Biological and Chemical Control of Melon Root Rot Disease: A Review

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Abstract

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Melon is an important crop grown in different regions of the world, and similar to many other crops, it is exposed to many diseases, including root rot, which is caused by a number of pathogens such as *Rhizoctonia solani, Fusarium solani, Macrophomina phaseolina, Fusarium oxysporum* f. sp. *melonis* (Fom), which causes Fusarium wilt and *Monosporascus* spp. which causes Monosporascus root rot and vine decline. To reduce the use of chemical pesticides because of their negative impact on health and the environment, biological control factors and some safe chemical agents are being increasingly used to control this disease. Many studies have shown the effectiveness of *Trichoderma* spp. and *Bacillus subtilis,* and vermicompost in reducing the disease by inhibiting the fungal growth of these pathogens present in the soil and inducing resistance in the melon plant against the disease. In addition, the use of algae was found to be efficient in the control of the disease. The use of some chemical agents, such as potassium salt (K_2HPO_4) and tannic acid, had a role in inhibiting some pathogens in the soil. This article summarizes research conducted to test the role of biological factors (vermicompost, microorganisms, and algae) as well as some chemical agents (tannic acid and K_2HPO_4) in controlling melon root rot disease.

Keywords: Melon root rot, biological control, K_2HPO_4, vermicompost, algae.

Introduction

Melon, *Cucumis melo* L. is a major economic crop in the Cucurbitaceae family. It is grown around the world (Rocha *et al*., 2010), including Iraq (Al-Juboori *et al*., 2018). Soil-borne pathogens such as *Fusarium solani, Verticillium dahlia*, *Macrophomina phaseolina*, and *Rhizoctonia solani* can cause root rot in this crop (Buzi *et al.*, 2002; Infantino *et al.*, 2004). Disease agents like these are commonly controlled by using chemical fungicides (Kasumbwe *et al*., 2014). Chemical fungicides are easy to use with high effectiveness, but they cause environmental pollution as well as the accumulation of chemicals in the food chain (Barák, 2017; Hussain *et al*., 2009).

Agricultural pests, including pathogens and arthropods, cause significant losses annually (Adhab & Alkuwaiti, 2022; Adhab *et al*., 2021; Al-Ani *et al*., 2011b; Khalaf *et al*., 2023; Schoelz *et al*., 2021). Many studies demonstrated the effective use of biological control of pathogens present in the soil as a good alternative to chemical control, because it is safer and more environmentally friendly (Al-Ani *et al*., 2021; 2013). One of these biological control agents that is used against these pathogens and pests is vermicompost; it is produced from the bio-oxidation process of many organic materials (plant and animal waste and sewage waste) by using various types of earthworms and microorganisms; it is rich in vitamins, microorganisms, growth hormones, and nutrients. (Ali *et al*., 2015; Mupambwa & Mnkeni, 2018; Sharma & Garg, 2018; Sulaiman & Mohamad, 2020).

Additionally, there are chemicals, such as potassium salt (K_2HPO_4), that reduce fungal pathogens population in the soil that cause damping-off, root rot, and wilting in beet plants (Abdel-Monaim *et al*., 2015). Tannic acid also greatly slows down the growth of fungal hyphae and the germination of *Fusarium oxysporum* conidia when tested in the laboratory (Wu *et al*., 2010). Furthermore, other biological factors such as algae were also investigated as control agents for soil-borne diseases (Hewedy *et al*., 2000). The blue-green algae and eukaryotic algae produce antifungal substances (Kulik, 1995; Schlegel *et al*., 1998) that can inhibit the growth of many fungal pathogens (Bonjouklian *et al*., 1991; Kiviranta *et al*., 2006). Moreover, it was found that algae extract in powder (Weed-Max) or liquid form (Oligo-Mix) had the ability to inhibit fungal pathogens transmitted through soil. Algae are considered a good biological factor, along with other biological factors, in reducing root rot. (Abdel-Kader & El-Mougy, 2013). All these methods were effective in controlling plant diseases, including a number of crops such as melon, by inducing host resistance (Smith-Becker *et al*., 2003), and thus reducing the effects of pathogens in the soil (Okubara & Paulitz, 2005).

