Influence of Watering Frequency and Electrical Conductivity of the Nutrient Solution on Phytophthora Root Rot in Pot Plants of *Gerbera*

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ABSTRACT

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Recirculation of nutrient solutions in nurseries with ebb-and-flow benches will reduce discharges to the environment, but a prerequisite is that the quality and health of the plants are satisfactory. An experiment investigating the possibility of reducing attacks of *Phytophthora cryptogea* through changes in watering frequency (WF) and values of electrical conductivities (EC) was carried out in pot plants of *Gerbera jamesonii* grown on ebb-and-flow benches with recirculating nutrient solution. Nutrient concentrations EC 1.5 and 2.2 mS cm^{-1}, respectively, were combined with WF 0.5 and 1.5 times per day, respectively, with or without inoculation with *P. cryptogea* in a factorial design. Symptoms of root rot were absent from plants on noninoculated benches. Raising EC and lowering WF both inhibited the attack, alone or in combination. Percent plant death caused by *P. cryptogea* was 73.6% at WF 1.5 times per day/EC 1.5 mS cm^{-1}. By contrast, only 4.7% plant death was observed at WF 0.5 per day/EC 2.2 mS cm^{-1}. Also, the treatments with WF 1.5 per day/EC 2.2 mS cm^{-1} and WF 0.5 per day/EC 1.5 mS cm^{-1} reduced the attacks (13.4 and 13.5%, respectively). Percent diseased plants was highest near the inoculation points in all four combinations, and there was no difference in the pattern of spreading, only in the severity of attack. The results show that *Phytophthora* zoospores in the nutrient solution in an ebb-and-flow system with recirculation could cause an epidemic under certain conditions. The findings also demonstrate that it is possible to reduce attacks of *Phytophthora* considerably without the use of fungicides by adjusting the WF and EC values appropriately. This is possible without effects on the growth and flowering of the plants, even when the nutrient solutions are recirculated.

Root rot caused by *Phytophthora* spp. is a very common and serious problem in many glasshouse crops grown in ebb-and-flow systems, especially where the nutrient solutions are recirculated (13). The majority of the Danish pot plant nurseries use the ebb-and-flow system with automatic control of the composition of the nutrient solution, pH, and watering frequency, and with recirculation of the nutrient solution. The system is environmentally safe, but when root disease problems arise, especially with *Phytophthora, Pythium,* and *Fusarium,* there is an interruption in recirculation that results in environmental pollution. In Denmark, attack by *Phytophthora cryptogea* Pethybr. & Lafferty in pot plants of *Gerbera jamesonii* H. Bolus ex J.D. Hook results in crop loss and irregular production. Although fungicides and surfactants are available, they have not controlled the disease satisfactorily.

In evaluating the interaction between a watering strategy and a root disease, it must be kept in mind that any change in availability of water, nutrient, or oxygen (due to flooding) may affect the plant as well as the pathogen, and that stressed plants may be more susceptible to disease. Stress due to flooding prior to inoculation with *Phytophthora* can predispose the plants, causing disease to develop more quickly and more severely (6). In experiments with *Pythium,* high nitrogen levels harmed the roots and increased attacks of root rot caused by *Pythium* (3,8). In contrast, it was found that an increase in concentration of the fertilizer could decrease root attack by *Phytophthora* in avocado (16), *Pythium* in *Peperomia obtusifolia* pot plants (1), and *Pythium* in hydroponically grown spinach seedlings (7).

Up to now, the research concerning electrical conductivity (EC) and water frequency (WF) in an ebb-and-flow system with recirculation of the nutrient solution has not considered the effects on attack of *Phytophthora* root rot. In order to make it possible to recirculate continuously in nurseries with *Phytophthora* disease problems, an investigation of the influence of the EC and WF values on the disease development in the growing system was initiated.

