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Chapter 9

WATER AS THE IMPOTRTANT SOURCE OF *PHYTOPHTHORA* SPECIES IN HORTICULTURE AND NATURAL ENVIRONMENT

Leszek B. Orlikowski and Magdalena Ptaszek
Res. Institute of Pomology & Floriculture, 18 Pomologiczna street,
96-100 Skierniewice, Poland.

ABSTRACT

Contaminated water is primary, if not a sole, source of inoculum for *Phytophthora* diseases of numerous nursery, fruit and vegetable crops but also an efficient means of spreading *Phytophthora* from one geographical location even to other countries and continents. Such water used for plant irrigation can results in serious disease epidemics and crop losses even to 100%. For preventive of *Phytophthora* spread and managing of diseases caused by this group of pathogens rapid, simple and universal methods were elaborated. Among at least 20 plant species rhododendron leaf baits are the most successful for recovery of *Phytophthora* from water and may be especially used for qualitative detection of that group of pathogens whereas filtration technique is also available for analysis of population density. Using of baits, filtration and molecular methods at least 17 *Phytophthora* species were recovered from water reservoirs, drainage and irrigation canals and rivers. It was found that *Phytophthora* species may be recovered from water irrespective to season but frequency of isolation was correlated with temperature, source of water and its physical and chemical factors. Filtration, ultraviolet irradiation, chlorination and application of nonionic surfactants and calcium may be used for water disinfection.

Keywords: Water, sources, *Phytophthora*, recovery, baits, filtration, factors, time, population, elimination.

INTRODUCTION

Phytophthora species are the most damaging plant pathogens. Zentmyer [1983] characterized shortly the genera name as plant destroyer. In the last 10 years severe decline of alders caused by *P. alni,* transports with river's water, was noticed from Great Britain and France to Greece and north part of Europe [Gibbs et al. 1999, Streito et al. 2002]. In horticulture and forestry *Phytophthora* species are the reason of root and foot or stem base rot. In favorable conditions disease outbreaks may occur at almost any time during the production cycle as well as in landscape plantings. In the production of some plant species losses varied from a few % even to 100% [van Steekelenburg 1974, Orlikowski 2006a, b]. Besides seedlings and cuttings surface water has been implicated as an important factor for dispersal of *Phytophthora* species. They are well adapted to live in water which is necessary to produce zoosporangia from which motile zoospores are released. They are the most important propagules for new infections and spread of that group of pathogens in water. Thomson and Allen [1974] found only zoospores in irrigation water and studies of Kliejunas and Ko [1976] with *P. cinnamomi* confirmed that finding. In opinion of Hong and Moorman [2005], the contaminated water is a primary, if not a sole, source of inoculum for *Phytophthora* diseases of numerous nursery, fruit, and vegetable crops. Themann et al. [2002] and Orlikowski et al. [2007] included also hardy ornamental nursery stocks as cultivations especially imperiled by *Phytophthora* spp.

In the last years crop bioterrorism, strictly connected with plant pathogens is an arising problem in the world. Water could be the easiest and the fastest source of pathogens, including *Phytophthora* spp., spread over the countries and even continents [Miligroom and Peever 2003].

PHYTOPHTHORA SPP. AND OTHER MICROORGANISMS IN WATER

Plant pathogens in irrigation water are very significant in crop health issue. In opinion of Hong and Moorman [2005] this issue increased greatly and will continue to be a problem as agriculture increasingly depends on the use of recycled water. Besides 17 *Phytophthora* species from water resources other plant pathogens were detected including 26 of *Pythium* spp., 27 genera of fungi , 8 species of bacteria, 10 viruses and 13 species of parasitic nematodes [Hong and Moorman 2005]. Thompson and Allen [1974], using RBA medium and additionally sieving technique for isolation of different organisms from irrigation water besides *P. parasitica, P. citrophthora* and *Phytophthora* spp., detected 47 genera of fungi including *Alternaria, Ascochyta, Aspergillus, Cephalosporium, Cladosporium, Diplodia, Fusarium, Geotrichum, Helminthosporium, Isaria, Macrophoma, Mucor, Penicillium, Pestalotia, Phoma, Pyrenochaeta, Pythium, Stachybotrys, Trechispora* and *Trichoderma*. In our study [Orlikowski et al., nonpubl.], besides *Phytophthora* spp. *Alternaria alternata, Botrytis cinerea, Fusarium avenaceum, F. culmorum, F. oxysporum, Penicillium* spp., *Pythium spp., Rhizoctonia solani* and *Trichoderma* spp. were detected from Polish rivers, canals, lakes and water ponds.

