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Status of Potato Wart Disease (*Synchytrium endobioticum*) in Turkey and Control Methods

Hale Gunacti[1*] • Ali Erkılıc[2] • Hulya Ozgonen[3]

[1] Biological Control Research Station, Adana, Turkey
[2] University of Cukurova, Agricultural Faculty, Department of Plant Protection, 01330, Adana, Turkey
[3] University of Suleyman Demirel, Agricultural Faculty, Department of Plant Protection, 32260 Isparta, Turkey
Corresponding author: * **hale_esen@hotmail.com**

ABSTRACT

Potato (*Solanum tuberosum*) is one of the most important global food sources and Turkey is one of the major seed and table potato-producing countries. There are many important pests and diseases preventing the production of potatoes. Potato wart disease caused by *Synchytrium endobioticum* was recently considered to be the most destructive fungal disease of potato. Typical symptoms of the disease occurring on tubers are cauliflower-like warts or tumours of different size. The disease can cause symptoms on the underground parts of potato plants including the crown, stolons and tubers, but not roots. *Solanum tuberosum* and other species of *Solanum* are the primary hosts of the disease. The disease prefers cool climates and is known to exist in 43 countries. Losses due to the disease range between 50 and 100% worldwide. Contaminated potato-growing areas ban seed potatoes because of the disease and there is zero tolerance in production. Recently, the disease has been well managed by strict quarantine measures and resistant varieties. However, it has still causing serious losses due to the existence of different races in different locations. In addition, some cultural methods are important to prevent the dispersal of this disease and, to date, there is no effective chemical application program against it. Despite control methods, the disease still remains economically significant. In this review, some informations about potato wart disease, including general characteristics of the disease, signs and symptoms, status in Turkey, epidemiology and disease management, are presented.

Keywords: control methods, disease symptoms, quarantine

CONTENTS

INTRODUCTION

In Turkey, potato is produced in Niğde, Nevşehir, Kayseri, Sivas, Bolu, Adana and Erzurum provinces. Especially, Nevşehir and Niğde are the centers of seed and table potato production. There are many pests and diseases that prevent the production of potatoes. Among these diseases, *Synchytrium endobioticum* (Schilberszky) Percival or potato wart disease (PWD) is the most important (harmful) quarantine pest of potato agriculture and production. In the infested areas, planting of seed and table potato is forbidden. The disease, which usually prefers cool climates, is known to exist in 43 countries today (Baayen *et al*. 2006). The losses in yield caused by PWD range from 50 to 100% (Hampson 1993; Melnik 1998). The economic losses caused by PWD do not occur only because of the direct infection of the pathogen, but also from the quarantine, long-term crop rotation, legal sanctions, increasing research activities and due to factors such as the promotion of training of only resistant potato varieties (Hampson 1993).

According to 2009 data, potatoes account for 18.326.242 ha of plantation area, 329.556.911 tons of production and 1798,3 kg of yield in the world while the area of plantation is 142.684 ha, production is 4.397.711 tons and yield is 3082,1 kg in Turkey (FAO 2009). Turkey ranks 7th after China, Russia, India, Poland, USA and Germany in terms of plantation area and production (Anonymous 2002).

PWD is caused by the soil-borne fungus *S. endobioticum* belonging to *Chytridiomycetes* class as an obligate fungus (Langerfeld 1984). PWD became distributed from the primary infection area in mountains of South America to North America and Europe at the end of the 19th century. Nowadays, PWD is well known in all potato-growing regions; Asia, Africa, America and Pacific Ocean countries (EPPO 2004).

