improved materials, resistant to the disease, would definitely help to decrease the losses and adequately complement those listed before.

In addition to this, strengthening the knowledge of peach producers in aspects such as the recognition of the disease and its control in early stages, as well as in the aspects previously mentioned, will contribute to a better management of the disease. Because of this, the training actions that contribute with knowledge and techniques represent a fundamental element. Another central aspect is to raise awareness among farmers who do not carry out actions for disease management, about the importance of implementing them.

Various authors (Abang *et al*., 2014; Mudde *et al*., 2017; Uwamahoro *et al*., 2018) have highlighted the advantages of farmers increasing their technical knowledge in the phytosanitary management of crops, since this generates multiple benefits such as the decrease in the severity of the disease (thanks to undertaking correct actions), the attenuation of its propagation, the decrease of harvest losses, and consequently, the increase in their income.

Finally, it should be mentioned that promoting the use of the practices described, which represent different control options, as well as others that are economically acceptable, environmentally sustainable, and healthy for humans, will allow advancing towards an integrated management plan, which could be extended to other phytosanitary problems.

CONCLUSIONS

Peach producers from the Sierra Nevada region in Puebla perform different practices for the management of brown rot, although they are insufficient and, in some cases, not entirely appropriate for an adequate control of the disease. For an effective control of it, there is the need to strengthen the farmers' knowledge on the importance of disease management, as well as its causes and progression, and to incorporate improvements in the practices they carry out, considering the options of cultural, mechanical, chemical, genetic, and biological control, through the Integrated Pest Management approach.

This study denotes the importance of brown rot in the region, as well as the urgency in the search for new and better alternatives for its control.

ACKNOWLEDGEMENTS

The authors wish to thank the peach producers from the localities where the study was conducted, who kindly agreed to answer the questionnaire designed for the research; the key informants and Agriculture councilors in each municipality, for their support in the localization of the producers; the State Committee for Plant Health in the state of Puebla, for their support in sharing the listing of peach producers; and Colegio de Postgraduados for the economic support given to conduct the project.

REFERENCES

Abang AF, Kouamé CM, Abang M, Hanna R, Fotso AK. 2014. Assessing vegetable farmer knowledge of diseases and insect pests of vegetable and management practices under tropical conditions. International Journal of Vegetable Science, 20. 240-253. https://doi.org/10.1080/19315260.2013.800625

Adaskaveg JE, Förster H. 2002. New detection and management practices for brown rot of peach in California. Acta Horticulturae, 592:637-643. https://doi.org/10.17660/ActaHortic.2002.592.87

Aiello D, Restuccia C, Stefani E, Vitale A, Cirvilleri G. 2019. Postharvest biocontrol ability of *Pseudomonas synxantha* against *Monilinia fructicola* and *Monilinia fructigena* on stone fruit. Postharvest Biology and Technology, 149. 83-89. https://doi.org/10.1016/j.postharvbio.2018.11.020

Amiri A, Brannen PM, Schnabel G. 2010. Reduced sensitivity in *Monilinia fructicola* field isolates from South Carolina and Georgia to respiration inhibitor fungicides. Plant Disease, 94:737-743. https://doi.org/10.1094/PDIS-94-6-0737

Barzman M, Bàrberi P, Birch ANE, Boonekamp P, Dachbrodt-Saaydeh S, Graf B, Hommel B, Jensen JE, Kiss J, Kusdsk P, Lamichhane JR, Messéan A, Moonen AC, Ratnadass A, Ricci P, Sarah JL, Sattin M. 2015. Eight principles of integrated pest management. Agronomy for Sustainable Development, 35. 1199-1215. https://doi.org/10.1007/s13593-015-0327-9.

Busi R, Vila-Aiub MM, Beckie HJ, Gaines TA, Goggin DE, Kaundun SS, Lacoste M, Neve P, Nissen SJ, Norsworthy JK, Renton M, Shaner DL, Tranel PJ, Wright T, Yu Q, Powles SB. 2013. Herbicide resistant weeds: from research and knowledge to future needs. Evolutionary Applications, 6. 1218-1221. https://doi.org/10.1111/eva.12098.