In conclusion, chemical pesticides are dangerous to health and the environment, so this review summarizes the importance of chemical and biological agents for the control of melon root rot disease as an alternative and safer approach than chemical pesticides.

Melon crop value and importance

The origin of melon has been reported to be from China in the past two thousand years BC (Keng, 1974). It is a member of the Cucurbitaceae family. It includes numerous commercially significant crops, including diverse horticultural and botanical types that are widely cultivated across subtropical, tropical, and temperate regions of the world (Napolitano *et al*., 2020). There are many uses for melon, as food, juice, nuts (seeds), and for medical use

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(Robinson & Decker-Walters, 1997). In terms of global production, China is in the lead, with its production reaching 17 million tons, followed by the American continent, with its production reached 3.6 million tons (FAO, 2019). Worldwide, melon is cultivated in an area estimated at around 1.1 million hectares, with annual production reaching about 28 million tons (FAO, 2020). In Iraq, melon crops are planted on around 13.77 thousand hectares, with a yield of around 12.547 tons per hectare (Arab Organization for Agricultural Development, 2020).

Melon fruit is rich in carbohydrates, protein, vitamins, and minerals such as potassium (Shafeek *et al.,* 2015). In addition, melon contains many antioxidant compounds. These compounds have the ability to protect the cells of the human body against cancer with low calories and fat content (about 17 kcal/100 g) (Shafeek *et al.,* 2015). Among the most potent antioxidants are ascorbic acid, carotenoids, and phenolic compounds. Seeds contain vitamin E and omega-3 fatty acids (Menon & Rao, 2012). Melons also contain alkaloids, and flavonoids, which increase their health benefits for people (Chang *et al*., 2015; Gómez-García *et al*., 2020).

Melon diseases

Melon, like many other crops, is susceptible to several diseases. One of these diseases that reduces melon yields globally is the fungus *Fusarium oxysporum* f. sp. *melonis* (Fom), which causes the Fusarium wilt disease (Silvia *et al.,* 2017). Moreover, one of the main genera of fungi in the soil that cause root and seed rot disease is *Macrophomina* sp. (Botryosphaeriaceae), which affects more than 800 host plants worldwide (Paiva *et al*., 2022).

One of the fungi that most often causes melon, *Cucumis melo* root rot or discolored vascular tissue is *Fusarium solani* (Aegerter *et al.,* 2000). Another disease is Monosporascus root rot and vine decline (MRRVD) caused by *Monosporascus* spp., which is currently one of the main obstacles to the production and spread of watermelon and melon crops globally (Bruton, 1998; Cohen *et al*., 2012a; Martyn & Miller, 1996). The major symptoms of MRRVD on cucurbits appear just before harvest, when the leaves start to show yellowing, wilting and dryness followed by a dramatic drop in vine health and death, which results in a large economic loss (Cohen *et al*., 2012a).

Among the common and destructive diseases that attack cucurbit leaves is powdery mildew (McGrath, 2017). The two most significant cucurbit powdery mildew (CPM) pathogen species are *Golovinomyces orontii* and *Podosphaera xanthii* (Kuzuya *et al.,* 2006). Mycelia and conidia are white in color, which mostly appear on stems and leaves but can also impact floral structures and fruits, as signs of infection. Leaf tissue that has been severely diseased may turn necrotic or chlorotic and brittle, and thus lowers photosynthetic capacity and consequently reduces yield and fruit quality (Stadnik & Bettiol, 2001). Another serious disease is downy mildew caused by the oomycete fungus *Pseudoperonospora cubensis* (Savory *et al*., 2011).

Many nematodes affect vegetable crops, but the root Knot nematode *Meloidogyne* spp. is perhaps the most serious and severely attacks cucumber and melon (Bertrand, 2001).