A study of the influence of small changes of WF and EC on the attack of *P. cryptogea* in *Gerbera* at two different EC and WF levels was performed. The four values were either a little lower or a little higher than the standard values used in practice in Denmark (about EC 1.8 mS cm^{-1} and WF 1.0 per day). The second item was to see if any of the EC and WF combinations were able to reduce the spread of *Phytophthora* with the nutrient solution and still produce plants of high quality. An accurate management of EC in the nutrient solution is necessary. This was accomplished in the experiment mentioned below with a fertilizer/irrigation computer that automatically controlled the addition of fertilizer, acid, and tap water to the recycling nutrient solution to ensure that the EC and pH values were correct.

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MATERIALS AND METHODS

Plant culture. Eleven-week-old plants of *G. jamesonii* cv. Hummingbird were potted in limed and fertilized peat (KTs1, Klasmann-Deilmann, Geeste, Germany) in 12-cm pots. The potted plants were placed on 24 ebb-and-flow benches, each 1.6 × 5.7 m (Viemose-Driboga A/S, Aarhus, Denmark), covered with a thin capillary matting (95 g/m^2) (Isola Glassfilt A/S, Brevik, Norway) at 10 plants per square meter. The only pesticide applied was methomyl (Lannate 20L) against white flies (*Trialeurodes vaporariorum*).

Greenhouse site. The experiment was performed in a greenhouse with three sections and one watering system. Each section was 8 × 17 m, with single glass as cladding material. There were eight ebb-and-flow benches per greenhouse section. The greenhouse had continuous ridge ventilation and was equipped with top-going shading screens (LS15, Ludvig Svensson, Kinna, Sweden). The shading screens were closed whenever the irradiation outside the greenhouse exceeded 1,600 $\mu E \cdot m^{-2} \cdot s^{-1}$ (800 W m^{-2}). During the night, the shading screens were used as thermal screens. Only natural light was used. The heating set point was 21 C, and the ventilation set point was 23 C; both were controlled by a climate computer (LCC1220 Super 2, DGT/ Volmatic, Farum, Denmark).

Inoculum production. Fifteen days after the start of the experiment, half of the plots (12 benches) were inoculated with a Danish isolate of *P. cryptogea* isolated from infected roots of *G. jamesonii* as follows: petri dishes (diameter: 13.5 cm) containing autoclaved 20% V8 juice with 15 g of agar were inoculated with *P. cryptogea* and grown for 6 days at 24 C in the dark. Sterile soil extract (20 g of garden soil in 1 L of distilled water, filtered overnight and autoclaved) was poured over the cultures, and 12 days later the fungus had produced sporangia ready for releasing zoospores.

Experimental design. Fertilizer was applied at two levels, with ECs of 1.5 mS cm^{-1} (EC 1.5) or 2.2 mS cm^{-1} (EC 2.2). EC of the nutrient solutions, a measure of the soluble salt concentration, was controlled by a fertilizer/irrigation computer (AMI 3000, DGT/Volmatic). The AMI 3000 automatically controls the amount of fertilizer, acid, and tap water added to the recycling water to the correct pH (5.8) and EC level. The nutrient solutions were never replaced.

The tap water contained K, Ca, Mg, S, Na, Cl, and Zn. Nutrient salts were added to tap water in order to get the same ratio of elements in each of the two nutrient solutions, except for Ca, Na, Cl, and S; here the concentrations in the tap water were a little higher than the desired level compared to the Danish standard fertilizer of *Gerbera*. The composition of the two nutrient solutions, EC 1.5 and EC 2.2, can be seen in Table 1.

There were two WFs: 1) WF 1.5 times per day (potting media remained moist), in which the plants were watered when the evaporator (VA 70, DGT/Volmatic) indicated 8 mm of evaporation from a water-saturated sand surface (1.5 times per day on average), and 2) WF 0.5 times per day (potting media dried between watering), in which the plants were watered when the evaporator indicated 21 mm of evaporation (0.5 times per day on average).

The nutrient solutions were pumped onto the benches for 10 min and drained off for 15 min to four separate tanks (each 900 L). The inoculated treatments were irrigated from tank 1 (EC 1.5) or tank 3 (EC 2.2), and the noninoculated from tank 2 (EC 1.5) or tank 4 (EC 2.2).