DETECTION METHODS OF *PHYTOPHTHORA* SPP. IN WATER

Plant baits have been shown by many authors to be very effective in assaying contaminated soils, water and host tissues for detecting *Phytophthora* species [Erwin and Ribeiro 1996]. Active zoospores congregate near the surface of water and are naturally attracted to plant parts. Trapping plants or their parts may be used as monitoring for changes in relative *Phytophthora* levels in water. Dance et al.[1975] specified the following criteria for the ideal bait in a *Phytophthora* bioassay in soil: susceptibility to all or at least the most important root-infecting species, high sensitivity, reasonable size, inexpensiveness, ready availability geographically and seasonally and convenience of use both in setting up an assay and in subsequent isolating procedures. In opinion of Chee and Newhook [1966] lupine and pine needle techniques closely satisfy the above criteria. At least 20 plant species or their parts were used for detection of individual species or groups of *Phytophthora* in recirculation water (Table 1). Themann et al. [2002] used as the baits apples, lupine seedlings and rhododendron leaves. The rhododendron leaves trapped 10 identified *Phytophthora* species in water pond (*P. cambivora*, *P. citricola*, *P. citrophthora*, *P. cryptogea*, *P. drechsleri*, *P. gonapodyides*, *P. richardiae*, *P. syringae*, *P. undulata*, *P. ramorum*) and some unknown isolates whereas other plant baits twice less. It indicates on rhododendron leaf baits as the most successfull. Lauderdale and Jones [1997] recovered *P. cinnamomi*, *P. cryptogea* and *P. parasitica* from nursery effluent by baiting assays. Lupine seedlings were excellent bait plant for recovery of *P. cinnamomi* from irrigation water in cranberry plantations [Oudemans, 1999]. Using filtering and baiting techniques Bush et al. [2003] recovered from recycled surface of effluent in perennial container nursery reservoir *P. capsici*, *P. citricola*, *P. citrophthora*, *P. cryptogea* and *P. drechsleri* whereas on the depth of 1 and 1,5 m additionally *P. cactorum*. From water used for irrigation of citrus orchards, citrus leaf bait allowed to recovered *P. parasitica*, *P. citrophthora* and unidentified *Phytophthora* species [Thomson and Allen 1974]. In trials of Yamak et al. [2002], using of pear baiting technique gave possibilities for detection of *P. cactorum*, *P. citricola*, *P. gonapodyides* and 4 clades of *Phytophthora* in orchards irrigation canals.

Using of filtration method allows seperation of *Phytophthora* species and qualify their population density [Hong et al., 2002]. Themann et al. [2002] used DAS-ELISA using polyclonal antisera produced against *P. cinnamomi* and *P. cactorum*. Ali-Shtayeh et al.[1991] filtered irrigation water samples through 0,45μm filters to concentrate *Phytophthora* zoospores before extraction. Using ELISA test the authors recovered even small amounts of zoospores in water. The method is especially important for HNS where growers are aware of Phytophthora root and stem base rot risk associated with recycled water. Hwang et al. [2007] used rhododendron leaf baits and filters for detection of Phytophthora spp. from forest streams. Isolation of that group of species varied depending on month, location and detecting method. Over the entire study period 13 of the 14 species and groups were detected by filtration while only 8 species and groups were isolated with using baits.