The pathogen is believed to have been first introduced to the European community with potato breeding material from the South American Andes brought in during the aftermath of the 1840-1850 potato late blight tragedy, a disease caused by *Phytophthora infestans.* PWD was reported to enter England in 1876 and then thought to have spread to most potato-growing areas in Europe, being first reported on the European continent in Czechoslovakia (1888), followed by one of the earliest formal descriptions of potato

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Invited Mini-Review

Fig. 1 (**A**) Sporangia of *Synchytrium endobioticum*. (**B, C**) Symptoms of potato wart disease. Photos by H.GUNACTI from PhD thesis.

wart and the pathogen (by Schilbersky) from upper Hungary in 1986. In 1908, PWD was reported in Ireland and Germany and shortly afterwards in Scotland and Wales. The diseases was first found in the Netherlands around 1914, and gradually spread into other potato-growing regions of Europe until World War II (Baayen *et al*. 2006). The first report of PWD in Turkey was in 2001 (Cakır 2005).

PWD is known by various names, including black scab, black wart, cauliflower disease, potato tumor, potato cancer, wart, warty disease, and certainly many other descriptive names in several languages. The agent of the disease, *S. endobioticum*, is considered to be the most important worldwide quarantine plant pathogen of cultivated potato (Walker 1983).

In this brief review, some information about the most important potato pathogen, *S. endobioticum*, including hosts, characteristics of the disease, disease cycle, status in Turkey and control measures are mentioned.

HOSTS

Potato is the principal host, but *S. endobioticum* was experimentally transferred to tomato, black nightshade and climbing nightshade (*Solanum nigrum* L. and *S. dulcamara* L.). Both nightshades showed wart symptoms in pot experiments, though neither had been observed to be attacked in nature. Extensive testing of a number of species belonging to the *Solanaceae* did not produce any infections (Weiss 1925; Hampson 1993).

CHARACTERISTICS OF THE DISEASE

S. endobioticum is an obligate parasite that produces sporangia containing 200-300 motile zoospores and does not produce hyphae. In the spring, at temperatures above 8°C and sufficient moisture, the winter (long-lived) sporangium in decaying warts in the soil germinates and releases uninucleate zoospores. The latter possess a single flagellum enabling them to move in soil water and reach the living host. The flagellum is then lost and the zoospore penetrates the host cell. This becomes greatly enlarged and the enclosed fungus forms a short-lived, quickly reproducing stage, the summer sporangium, from which numerous zoospores are rapidly discharged and reinfect surrounding cells, which again produce summer sporangia. Resting sporangia are golden brown and spheroidal (35 to 80 µm in diameter) (**Fig. 1A**). Summer sporangia are of similar size with winter sporangia but transparent and thin-walled, and contain numerous flagellate zoospores (CABI 2003).

PWD distribution is limited by warm summer soil temperatures. Stachewicz and Enzian (1998) found that PWD was a problem in areas that have mean temperatures between 15.9 and 16.6°C from June to August. The effect of temperature on disease incidence was studied in controlled experiments with micropropagated potato plantlets. Maximum disease incidence occurred at 15°C. Incidence of PWD at 12 and 18°C was approximately 10% of that at 15°C (Hampson *et al*. 1994). Conditions favorable for disease development include cool summers with average temperatures of 18°C or less, winters of approximately 160 days at or below 5°C and annual precipitation of 70 cm. Temperatures between 12-24°C favor infection.

DISEASE CYCLE

In the spring, resting sporangia in decaying warts and soil germinate to release haploid (uninucleate) zoospores (Hampson 1993; Franc 2001). These zoospores migrate in soil water for a limited distance (50 mm or less) via a single flagellum to arrive at epidermal cells of meristematic tissues of growing points, buds, stolon tips, or young leaf primordia. Zoospores are short-lived and must encyst and infect susceptible host tissue within 1-2 h after their formation. After infection by zoospores, potato host cells greatly enlarge and haploid sori form inside the host cells while neighboring host cells begin to proliferate, resulting in the characteristic warty galls and the increased presence of the meristematic tissue that provides new infection courts for the fungus. Each sorus contains 1-9 summer sporangia, which in turn germinate to produce new haploid zoospores which reinfect susceptible tissue. These rapidly repeating secondary disease cycles ultimately result in an extensive invasion of host cells and rapid onset of gall formation. Young galls are a nutrient sink and expand rapidly at the expense of other plant tissue (Weiss 1925).