The experiment thus consisted of full factorial design with eight treatments. There was a total of 24 plots (eight in each of the greenhouse sections). Because of some practical restrictions in the watering system, only four different treatments could be accommodated in one greenhouse section. The restrictions also prevented equal replications of all the treatments. To avoid confusing greenhouse sections, an incomplete block design was used. The eight treatments and their replications are summarized in Table 2.

There were 82 plants per bench (plot); however, only 60 plants per bench were used in the experiment because plants positioned in front of and beside the inoculated plants were eliminated. Three pot plants on each of the 12 benches, situated four rows from the water inlet, were inoculated with zoospores by standing the pots in the flooded petri dishes on the benches for 48 hr to release the zoospores from the formed sporangia to the pot plant roots.

The benches were split into zones in order to investigate if the spread of *P. cryptogea* was influenced by the distance from the inoculum point. Each bench was divided into three zones starting at the first row nearest the inoculated plants: zone 1 from 0 to 132 cm, zone 2 from 133 to 264 cm, and zone 3 from 265 to 396 cm (20 plants in each zone).

Determination of EC in the potting media. Peat samples from six pots per treatment were dried at 105 C, and extracts were prepared with distilled water 0, 29, and 44 days after beginning the experiment. EC in the extracts was measured with a Conductivity Radiometer CDM3 (Radiometer Danmark A/S, Copenhagen).

Detection of *P. cryptogea* in pot plants. Dead plants and plants with symptoms of brown, decaying roots and wilting leaves were recorded approximately every other day for 33 days. To confirm that dead plants and plants showing symptoms were infected with *P. cryptogea,* surface-sterilized (70% ethanol for 30 sec) root segments (1–2 cm) were assayed by plating on selective medium HMI (15), incubating for 5 days at 24 C in darkness, and examining the plates microscopically for growth of the fungus. Spot tests of root samples were taken during the course of the experiment. At the termination of the experiment, root samples from 20 identically placed plants from each of the benches were taken.

Detection of *P. cryptogea* in nutrient solutions. Nutrient solution in the four tanks supplying the watering systems was examined weekly for *P. cryptogea* zoospores as follows: 1-L samples from each tank were baited with four needles of *Cedrus deodara* for 3 days. The needles were then removed, surface-sterilized with 1% sodium hypochlorite for 30 sec, rinsed in sterile distilled water, blotted dry, placed on selective medium (HMI) for 5 days at 24 C in darkness, and examined with the light microscope for growth of *P. cryptogea.*

Statistical analysis. Percent dead plants caused by *Phytophthora cryptogea* was recorded in three distance zones in the 12 plots inoculated with *P. cryptogea* on five separate occasions. To follow the disease spread with the nutrient solution and to see if the spread of disease was influenced by the distance from the inoculum point, the data were analyzed in a generalized, linear model, assuming that the number of plants was binomially distributed. The model contained all main effects, and two-way and three-way

Table 1. The total content of elements (ppm) and salts (mg/L) in the two nutrient solutions (with electrical conductivity [EC] 1.5, 2.2 mS cm^{-1}) and tap water

Element/salt	Nutrient solution EC 1.5 (ppm)/(mg/L)	Nutrient solution EC 2.2 (ppm)/(mg/L)	Tap water (ppm)/(mg/L)
Ca	153	153	153
K	163	268	2
Mg	23	38	13
N	141	232	...
P	17	28	...
S	57	74	41
B	0.26	0.44	...
Cl	43	43	43
Cu	0.07	0.12	...
Fe	1.3	2.2	...
Mn	0.4	0.7	...
Mo	0.05	0.09	...
Na	19	19	19
Zn	0.26	0.44	0.26
KNO_3	423	701	
NA_4NO_3	92	257	
$Mg_2SO_4 \cdot 7H_2O$	104	257	
H_3PO_4 (75%)[a]	45	74	
HNO_3 (62%)[a]	263	237	
FeHEEDTA (5.2%)[b]	26	42	
H_3BO_3	1.51	2.48	
$MnSO_4 \cdot 4H_2O$	1.42	2.34	
$CuSO_4 \cdot 5H_2O$	0.28	0.46	
$Na_2MoO_4 \cdot 2H_2O$	0.13	0.22	
$ZnSO_4 \cdot 7H_2O$	...	0.81	

[a]Added as milliliters.
[b]Source: Brøste Industri A/S, Lyngby, Denmark.