Lutz and Menge [1990] quantified the types of *P.parasitica* propagules present in irrigation water in citrus groves from Novemeber through August using selective medium and soil-dilution plant assay. In November and from May through August sporangia and zoospore cysts accounted for the majority of the population whereas from December through April chlamydospores were the most frequently observed.

Table 1. Plant baits and filters used for detection of *Phytophthora* species from water.

Phytophthora species	Plant baits	Authors
P. cactorum, *P. cambivora*, *P. cinnamomi*, *P. citricola*, *P. citrophthora*, *P. cryptogea*, *P. drechsleri*	apple, apricot, camelia leaves, ceder twigs, citrus leaves, eucalyptus, hemp seeds, holly, lemon fruits, lupine seedlings, oak leaflet, peach, pear, rhododendron leaves, shore juniper needles, tomato seedlings	Bush et al. [2003], Ferguson and Jeffers [1999], Hansen and Delatour [1999], Hwang et al. [2007], Jeffers et al. [1987], Kliejunas and Ko [1976], Klotz et al. [1959], McIntosh [1966], Oudemans [1999], Pettitt et al. [1997, 2002], Themann et al. [2002], Yamak et al. [2002],
P. megasperma	apple, apricot, begonia petioles, citrus leaves, cress seedlings, cuttings of hebe, grass leaves, hemp seeds, lupine seedlings, oak leaflet, peach, pear, wheat coleoptile	Hansen and Delatour [1999], Oudemans [1999], McIntosh [1996]
P. nicotianae (*P. parasitica*)	camellia leaves, citrus leaves, holly, juniper, lemon fruit, tomato	Ferguson and Jeffers [1999], Klotz et al. [1959], Neher and Duniway [1992], Thomson and Allen [1974]
P. quercina	oak leaflet	Hansen and Delatour [1999]
P. ramorum	apple, rhododendron leaves, filtration	Hwang et al. [2007], Themann et al. [2002]
P. syringae	lemon fruit, rhododendron leaves	Klotz et. al. [1959], Themann et al. [2002]
P. undulata	lupine seedlings, rhododendron leaves	Themann et al. (2002)

OCCURRENCE OF *PHYTOPHTHORA* SPP. IN RECIRCULATION WATER AND ITS INFLUENCE ON A DISEASE INCIDENCE

In more and more horticultural farms under covering and in open field increased of collection and reuse of effluent water are observed because of its shortage, increasing costs of operations and to reduce release of pollutants into the environment. Effluent water from orchards, ornamental nurseries and vegetable farms are collecting in reservoirs. During the summer time demand for water strongly increased so effluents are mixed with well, lake, river, local stream water before use for irrigation. Besides pesticide and fertilizer pollutants, recycling water may be the source of *Phytophthora* species and could spread them from one or a few places with occurring of *Phytophthora* root and stem base rot to entire nurseries. In opinion of MacDonald et al. [1994] pathogens contaminated rivers and canals probably represents an overall lesser risk of disease than the recirculation of crop effluents. This is because a small number of infected plants in a nursery crop could release large numbers of propagules into irrigation leachates, which then would be recirculated back to susceptible crops. Studies of McIntosh [1966] indicated that about 7/8 of irrigation water sources were contaminated by *Phytophthora* spp. Orlikowski [2006a] and Orlikowski et al. [2007] showed that *P. citricola* detected in HNS reservoir was spread with effluent water, used for sprinkling of *Thuya occidentalis* and *Buxus sempervirens*, is the causal agent of tip blight (Photo. 1), yellowing and browning of leaves and development of root and stem rot symptoms (Photo 2).

a species from water.

Authors
Ferguson and Jeffers d Delatour [1999], '], Jeffers et al. [1987], 1976], Klotz et al. 1966], Oudemans [1999], 2002], Themann et al. al. [2002],
ur [1999], Oudemans 1996]
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open field increased of tage, increasing costs of at. Effluent water from n reservoirs. During the mixed with well, lake, and fertilizer pollutants, d spread them from one ot to entire nurseries. In rs and canals probably crop effluents. This is elease large numbers of ted back to susceptible tion water sources were ski et al. [2007] showed ater, used for sprinkling of tip blight (Photo. 1), ot symptoms (Photo 2).