S. endobioticum has a very limited capacity for natural spread, making it possible to control it effectively by statutory means. Spread of PWD between countries or between farms is primarily through infected seed potatoes.

SYMPTOMS

Typical symptoms of PWD is the cauliflower type warts on potato tubers (**Figs. 1B, 1C**). Initially, the size of warts change in pea size to hand punch size with white to green color (Hampson 1981). The disease can cause symptoms on all other parts below the soil apart from roots; however, on other varieties such as tomatoes it can cause symptoms on roots as well (Hampson and Haard 1980). The disease is distributed by infected soil, irrigation water, soil equipment and plant materials (Hampson 1995).

STATUS IN TURKEY

PWD was determined only in Ordu and Nevşehir provinces in 2002, was found in Niğde and Giresun in 2004, in Kayseri and Trabzon in 2005, in Erzurum in 2007 and in Aksaray in 2010. In fact, the presence of the disease in Turkey was first determined in 2001 in two fields, one in Ordu an one in Nevşehir. According to the official results of a survey conducted in the provinces where potato is commonly grown across the country between 2002-2006, PWD was determined in the Black Sea Region: in 206 fields in Ordu, in 15 fields in Giresun and in 9 fields in Trabzon. In the Central Anatolian region where seed and table potato are grown commercially, contamination was found in 25.714 decare in Nevşehir, in 1.473 decare in Niğde and in 319 decare in Kayseri. Then in 2007 in the county of Tortum, Erzurum in the Eastern Anatolia and in 2010 in a field in Aksaray the presence of PWD was reported (Anonymous

2010). After the survey, field work was carried out in Turkey, and disease maps of contaminated areas were created and quarantine measures to prevent spread of disease were taken. In this context, because of the risk for growing potato in contaminated fields and spreading contaminated soil to clean areas, propagating seedlings, seedling production and growing storage rooted crops were prohibited. Creating safety zones around contaminated areas has been attempted to restrict the disease in the area. In the traceability and the eradication of contaminated areas in Turkey, monitoring criteria related to plant health procedure number EPPO PM 3/59 (2) are used (EPPO 2003). When the fields in which the spread rate and spread areas of the disease were identified in Turkey were compared, it was observed that the disease is irregular and increasing rapidly in fields between cities or far away from each other in the same city (Anonymous 2009a). Especially in the Central Anatolia Region PWD carried with movement of tubers and earth was more rapid and irregular than other provinces because of the exchange of seeds, raising animals and making contraband production in areas where potato agriculture was banned (Günaçtı and Erkılıç 2010).

As in other contaminated countries, the human factor in Turkey plays a major role in the spread of the disease (Hampson 1993). In Nevşehir province where PWD was most prevalent, the amount of quarantined fields has increased year by year and that led to a decrease in potato production. In 1998-2000 approximately 27.000 ha of potato was produced in Nevşehir when there was no disease. It was determined that in 2009 the disease was very common and in 10.540 ha potato was produced and the production area fell by around 60% (Anonymous 2009b).

PWD usually prefers cool climates and is known to exist in 43 countries today (Baayen *et al*. 2006). 18 different pathotypes of the fungus which infect different potato varieties were identified and among them pathotype 1 (European race) was the most common (Bojnansky 1984). In studies about the races in Turkey, Pathotype 1 was identified in the Black Sea Region and Central Anatolia and Pathotype 6 and Nev 38 a new pathotype were identified in Central Anatolia (Çakır *et al*. 2009).

Control methods

S. endobioticum has been subjected to quarantine and domestic legislation to prevent its spread worldwide for more that 65 years. Crop protection chemicals were not effective in controlling PWD. Exclusion of the pathogen from non-infested areas is the most efficient method of disease control. PWD is very difficult to control. Nowadays, quarantine measures are carried out to prevent the spread of the disease. The disease is a zero-tolerance quarantine disease all over the world. Therefore, growing areas that are considered to be contaminated prohibit the cultivation of potato even if only a single spore of the disease is found.