Calderón-Zavala G, Rodríguez-Alcázar J, de la Cruz Espíndola-Barquera M, García-Ávila A. 2019. Variedades mejoradas de durazno (*Prunus persica* L.). Agroproductividad, 12. 81-84. https://doi.org/10.32854/agrop.v12i9.1492.

Chen SN, Shang Y, Wang Y, Schnabel G, Lin Y, Yin LF, Luo CX. 2014. Sensitivity of *Monilinia fructicola* from peach farms in China to four fungicides and characterization of isolates resistant to carbendazim and azoxystrobin. Plant Disease, 98. 1555-1560. https://doi.org/10.1094/PDIS-11-13-1145-RE.

Dini M, Raseira M, Scariotto S, Marchi PM, Mello-Farias P. 2021. Peach phenological characters: heritability, maternal effect and correlation with brown rot. Genetics and Molecular Research. 20. 1-12. http://www.alice.cnptia.embrapa.br/alice/handle/doc/1129827.

Dini M, Raseira MdoCB, Scariotto S, Carpenedo S, Ueno B. 2022. Peach and nectarine susceptibility to brown rot and protocol optimization to evaluate *Monilinia fructicola* sporulation. Acta Scientiarum. Agronomy, 4. e55850. https://doi.org/10.4025/actasciagron.v44i1.55850.

Emery KM, Michailides TJ, Scherm H. 2000. Incidence of latent infection of immature peach fruit by *Monilinia fructicola* and relationship to brown rot in Georgia. Plant Disease, 84. 853-857. https://doi.org/10.1094/PDIS.2000.84.8.853.

Fernández MR, Pérez S, Mondragón C. 2010. Guía para cultivar duraznero en Tlaxcala. Folleto Técnico No. 41. INIFAP. Tlaxcala, México. https://www.academia.edu/40410447/CENTRO_DE_INVESTIGACI%C3%93N_REGIONAL_CENTRO_INIFAP_TLAXCALA_CENTRO_DE_INVESTIGACI%C3%93N_REGIONAL_CENTRO_INIFAP_TLAXCALA.

FRAC (Fungicide Resistance Action Committee). 2024. Background information on benzimidazoles. https://www.frac.info/frac-teams/expert-fora/benzimidazoles/information.

Gabilondo J, Budde C. 2014. Prácticas de manejo poscosecha que reducen la incidencia de podredumbre morena. *In*: Manejo de la podredumbre Morena (*Monilinia fructicola* y M. *laxa*) en huertos frutales de Uruguay, Chile, Bolivia, Brasil y Argentina. Mitidieri M y Castillo JA (eds). CYTED/RedFrut-san. Argentina. https://www.researchgate.net/publication/277721033_Manejo_de_la_Podredumbre_Morena_Monilinia_fructicola_y_M_laxa_en_huertos_frutales_de_Uruguay_Chile_Bolivia_Brasil_y_Argentina. pp: 35-42.

García-Figueroa G, Parra-Inzunza F, Escobedo-Castillo JF, Peña-Olvera B, Gutiérrez-Rangel N, Sagarraga-Villegas M. 2013. Rentabilidad del cultivo de durazno en cuatro municipios del estado de Puebla, México.

Agraria, 10. 71-78. https://www.redinnovagro.in/docs/Revista_Agraria_vol(10)_No(2).pdf.

Gell I, De Cal A, Torres R, Usall J, Melgarejo P. 2008. Relationship between the incidence of latent infections caused by *Monilinia* spp. and the incidence of brown rot of peach fruit: factors affecting latent infection. European Journal of Plant Pathology, 121. 487-498. https://doi.org/10.1007/s10658-008-9268-3.

Gort JA, Marín JP. 2011. La podredumbre parda del melocotonero, ¿cuarentena o enfermedad común? Vida Rural, 323. 36-42. https://repositori.udl.cat/items/9a2e7b7f-5513-4cad-90c1-e40bf80064a2.

Hashemi SM, Damalas CA. 2010. Farmers' perceptions of pesticide efficacy: reflections on the importance of pest management practices adoption. Sustainable. Agriculture 35. 69-85. https://doi.org/10.1080/10440046.2011.530511.

Holb IJ. 2008. Brown rot blossom blight of pome and stone fruits: symptom, disease cycle, host resistance, and biological control. International Journal of Horticultural Science, 14. 15-21. https://doi.org/10.31421/IJHS/14/3/796.