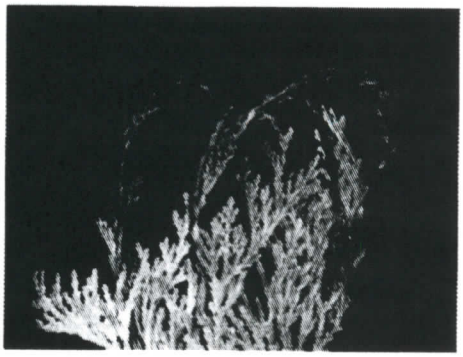

Photo. 1. Tip blight of thuja caused by *Phytophthora citicola.*

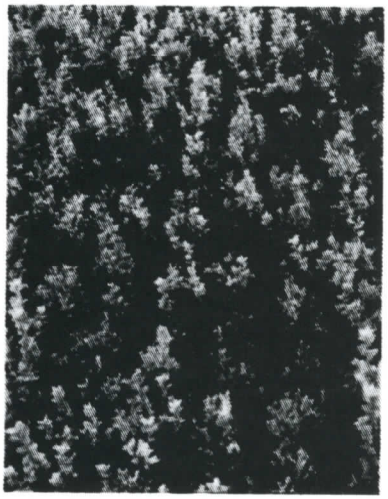

Photo. 2. Boxwood sprinkled with irrigation water contaminated with *Phytophthora citricola.*

Table 2. Spread of *Phytophthora* shoot rot on *Buxus sempervirens* in hardy ornamental nursery stock [Orlikowski 2006a].

Days after first observation	% of plants (n=200) with disease symptoms:	
	Yellowing of individual shoots	Browning, yellowing and straw-coloured shoots
0 (initial)	3.0 a	0 a
26	7.0 b	1.0 ab
60	11.3 c	2.0 b
78	15.8 d	5.5 c
110	19.3 e	9.5 d

Note: means in columns, followed by the same letter, do not differ with 5% of significance (**Duncan's multiple range** test)

Occurrence of disease symptoms was preceded by drizzly weather with temperature about 20°C and relative air humidity about 90% during at least 2 days. In case of boxwood, the disease spread from about 1,5% of affected plants to about 10% within 3 months (Table 2)

whereas on thuja the tip brown symptoms spread from about 6% to 28% within one week (Table 3).

Table 3. Spread of *Phytophthora* tip rot of *Thuja occidentalis* in hardy ornamental nursery stock [Orlikowski 2006a].

Days after first observation	% of diseased plants (n=200) with symptoms:	
	Browning of single tips	Browning of 2-5 tips/plant
0 (initial)	6 a	2 a
3	20 b	8 b
8	28 c	12 c

Note: see Table 2

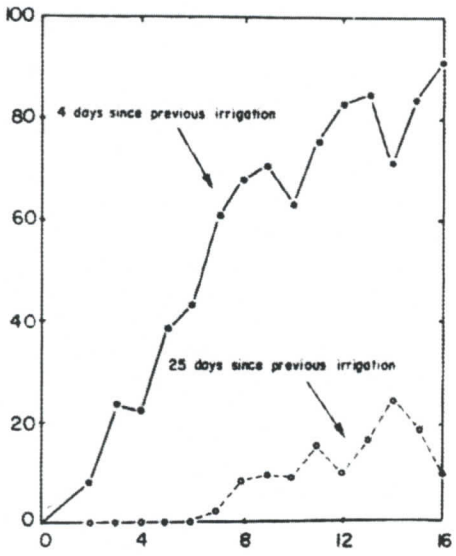

Figure 1. Incidence of buckeye rot caused by *Phytophthora parasitica* in green tomato fruit sampled at hourly intervals after the onset of an irrigation following either a 4-day or 25-day period without irrigation [Hoy et al. 1984].