PWD is resistant to fungicides. More than 120 inorganic and organic chemicals alone or in combination were tested but reported to be successful, as their applications were phytotoxic or resulted with unproductive soil (Gimingham and Spinks 1919; Roach *et al*. 1925; Crowther *et al*. 1927; Zakopal 1950; Hartman 1955; Olsen 1966).

PWD was banned in all countries where it was found in potato-growing areas. The first control measure of the disease is to limit the disease inoculum of infected areas and to prevent the spread of the disease-contaminated plots; the second is to cultivate resistant potato varieties in growing areas which have contaminated plots around. The use of resistant varieties in contaminated areas officially designated zones established for protection by the European Union (EU 1969). In addition, countries are required to take preventive measures in the spread of the disease to neighboring countries. Thus, potato production areas must be disease free in international trade and countries must provide it (EU 1969; EPPO 2007a).

Kharitonova (1969) tested approximately 200 organic and inorganic compounds. Chloropicrin achieved effective results after application but it was not appropriate to use because of its high cost. In addition, studies with fumigants and some other chemicals against PWD were conducted and these chemicals gave effective results in the control of disease.

Noehr and Mygrind (1977) reported that 98% methyl bromide at doses of 50–200 g/m^2 for 72 h could control *S. endobioticum* in infected soils. Nowadays, the use of methyl bromide is prohibited. Potocek (1991), conducted a study comparing the effectiveness of chemical control of PWD: best results were achieved by granular urea (500 g/m^2) in the implementation. The effects of four different concentrations of metham sodium, formaldehide, metham sodium and urea against disease formation of *S. endobioticum* were investigated: the most effective result was achieved by metham sodium at 60 and 80 g/m^2 (Günaçtı and Erkılıç 2010). To date, the disease has been eradicated with chemicals according to the amount of inoculum in the soil in infected areas but this is not a long-term success (De Boer 2005; Reigner 2006).

The efforts to control the disease were focused on biological control and agroecological studies, besides chemical control. Hampson (1979) stated that agrotechnical control methods including the use of resistant varieties, fallowing, organic soil fertilization and cultivation of early season potatoes could be used in the control of the disease. Hampson and Coombes (1995) reported that the use of chemicals for the eradication of the pathogen in soil were not preferred because of the phytotoxic effects on the environment and instead crushed crab legs reduced the PWD by 100% without phytotoxity. Amendment of infested soil with crushed crab shell (23% chitin) has been found to suppress the disease in some situations. The mechanism of disease suppression is not known with certainty, but may be related to changes in soil microflora activity following incorporation of crushed crab shell or may be related to physiological changes in the host. In a study to investigate the role of alternative plants and the impact of root exudates on sporangium amount was designated. In this research, the interaction in between the sporangium amount and root exudates released by the seeds while germinating was taken into consideration. At the end, the highest sporangia death ratio was obtained from the sunflower and rye within 15 different alternative plants to potato cultivation. The crops such as cereals, maize, garlic, onion and alfalfa keeping the cultivation soil as dried in the areas infected with PWD were found significantly efficient on the ratio of sporangia death (Günaçtı and Erkılıç 2010).

The investigators agreed that the control of the disease is very difficult because of the transportation of *S. endobioticum* by soil and by seeds and the resting spores of the pathogen in soil maintain their vitality up to 38 years. Quarantine programs should be targeted to the prevention of the disease because of the longevity of the organism and ineffective chemical control methods. In addition, it has also been reported by many researchers that prohibiting the cultivation of potatoes, quarantine measures, long term crop rotation, increasing research activities and cultivation of resistant varieties helped to prevent the spread of disease (Laidlaw 1985; Karamchandani 1987; Hampson 1988; Putnam and Sinderman 1994).

In summary, considering the characteristic features of the disease, and the zero tolerance in soil, any practice alone is not sufficient. The transport of soil and tubers should absolutely be avoided. There are two major problems encountered in chemical control; one is the hazardous effects of chemicals to human, animal and plant health, and the other is the limited control methods in integrated crop management. Therefore, the main principle in the control of the disease should be strict quarantine measures to prevent transmission of disease among regions.

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