Holmes R, Kreidl S, Villalta O, Gouk C. 2011. Through chain approach for managing brown rot in summer fruit and canning fruit. Project Code MT08039. Biosciences Research Division, Department of Primary Industries. Victoria, Australia. https://www.hin.com.au/__data/assets/pdf_file/0017/5066/Brown-Rot-Combined-sml.pdf

INEGI (Instituto Nacional de Estadística, Geografía e Informática). 2010. Compendio de información geográfica municipal de los Estados Unidos Mexicanos 2010. Puebla. https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825293109.

Iqbal S, Abbas A, Mubeen I, Sathish M, Razaq Z, Mubeen M, Sathish M, Razaq Z, Mubben M, Kamran M, Haroon M, Syed SA, Naqvi SAH, Ahmed, MA. 2022. Taxonomy, distribution, epidemiology, disease cycle and management of brown rot disease of peach (*Monilinia* spp.). Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 50. 12630-12630. https://doi.org/10.15835/nbha50112630.

Ji ZL, Peng S, Zhu W, Dong JP, Zhu F. 2020. Induced resistance in nectarine fruit by *Bacillus licheniformis* W10 for the control of brown rot caused by *Monilinia fructicola*. Food Microbiology, 92:103558. https://doi.org/10.1016/j.fm.2020.103558.

Keske C, Amorim L, May-De Mio LL. 2011. Peach brown rot incidence related to pathogen infection at different stages of fruit development in an organic peach production system. Crop Protection, 30. 802-806. https://doi.org/10.1016/j.cropro.2011.03.005.

Kogan M. 1998. Integrated pest management: Historical perspectives and contemporary developments. Annual Review of Entomology, 43. 243-270. https://doi.org/10.1146/annurev.ento.43.1.243.

Larena I, Torres R, De Cal A, Liñán M, Melgarejo P, Domenichini, P, Bellini A, Mandrin JF, Lichou J, Usall, J. 2005. Biological control of postharvest brown rot (*Monilini*a spp.) of peaches by field applications of *Epicoccum nigrum*. Biological Control, 32. 305-310. https://doi.org/10.1016/j.biocontrol.2004.10.010.

Li H, Yu T. 2001. Effect of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. Journal of the Science of Food and Agriculture, 81. 269-274. https://doi.org/10.1002/1097-0010(20010115)81:2<269::AID-JSFA806>3.0.CO;2-F.

Luo CX, Schnabel G, Hu M, De Cal A. 2022. Global distribution and management of peach diseases. Phytopathology Research, 4. 1-15. https://doi.org/10.1186/s42483-022-00134-0.

Luo CX. 2017. Advances and prospects on researches of brown rot disease on fruits. Acta Psychopathological Sinica, 47. 145-153. https://doi.org/10.13926/j.cnki. apps.000015.

Ma Z, Yoshimura MA, Holtz BA, Michailides TJ. 2005. Characterization and PCR-based detection of benzimidazole-resistant isolates of *Monilinia laxa* in California. Pest Management Science, 61. 449-457. https://doi.org/10.1002/ps.982.

Martini C, Mari M. 2014. *Monilinia fructicola*, *Monilinia laxa* (Monilinia rot, brown rot). *In*: Postharvest decay. Bautista-Baños S (ed). Academic Press. Massachusetts, USA. https://doi.org/10.1016/C2012-0-07916-1. pp: 233-265.

McLaren GF, Fraser JA, Lynch DG. 1996. An evaluation of sulphur for brown rot control in Central Otago stone fruit. Proceedings of the New Zealand Plant Protection Conference, 49. 32-36. https://doi.org/10.30843/nzpp.1996.49.11406.

Mendoza R, de los Ríos I, Hernández E, Regalado J, Parra F. 2011. Modelo de desarrollo local para el sector rural: Aplicación a un estudio de caso en Puebla, México. Actas del XV Congreso Internacional de Ingeniería de Proyectos. Huesca, España, 6 al 8 de junio de 2011. Asociación Española de Ingeniería de Proyectos. España. http://dspace.aeipro.com/xmlui/bitstream/handle/123456789/1470/CIIP11_1596_1606.pdf?sequence=1. pp: 1596-1606.