Occurrence of disease symptoms was preceded by drizzly weather with temperature about 20°C and relative air humidity about 90% during at least 2 days. In case of boxwood, the disease spread from about 1,5% of affected plants to about 10% within 3 months (Table 2) whereas on thuja the tip brown symptoms spread from about 6% to 28% within one week (Table 3).

Hoy et al. [1984] showed that rate and incidence of buckeye rot of tomato, caused by *P. parasitica* (Figure 1) increased significantly as the interval between prior irrigations was decreased. The final incidence of infection on fruits grown in the field increased from 24 to 84% as irrigation frequency increased from once every 32 days to once every 4 days. (Figure 1).

In trials of Ristaino et al. [1992] disease incidence on field growing pepper, inoculated with *P. capsici*, increased to 100% during 85 days. Initial inoculum density influenced the

disease development during the first 50 days and in the highest pathogen level root and stem rot development spread the quickest. Studies of Oudemans [1999] showed that about 80% of cranberry plantations in New Jersey were exposed to *P. cinnamomi*, the causal agent of root rot or that species and *P. megasperma* through application of infested water from irrigation reservoirs.

Quantitative analysis of *P. citricola* occurrence in water reservoirs, using rhododendron leaves as baits [Orlikowski 2006a], indicated on significant decrease of the pathogen density since June till October. Themann et al. [2002] using direct plating, bait plants and DAS-ELISA methods for detection of *Phytophthora* species from 4 HNS recirculation water and drains during the year, identified at least 12 species with domination of *P. gonapodyides, P. cryptogea, P. drechsleri, P. citricola P. ramorum, P. cactorum, P. cambivora* and *P. citrophthora. P. richardiae, P. syringae, P. undulata* were recovered rarely or sporadically. *P. cinnamomi* was detected only from sediments [Themann et al. 2002]. Bush et al. [2003], on the base of own studies and other authors, mentioned 11 species recovered from irrigation water included additionally *P. megasperma, P. nicotianae* var. *nicotianae* and *P. palmivora.*

OCCURRENCE OF *PHYTOPHTHORA* SPP. IN CANALS AND RIVERS

Some *Phytophthora* species are primary agents of several losses of fruit orchard trees, causing root and/or collar rot. The primary pathogens including *P. cactorum, P. cinnamomi, P. citricola P. citrophthora* and *P. parasitica* (=*P. nicotianae*) were recovered from irrigation water of the USA states. [McIntosh 1996, Thomson and Allen 1974, Yamak et al. 2002]. Most of water used for irrigation is caught during spring runoff in storage dams situated among hills or orchard reservoirs. In some areas water is taken from local lakes, streams or rivers. In the most often cases water flows by gravity by special flames or ditches [McIntosh 1996]. The author found that in British Columbia about 7/8 of water sources for fruit trees irrigation were contaminated by *P. cactorum* and additionally by *P. citricola* and *P. megasperma.* Studies of Yamak et al. [2002] confirmed results of McIntosh [1966]. The authors revealed additionally clades of *P. gonapodyides, P. parasitica, P. citricola/capsici, P. cambivora/pseudotsugae.* Rhododendron leaf baits were efficient in the detection of *Phytophthora* from Polish rivers located in different regions (Table 4). In all of them *P. citricola* was recovered the most often and additionally *P. cactorum, P. cambivora, P. cinnamomi, P. citrophthora, P. cryptogea, P. inflata, P. megasperma* [Orlikowski 2006a, Orlikowski et al.2007, Orlikowski et al. unpubl.]. In spring and late summer *Phytophthora* spp. were recovered more often from river running through the horticulture area than forests (Table 5). Hensen and Delatour [1999] recovered *P. gonapodyides, P. megasperma* from forest streams and soil in water and low spots where water had been. Author's studies showed that only in a small forest nursery root and stem rot of Douglas-fir seedlings was associated with *Phytophthora.*