Phytobacterium *Acidovorax citrulli* is the causal agent of the economically important disease known as bacterial fruit blotch (BFB), which affects the production of cucurbits. *A. citrulli* that infects the seed coat and spreads infection to the germinating seedling (Burdman & Walcott, 2012). BFB can appear in melons and other cucurbits at any growth stage. Water-soaked lesions on hypocotyls, cotyledons, and leaves are among the signs of BFB infection. Little and erratic water-soaked lesions on fruits spread through the peel, causing decays, fissures, and total product loss (Cunty *et al*., 2019).

Melon root rot disease

Root rot diseases remain a major global threat to agricultural crop productivity. They are usually caused by more than one type of pathogen and are therefore often referred to as the root rot complex. Fungal and especially oomycete species are considered the main causes of the formation of this disease complex, and bacteria and viruses are also among the causes of root rot (Williamson-Benavides & Dhingra, 2021). Melon, like any other crop, is susceptible to infection with a variety of pathogens, and among these are soil-borne pathogens such as *Fusarium solani, Verticillium dahlia, Macrophomina phaseolina, and Rhizoctonia solani* that cause root rot (Buzi *et al*., 2002; Hashem *et al.,* 2017; Infantino *et al.,* 2004; Jabr & Al-Jubouri, 2014; Matloob & al-Amiri, 2017). The fungi *M. cannonballus* and *M. eutypoides* are two of the most important causes of root rot and vine decline in melons worldwide, and *Fusarium oxysporum* f. sp. *melonis* vascular wilt disease affects the world's melon production (Castro *et al*., 2020; Najeem & Kareem, 2018; Silvia *et al*., 2017).

Failure to follow appropriate crop rotation enhances the survival of pathogens in the soil, which leads to a high infection rate and a decrease in crop yield and quality, as a result of the root system damage, which leads to the deterioration of the plant and consequently its death. In addition, these fungi remain in the soil or crop residue for long periods of time, they form reproductive structures and stone bodies that are resistant to unfavorable environmental conditions (Oumouloud *et al.,* 2013).

In response to the failure to deliver nutrients through vascular bundles because of root rot induced by the fungal pathogen *Monosporascus sp.* and causes yellowing of leaves and wilting of the plants (Cluck *et al*., 2009; Picó *et al.,* 2008). For the first time in Iraq, Najeem & Kareem (2018) identified *M. cannonballus* as the causal agent of melon root rot.

The fungus *Macrophomina phaseolina* is one of the causes of fungal diseases found in the soil, which causes charcoal rot disease, which affects more than 500 plant species, including melon *Cucumis melo,* which again leads to rotting of the roots. The occurrence and severity of the disease is affected by the genetic nature of the cultivated variety, the age of the plant, temperature, and water availability (Cohen *et al.,* 2022).

Root rot disease often affects the productivity of melon crops in Brazil, and several Fusarium species were found to be the cause of this disease. 31 Fusarium isolates similar in morphology to *Fusarium solani* were collected from melon plants that showed root rot symptoms. Genetic analysis of these isolates showed that 29 isolates belong to the fungus *Fusarium falciforme* and 2 isolates belong to the fungus *F. sutonianum.* The pathogenicity test showed that all isolates cause watermelon root rot and there are no significant differences between these isolates in terms of virulence (Silva *et al*., 2003).

Chemical control of root rot disease

Chemicals such as potassium salt (K_2HPO_4) are effective in reducing the incidence of diseases caused by soil-borne fungi, including damping-off disease, root rot, and beet wilt (Abdel-Monaim *et al*., 2015; Aleandri *et al*., 2010). Previous research showed that seeds treated with acybenzolar-S-methyl (BTH) and dipotassium hydrogen phosphate (K_2HPO_4) produced plants that were more resistant to the pathogen *M. cannonballus* than seeds treated with methyl jasmonate, and reduced root rot disease severity. These products enhanced resistance through the production of a number of disease-related proteins (PR) that play a role in the resistance of the root system to the disease caused by the fungus *M. cannonballus*. It is known now that there is a complex pathway inside the plant cell that induces the production of hormones and enzymes that can inhibit the pathogen growth (Adhab, 2021). Previously reported studies conducted in the field and under greenhouse conditions showed that treatment with K_2HPO_4 induced resistance in beet plants against pathogenic fungi that cause damping off, root rot, and wilt, namely *R. solani, F. solani, and F. oxysporium* (Abdel-Monaim *et al.*, 2015).