Mendoza-Robles R, Hernández-Romero E. 2019. Producción de durazno (*Prunus persica* L.) en Puebla, México. Agroproductividad, 12. 87-88. https://doi.org/10.32854/agrop.v12i9.1495

Mitidieri M, Barbieri M, Brambilla V, Peralta R, Piris E, Piris M, Celié R, Arpía E, Verón R. 2011. Evaluación de dos cepas comerciales de *Trichoderma harzianum* y *Trichoderma viride* como biocontroladores de *Monilinia fructicola* en la zona de San Pedro. *In:* Libro de Resúmenes. 2do Congreso Argentino de Fitopatología, Mar del Plata, Buenos Aires, 2011. 315 p.

Mondino P. 2014. Sintomatología etiología, características epidemiológicas de la enfermedad. *In*: Manejo de la podredumbre Morena (*Monilinia fructicola* y M. *laxa*) en huertos frutales de Uruguay, Chile, Bolivia, Brasil y Argentina. Mitidieri M y Castillo JA (eds). CYTED/Red Frut-San. Argentina. https://www.researchgate.net/publication/277721033_Manejo_de_la_Podredumbre_Morena_Monilinia_fructicola_y_M_laxa_en_huertos_frutales_de_Uruguay_Chile_Bolivia_Brasil_y_Argentina/link/557221c008aeb6d8c017374e/download . pp: 35-42.

Moreira LM, May de Mio LL. 2007. Crescimento micelial de *Monilinia fructicola* e *Trichothecium roseum* em diferentes temperaturas e sensibilidade do antagonista a fungicidas e fosfitos. Scientia Agraria, 8. 337-341. https://www.redalyc.org/articulo.oa?id=99516570017.

Mudde B, M'mogi FO, Miano DW, Asea G, Kilalo DC, Adriko J, Kiggundu A. 2017. Farmer knowledge, perceptions and management of maize lethal necrosis disease in selected agro-ecological zones of Uganda. African Journal of Rural Development, 2. 247-261. https://ageconsearch.umn.edu/record/262842/.

Obi VI, Barriuso JJ, Gogorcena Y. 2018. Peach brown rot: still in search of an ideal management option. Agriculture, 8. 125. https://doi.org/10.3390/agriculture8080125.

Owen MDK, Beckie HJ, Leeson JY, Norsworthy JK, Steckel LE. 2014. Integrated pest management and weed management in the United States and Canada. Pest Management Science, 71. 357-376. https://doi.org/10.1002/ps.3928.

Palwasha, Din SU, Fahim M. 2022. Significance and implications of farming practices, knowledge and methods of disease management in developing countries: A case study of peach farmers in Pakistan. Sarhad Journal of Agriculture, 38. 595-610. https://dx.doi.org/10.17582/journal.sja/2022/38.2.595.610.

Pavanello EP, Brackmann A, Thewes FR, Both V, dos Santos JRA, Schorr MRW. 2015. Eficiência de fungicidas no controle da podridão parda do pessegueiro e sua relação com parâmetros fisiológicos dos frutos. Semina: Ciências Agrárias, 36. 67-76. https://doi.org/10.5433/1679-0359.2015v36n1p67.

Penrose LJ. 1990. Prolonged field persistence of resistance to benomyl in *Monilinia fructicola*. Crop Protection, 9. 190-192. https://doi.org/10.1016/0261-2194(90)90162-Z.

Prusky D. 1996. Pathogen quiescence in postharvest diseases. Annual Review of Phytopathology 34. 413-434. https://doi.org/10.1146/annurev.phyto.34.1.413.

Rivas P. 2015. Propuesta de innovación tecnológica del manejo fitosanitario de durazno para productores de temporal de Tlaxcala. *In*: Desarrollo y Tecnología. Aportaciones a los problemas de la sociedad. Santiago C, Ayala AV y Almaguer Vargas G (eds). Plaza y Valdés Editores. Distrito Federal, México. https://www.researchgate.net/profile/Elizabeth-Acosta-2/publication/280114658_Sistema_Agroforestal_establecido_en_suelos_del_Distrito_de_Riego_028_Tulancingo_Hidalgo/links/55aaf4e208ae815a04279460/Sistema-Agroforestal-establecido-en-suelos-del-Distrito-de-Riego-028-Tulancingo-Hidalgo.pdf#page=316. pp: 315-344.