RELATIONSHIP BETWEEN TEMPERATURE, LOCATION OF WATER SOURCES, FREQUENCY OF IRRIGATION AND RECOVERY OF *PHYTOPHTHORA*

Themann et al. [2002] recovered *Phytophthora* species in water recirculation systems of HNS irrespective of the season. Number of isolate obtained, however, increased about sevenfold between late summer and spring. Klotz et al. [1959] analysed the detection of *Phytophthora* spp. in water canals and reservoirs in southern California using lemon fruit bait method. The frequency of isolation of *P. parasitica, P. citrophthora* and *P. syringae* was correlated with the time of year and water temperature. *P. syringae* was isolated most frequently at water temperature of 6-17°C and *P. parasitica* at 17-31°C. *P. citrophthora*, however, was isolated through the year. The authors, however, isolated these species even at water temperature 45°C. In studies of Oudemans [1999] detection period influenced recovery level of *Phytophthora* species. In case of *P. cinnamomi* the highest level of the species was noticed during the summer months whereas *P. megasperma* in spring and fall. Ali-Shtayeh et al. [1991] found that water collected in late winter from a recycling pond in northern California nursery did not contain any viable propagules but similar sample taken in early spring from southern California nursery contained about 450 viable propagules/liter of water, including *P. parasitica, P. citrophthora, P. cryptogea* and unidentified *Phytophthora* species. Oudemans [1999], using lupine seedlings for baiting *P. cinnamomi* in reservoirs and drainage canals, recovered the species for at least 6-7 months of the year. The highest levels of *P. cinnamomi* were found during the summer months whereas *P. megasperma* during the spring and fall months. In studies of Ferguson and Jeffers [1999] baiting temperature of 15°, 20° and 25°C did not have a dramatic effect on *Phytophthora* detection, however, at highest temperature these species were detected more frequently. Orlikowski et al. [unpubl.] recovered *Phytophthora* species all the year (Table 4) even at air temperature beneath –10°C. From river running through forests *P. ciricola* and *P. citrophthora* were recovered in April whereas in other months only the first species. *P. citricola* was recovered more often during the summer than in spring and autumn. In river running through horticultural and agricultural areas 5 species were recovered with domination of *P. citricola* and *P. citrophthora* (Table 5). In 2 analysed nursery canals *P. cryptogea* was additionally recovered [Orlikowski et al. unpubl.]. Oudemans [1996] found that inoculum density of *P. cinnamomi* in reservoirs correlated with the level found in drainage canals surrounding the cranberry beds suggesting, that the fluctuations in the pathogen recovery were due to environmental factors rather than random variation. Feld et al. [1990] and Ristaino et al. [1988, 1992] concluded that population densities of *Phytophthora* species in soil and water are dynamic and can be influenced by soil physical and chemical factors and the presence of actively growing susceptible plant roots.

POSSIBILITIES OF *PHYTOPHTHORA* SPP. CONTROL IN IRRIGATION WATER

Using nondisinfested recycled water for plants irrigation can result in serious disease epidemics and crop losses caused by several *Phytophthora* species. Among them Hong et al.

[2003] mentioned *P. cactorum, P. capsici, P. cinnamomi, P. citricola, P. cryptogea, P. nicotianae.* Application of fungicides containing metalaxyl, dimetomorph, fosetyl-Al, propamocarb hydrochloride and others may effectively controlled the development of root and stem rot and *Phytophthora* sporulation but they do not eliminate pathogens from diseased plants, soil/substratum and water. Additionally overuse of them may increase the risk of development of fungicide resistance and water pollution [Hu et al. 1994 Using of water even with very low propagule numbers of some *Phytophthora* species for irrigation of ornamental plants in HNS can cause colonization of roots and development of disease symptoms after their selling. Studies of Oudemans [1999] confirmed that hypothesis. In author's trials application of metalaxyl for the control of cranberry root rot, caused by *P. cinnamomi*, had only very little effect for recovery of the pathogen from contaminated drainage canals.