Tannic acid, one of the tannins and a member of the phenolic acids family, is another chemical compound that has ten molecules of gallic acid connected to its core glucose molecule (Aelenei *et al*., 2009). In both laboratory and field experiments, Bien (2016) demonstrated that tannic acid inhibited the growth of the fungus *F. graminearum,* which causes Fusarium head blight (FHB) on barley. In addition, tannic acid was also shown by Osman *et al.* (2019) to have an inhibitory effect on the *R. solani* fungus in both the laboratory and in the field. In many crops, including melon, chemically induced resistance to plant diseases is an efficient effect on disease control (Okubara & Paulitz, 2005; Smith-Becker *et al*., 2003).

Biological control as an alternative to fungicides

Chemical fungicides were used to control root rot diseases because they are effective and easy to use (Kasumbwe *et al*., 2014). However, these chemicals are expensive, can induce the emergence of pesticide-resistant plant pathogenic strains and pollutes the environment (Seong *et al*., 2017). Accordingly, alternative, environment-friendly solutions need to be developed. Research showed that the biological management of diseases found in the soil is an effective safe substitute for chemical control (Al-Ani *et al*., 2011a; 2011c; 2013).

Using natural farming products, such as vermicompost and its variants made from earthworms' metabolic fluids, mucus, and skin secretions, and bacteria that break them down, makes the soil more fertile and reduces the biological stress that soil pathogens put on plants (Gudeta *et al*., 2021). Vermicompost useful components such as phosphorus bacteria, gibberellins, cytokinins, auxins, and Rhizobium bacteria are needed for plant's growth. Vermicompost is rich in the major element's phosphorus 1.55-2.25%, potassium 1.85-2.25%, and nitrogen 2-3%, as well as the microelements necessary for plants (Edwards *et al*., 2004; Sinha *et al*., 2010). Vermicompost has the potential to inhibit infection, which makes it a superior option to chemical pesticides; this is because vermicompost is connected with earthworm excretions, especially skin secretions that include the antifungal substance lumbricin-PG (Li *et al*., 2011; You *et al*., 2019).

In both laboratory and field experiments, vermicompost inhibited the growth of *R. solani*, the fungus that causes cucumber damping off (Ersahin *et al*., 2009; You *et al.*, 2019). *In-vitro* studies showed that when coelomic fluid from the earthworm *Eudrilus eugeniae* was added to the media, it inhibited the growth of four fungi: *Verticillium dahliae, Aspergillus flavus, R. solani,* and *F. oxysporum* (Rajesh *et al*., 2019).

Vermicompost and the bacteria it contains, such as *Streptomyces* sp., *Pseudomonas* sp., *Burkholderia* sp., and *Bacillus* sp., can produce compounds that can suppress plant diseases (Sulaiman & Mohamad, 2020). In 2014, Jabr & Al-Jubouri reported that root and stem rot disease in melon plants is caused by a number of different fungi, such as *Drechslera australiansis, M. phaseolina, F. solani, F. oxysporum, F. proliferatum, R. solani,* and *Plectosphaerella cucumerina*. They also reported that *Azotobacter chroococcum* and *Pseudomonas fluorescens* were effective at suppressing these pathogens.

Hashem *et al*. (2017) showed that the bacteria *Bacillus subtilis* and the fungus *Trichoderma viride* could reduce the effects and frequency of charcoal rot in melons caused by the fungus *Macrophomina phaseolina*. It was found that treatments with salicylic acid, *Trichoderma harzianum*, and *B. subtilis* made root rot disease in melon caused by the fungus *R. solani* less common and less severe (Matloob & Al-Amri, 2017). According to Ahmed (2022), *Trichoderma harzianum* is a highly effective inhibitor of the fungi *F. oxysporium* and *Macrophomina phaseolina,* which are among the causes of root rot disease in melon plants.