Rodríguez J, Carrillo O, Elías RD. 2008. Nuevas variedades de durazno para el subtrópico de México. Agro Productividad, 1. 8-10. https://revista-agroproductividad.org/index.php/agroproductividad/article/view/611.

Rungjindamai N, Jeffries P, Xu XM. 2014. Epidemiology and management of brown rot on stone fruit caused by *Monilinia laxa*. European Journal of Plant Pathology, 140. 1-17. https://doi.org/10.1007/s10658-014-0452-3.

SAS Institute Inc. (2012-2020). SAS® OnDemand for Academics. Cary, NC, USA. https://www.sas.com/en_us/software/on-demand-for-academics.html.

SIAP (Servicio de Información Agroalimentaria y Pesquera). 2022. Anuario estadístico de la producción agrícola. https://nube.siap.gob.mx/cierreagricola/.

Singh R, Mangat NS. 1996. Elements of Survey Sampling. First Edition. Springer Science & Business Media, Netherlands. 390 p.

Stenberg JA. 2017. A conceptual framework for integrated pest management. Trends in Plant Science, 22. 759-769. https://doi.org/10.1016/j.tplants.2017.06.010.

Usall J, De Cal A, Casals C, Peris M, Segarra J, Viñas I. 2010. Control de la podredumbre parda en melocotones y nectarinas del Valle del Ebro. Vida Rural, 302:54-57. https://repositori.udl.cat/server/api/core/bitstreams/ffc7c97a-90c0-48f9-9ebe-1760b2b93234/content.

USDA-ARS (United States Department of Agriculture-Agricultural Research Service). 2018. A national road map for integrated pest management. https://www.ars.usda.gov/ARSUserFiles/OPMP/IPM%20Road%20Map%20FINAL.pdf.

Uwamahoro F, Berlin A, Bucagu C, Bylund H, Yuen J. 2018. Potato bacterial wilt in Rwanda: occurrence, risk factors, farmers' knowledge and attitudes. Food Security, 10. 1221-1235. https://doi.org/10.1007/s12571-018-0834-z.

Villarino M, Melgarejo P, Usall J, Segarra J, de Cal A. 2010. Primary inoculum sources of *Monilinia* spp. in Spanish peach orchards and their relative importance in brown rot. Plant Disease, 94. 1048-1054. https://doi.org/10.1094/PDIS-94-8-1048.

Zaccagnini ME, Canavelli S. 1998. El Manejo Integrado de Plagas (MIP): Su aplicación a la resolución de problemas con aves perjudiciales a la agricultura. *In*: Manual de Capacitación sobre Manejo Integrado de Aves Perjudiciales a la Agricultura. Rodríguez EN y Zaccagnini ME (eds). FAO. Uruguay-Argentina, 1998. https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/sites/ministerio-ganaderia-agricultura-pesca/files/documentos/publicaciones/Manual_de_capacitacion_sobre_manejo_integrado_de_aves_perjudiciales_a_la_agricultura.pdf.

Zegbe JA, Mena J, Rumayor AF, Reveles LR y Medina G. 2005. Prácticas culturales para producir durazno criollo en Zacatecas. Publicación Especial No. 15. INIFAP. Zacatecas, México. http://zacatecas.inifap.gob.mx/publicaciones/PracticasDurazno2005.pdf. pp: 15-30.

Zehr EI. 1982. Control of brown rot in peach orchards. Plant Disease, 66:1101-1105. https://www.apsnet.org/publications/PlantDisease/BackIssues/Documents/1982Articles/PlantDisease66n12_1101.PDF.

Zehr EI, Toler JE, Luszcz LA. 1991. Spread and persistance of benomyl-resistant *Monilinia fructicola* in South Carolina peach orchards. Plant Disease, 75:590-593. https://doi.org/10.1094/PD-75-0590.

Zhou T, Schneider KE, Li XZ. 2008. Development of biocontrol agents from food microbial isolates for controlling post-harvest peach brown rot caused by *Monilinia fructicola*. International Journal of Food Microbiology, 126:180-185. https://doi.org/10.1016/j.ijfoodmicro.2008.05.020.