Current methods for disinfesting irrigation water include: filtration, ultraviolet irradiation, ozonation, nonionic surfactants, chlorination and calcium [Hong et al. 2003].

Table 4. Relationship between detection time, location of rivers and recovery of *Phytophthora* spp. using rhododendron leaf baits [Orlikowski et al., unpubl.]

Rivers	Location	Number of spots/rhododendron leaf blade in months of 2008			
		IV	VI	IX	XI
Korabiewka	forests	14,3 ab	11,8 a	11,3 a	4,8 a
Ner	horticultural area	22,5 b	5,3 a	19,3 b	15,0 b
Rawka	agricultural area	6,8 a	26,0 b	11,0 a	13,0 b

Note. see Table 2

Table 5. *Phytophthora* species recovered from 3 rivers in relation to months of detection and colony number [Orlikowski et al., unpubl.].

Phytophthora species	Rivers and months of detection											
	Korabiewka				Ner				Rawka			
	IV	VI	IX	XI	IV	VI	IX	XI	IV	VI	IX	XI
P. cactorum	2	-	-	-	-	11	-	-	-	-	-	-
P. cambivora	-	-	-	-	8		-	-	-	-	11	-
P. citricola	2	12	9	3	-	4	22	-	10	21	11	-
P. citrophthora	2	-	-	-	-	-	-	-	10	20	-	-
P. megasperma	-	-	-	-	8	15	-	2	-	-	-	2

Filtration, especially slow sand filtration is effective in removing of very wide groups of plant pathogens but has been limited use due to its low capacity and high maintenance requirement [Hong et al. 2003]. Sand filter are already used for elimination of plant pathogens, including *Phytophthora* spp. in hardy nursery stocks. Jamart [1998] and Wohanka [1999] on the base of own studies notified 100% elimination of *Phytophthora* spp. from irrigation water. Trials of Ufer et al. [2005] confirmed these results. Jamart [1998] underlined adventages of slow filtration because of low cost of filter construction and water desinfection.

Stanghellini et al. [1996] found that amending of nutrient solution with nonionic surfactant (90% of alkyl phenolethylene oxide) at dose 20 μg a.i./ml resulted in the complete suppression of the dispersal of zoospores of *P. capsici* from a point source, the hypocotyls

inoculated pepper, whereas in the absence of the surfactant, *P. capsici* was dispersed from the point source and killed all plants in the hydroponic unit within 12 days. Surfactant limited also the pathogen spread via hyphe from to plants growing within the same individual rock wool slab. Motile zoospores, released from zoosporangia formed on diseased plant tissues, ceased motility and lysed within 1 min after placement in surfactant solution containing 20 µg a.i./ml [Stanghellini et al. 1987]. Studies conducted by Stanghellini and Tomlinson [1987] demonstrated that the lytic effect of surfactant on zoospores and vesilcles of *Pythium* spp. and *P. nicotianae* may reside in alteration of the integrity and/or permeability of the plasma membrane.

Chlorination is the most economical water decontamination method but specific recommendations for use in nursery irrigation are lacking [Hong et al. 2003].This technology is one of the primary methods for treating municipal water but it is still not used widely for control of *Phytophthora* diseases. It is known that chlorine sensitivity can differ with species, pathovar and propagule type of plant pathogens, concentration, exposure time, water temperature, amount of organic matter and other oxidizable substances, chemistry and pH [Segall 1968]. Additionally, phytotoxicity of chlorine is especially important for nursery production because of numerous number of plant grow, cultivars and varieties with varying sensitivity to chlorination. Skimina [1992] considered that free available chlorine at 2,9 mg/liter is safe for most of ornamental crops. Is this level of chlorine is good enough for effective control of plant pathogens in irrigated water? The lethal dose of chlorine for zoospores of *P. cinnamomi* and *P. nicotianae* was 1 mg/liter whereas for hyphe 100 higher [Hong et al. 2003]. In authors studies 1-2 mg of chlorine solutions killed 100% of zoospores of *P. capsici, P. cinnamomi, P. citricola, P. cryptogea, P. megasperma* and *P. nicotianae* when exposed for 2 min. The authors found that level of free chlorine in irrigation water varying in relation to nursery and collection time. The highest amount of chlorine was detected in one from 4 surveyed nursery in November and June whereas in other place in May. The only tests with chlorinated of irrigation water targeting *Phytophthora* species were conducted in citrus orchards where 50 and 10 mg of free product/l combined with filtration provided effective control of *P. citrophthora* and *P. citricola* [Grech and Rijkenberg 1992].