The fungus *Trichoderma viride* Pers. is one of the powerful biological control agent that inhibits many plant pathogens, as it possesses enzymes that can decompose the cell walls of pathogenic fungi; It is also a good competitor for food and space, has the ability to produce antibiotics, and also works to induce systemic resistance in the plant and stimulate its growth (Sood *et al*., 2020).

The use of yeasts to control pathogens is an additional bio-control method due to their ability to inhibit the growth of many pathogens; they are also considered safe for humans and the environment (Shalaby & El Nady, 2008). Fungal species like *Pythium* sp., *Fusarium* sp., and *Rhizoctonia solani* are inhibited by the yeasts *Saccharomyces cerevisiae* and *Kluyveromyces lactis* in the soil (Porhanife, 2010).

Hussein *et al*. (2022) showed that *Chaetomium cupreum*, *Trichoderma viride*, and *Saccharomyces cerevisiae* are bio-control agents that could effectively inhibit the growth of the soil-borne pathogens *Fusarium oxysporium, F. solani, Rhizoctonia solani, Pythium aphanidermatum,* and *Macrophomina phaseolina*. Such treatment reduced the infection rate and severity of root rot disease in tomatoes, cucumbers, and cowpeas, and improved seed germination rate.

Another natural agent that can be used against pathogens is algae. *Chlorella vulgaris* and *Spirulina platensis* were found to reduce the symptoms of tomato root rot caused by the fungus *R. solani* (Muhanna *et al*., 2015). In the laboratory, algae inhibited the growth of the fungal mycelium of *R. solani*, *F. oxysporum*, and *F. solani*. In greenhouse application, algae made it much less likely for seedlings to be killed pre- or post-germination compared to the control treatment (El-Sayed *et al*., 2015).

At different locations, studies showed that commercial algae products treated with microorganisms (biological factors) protected tomato, cucumber, pepper, and melon plants from attack by root rot better than other treatments, such as chemical pesticides, with nsignificant increase in yield. The commercial algae product Weed-Max (2 g/L) + *Bacillus subtilis* showed superiority in reducing the incidence of the disease in vegetable plants over the treatment of the commercial algae product Oligo-X (2 ml/L) + *Trichoderma harzianum, or the* fungicide treatment (Abdel-Kader & El-Mougy, 2013). The blue-green algae extract had a role in inhibiting the growth of *Fusarium oxysporum* f. sp. *lycopersici*, the causal agent of tomato wilt in the laboratory and the field (Kim & Kim, 2008).

Integrated management of melon root rot disease

Integrated Pest Management (IPM) is a more recent eco-friendly approach for pest control where several control components are integrated with minimal use of chemical pesticides (Al-Ani *et al*., 2021). Large reduction in melon productivity is caused by fungal diseases, mostly due to damage of the root system which can lead to plant death. Fungi are often difficult to control because they leave behind stable structures that can survive for a long period in the soil or crop residue such as sclerotia (*Rhizoctonia* sp., *Sclerotium* sp., and *Macrophomina* sp.) and chlamydospores (*Fusarium* sp.). When available, host resistance is the most appropriate control measure, but pathogens can develop new strains that can break down host resistant genes (Adhab *et al*., 2018; Mohammed *et al.*, 2021; Oumouloud *et al*., 2013). Soil fumigation with methyl bromide proved to be effective in controlling many soil-borne pathogens (Noling & Becker, 1994). However, methyl bromide application was banned internationally because of the environmental hazards it caused, and consequently encouraged the adoption of integrated disease/pest management. The environmentally friendly methods of managing root diseases include the utilization of resistant varieties (Ambrósio *et al.*, 2015; Dias *et al*., 2004; Salari *et al*., 2012;), modification of irrigation systems (Cohen *et al*., 2002), soil solarization (Cohen *et al*., 2012b; Gamliel *et al*., 1996; Guimarães *et al*., 2008; Stapleton 2000), resistant rootstocks for grafting onto melon (Cohen *et al*., 2012b; Cohen *et al*., 2002), biopesticides (Narayan *et al.*, 2015), and incorporation of green manure (Dantas *et al*., 2013). all proved to have good control potential. Such approaches can better support a balanced soil microbiome and enhance disease management. Such approaches need to be investigated for the control of melon root rot. Plant residues can boost soil fertility and microbial biomass when they are added to the soil, and at the same time release chemicals that inhibit soil-borne pathogens (Stone *et al.*, 2004). In green manure farming, root pathogens can be controlled via biofumigation, in which poisonous compounds are generated when plant residue decomposes. Mulching has the ability to physically obstruct light in the soil, which is necessary for the development of pathogen structures, the emergence of dormant spores, and/or the development of resistant structures such as sclerotia (Lobo Junior *et al*., 2009).