For zoosporangia formation by *Phytophthora* spp. normal motility of zoospores, adhesion of zoospore cysts to host plant and their germination a minimum level of extracellular calcium is necessary [von Broemmsen and Dracon 1997]. An alternative for fungicide used and more durable approach of *Phytophthora* and *Pythium* zoospores suppression and their taxis to root would be intercellular and extracellular calcium. Von Broembsen and Deacon (1997) demonstrated that application of calcium as either calcium chloride or calcium nitrate to water or soluble fertilizer solution affected several important stages of the production and behavior of *P. parasitica* zoospores. Calcium has the potential to reduced markedly the availability of inoculum for primary infection and secondary spread of infection caused by that species in irrigation systems, behavior relevant to infection and disease spread. Release of zoospores from zoosporangia was suppressed by calcium ions at concentrations from 10 to 50 meq.

Ultraviolet (UV) light is used for the treatment of recycled irrigation water to minimize its potential as a source of pathogens inoculum, including *Phytophthora* spp., in the growing of vegetables and flowers under covering. In studies of Cohn and Hong (2003) efficacy of UV light was connected with flow rates of pathogen. Inoculum level of pythiaceous species

decreased at least 3, 6 and 70 times in reservoirs with water swimming about 200, 120 and 40 l/min, respectively.

CONCLUSIONS

1. Infested irrigation water is one of the most important source of *Phytophthora* species but also an efficient means of spreading that group of pathogens from one place to entire horticultural production and forestry as well as from one geographical location even to other countries and continents,
2. Using nondisinfected water for plant irrigation can result in serious disease epidemics and crop losses caused by several *Phytophthora* species. Among them *P. cactorum, P. capsisci, P. cinnamomi, P. citricola, P. cryptogea* and *P. nicotianae* var. *nicotianae* are the most dangerous,
3. For preventive of *Phytophthora* spp. spread and managing of diseases caused by these pathogens rapid, simple and universal methods were elaborated, mainly plant baits and filtration,
4. Rhododendron leaf baits are the most successful for recovery of *Phytophthora* spp. from water, susceptible to the widest species groups, inexpensive, ready availability geographically and seasonally and convenience for use. This technique is especially available for qualitative detection of *Phytophthora* spp. whereas filtration may be use additionally for quantitative analysis of population density,
5. *Phytophthora* species may be recovered from water irrespective to season,
6. More *Phytophthora* species were recovered from water recirculation systems of hardy ornamental nursery stocks than from irrigation reservoirs, canals and rivers,
7. The frequency of *Phytophthora* isolation, especially some species, was correlated with the time of year and water temperature,
8. *P. cinnamomi*, the species with the widest group of host plants, was recovered in reservoirs and drainage canals for at least 6-7 months of the year with the highest levels during the summer,
9. Population densities of *Phytophthora* species in water are dynamic and can be influenced by physical and chemical factors and the presence of actively growing susceptible plant roots,
10. Filtration, ultraviolet irradiation, chlorination and application of nonionic surfactants and calcium can be used for elimination or strong decreasing of *Phytophthora* levels in irrigation water,
11. Disinfecting techniques ought to be connected with methods of plant irrigation, place, surface and kind of plant production.

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