Conclusions

Melon is a major crop and is grown in many regions of the world and over large areas. It is infected with many fungal pathogens, which cause many diseases that affect yield and quality. Among these diseases is root rot disease, which is caused by many pathogens present in the soil, and belong to the genera *Fusarium, Rhizoctonia, Pythium, Macrophomina, Monosporascus,* and possibly others.

Chemical pesticides have played a role in controlling these diseases, including root rot, but for the negative effects of these pesticides on health and the environment and for the purpose of finding safe and environment-friendly alternatives in combating these diseases, some biological and physical factors have been successfully used (Al-Ani *et al*., 2011b; 2011c). Among the biological factors are microorganisms such as *Trichoderma* sp., *Bacillus* sp. bacteria, and others. Vermicompost was successfully used to control the toot rot disease by inhibiting the pathogens, improving plant growth and inducing host resistance. Furthermore, algae extracts were found to be an effective component for the control of the disease. The safe chemical agents found to effectively control the disease include tannic acid and potassium salt K_2HPO_4.

الملخص

صليبي، عماد علي وحرية حسين الجبوري. 2024. المكافحة الحيوية والكيميائية لمرض تعفن جذور البطيخ: مراجعة علمية. مجلة وقاية النبات العربية، 42(4): 465–473. https://doi.org/10.22268/AJPP-001271

يعدّ البطيخ من المحاصيل المهمة والذي يزرع في مناطق مختلفة من العالم. يتعرض محصول البطيخ مثل باقي المحاصيل الأخرى إلى العديد من الأمراض، ومنها مرض تعفن الجذور الذي تسببه العديد من المسببات المرضية، مثل: *Rhizoctonia solani*، *Fusarium solani*، *Macrophomina phaseolina*، *Fusarium oxysporum* f. sp. *melonis* (Fom) الذي يسبب الذبول الفيوزارمي و *Monosporascus* spp. الذي يسبب مرض تعفن الجذور وتدهور الأفرع. وللحدّ من استخدام المبيدات الكيماوية بسبب تأثيرها السلبي على الصحة والبيئة، يتمّ استخدام عوامل المكافحة الحيوية وبعض المركبات الكيميائية الآمنة على نحوٍ متزايد للسيطرة على

هذا المرض. أظهرت العديد من الدراسات فعالية كلّ من .Trichoderma spp و Bacillus subtilis والسماد الدودي في الحدّ من المرض عن طريق تثبيط نمو الفطور الممرضة الموجودة في التربة وتحفيز مقاومة نبات البطيخ للمرض. بالإضافة إلى ذلك، وجد أن استخدام الطحالب ذو فعالية في السيطرة على المرض. وكان لاستخدام بعض المركبات الكيميائية، مثل ملح فوسفيت البوتاسيوم (K_2HPO_4) وحمض التانيك، دور في تثبيط بعض مسببات الأمراض في التربة. يلخص هذا المقال الأبحاث التي أجريت لاختبار دور العوامل الحيوية (السماد الدودي، الكائنات الحية الدقيقة والطحالب) وكذلك بعض المركبات الكيميائية (حمض التانيك و K_2HPO_4) في السيطرة على مرض تعفن جذور البطيخ.

كلمات مفتاحية: تعفن جذور البطيخ، المكافحة الحيوية، K_2HPO_4، السماد الدودي، الطحالب.

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