Table 2. The number of replications in each of the eight treatments in *Gerbera* pot plants with water frequency (WF) and electrical conductivity (EC). Half of the treatments were inoculated with *Phytophthora cryptogea*

WF/EC	Inoculation[a] (No. replications) +	−
1.5/1.5	2	2
1.5/2.2	4	4
0.5/1.5	4	4
0.5/2.2	2	2

[a]+ = Inoculation with *P. cryptogea.* − = No inoculation with *P. cryptogea.*

interactions among the four factors (WF, EC, distance, and days). The logit function was used as response function, and the calculation was done applying the Catmod procedure in SAS (11). The logit transformed percent dead plants in all zones after 33 days was in addition analyzed in a general linear model. This model included the two treatment factors and their interactions. These calculations were done applying the GLM procedure in SAS (11).

RESULTS

Average and maximum daily temperatures in pots varied from 20.8 to 24.4 C and from 21.3 to 30.3 C, respectively. The root systems of the plants did not develop extensively outside the pots, and there were no signs of root contact. Visual observation showed that the plants at the WF 0.5 and EC 1.5 or EC 2.2 had a more compact growth, reducing the requirement for chemical retardation. However, flowering was similar at both watering levels, and there was no difference in plant habit between the two EC values at the same WF. EC values in peat samples are shown in Table 3.

Table 3. Electrical conductivity (EC) level in the potting media measured 29 and 44 days after the start of the experiment. The EC level was 3.1 mS cm^{-1} on day zero (15 days before inoculation)

Treatments	Days	
	29	44
WF 1.5, EC 1.5	10.2 ± 1.6[a]	10.4 ± 0.7
WF 1.5, EC 2.2	15.0 ± 2.5	15.7 ± 3.2
WF 0.5, EC 1.5	12.0 ± 0.6	8.9 ± 0.2
WF 0.5, EC 2.2	16.2 ± 3.8	13.9 ± 3.6

[a] Values represent EC (mS cm^{-1} ± SD).

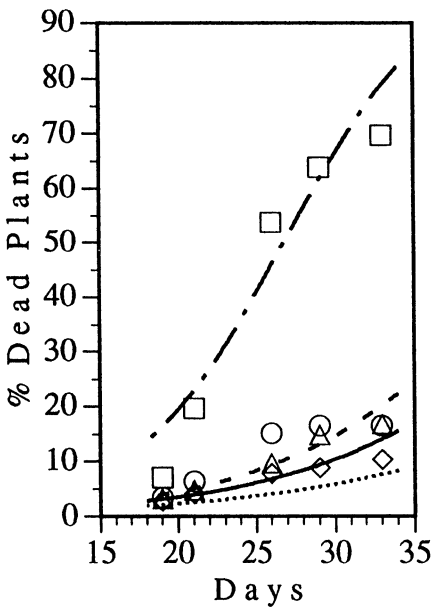

Fig. 1. Observed (symbols) and predicted (lines) percent dead *Gerbera* pot plants caused by *Phytophthora cryptogea* ($P_{WE.D}$) after inoculation with the fungus as a function of electrical conductivity (EC) and watering frequency (WF). Model estimations: WF 1.5/EC 1.5 = lines and dots, WF 0.5/EC 1.5 = solid line, WF 1.5/EC 2.2 = dashed line, and WF 0.5/EC 2.2 = dotted line. Actual datapoints are represented by: □ = WF 1.5/EC 1.5, △ = WF 0.5/EC 1.5, ○ = WF 1.5/EC 2.2, and ◇ = WF 0.5/EC 2.2. Lines were estimated from equation 1 (see text), the estimated parameter β_0 was −5.62, and $\beta + \beta_{WE}$ for the four treatments was: 0.2099 for WF 1.5/EC 1.5, 0.1155 for WF 0.5/EC 1.5, 0.1287 for WF 1.5/EC 2.2, and 0.0947 for WF 0.5/EC 2.2.

Statistical models. To estimate the course of the epidemic, the data were transformed as follows: the expected value of the logit transformed data was fitted to a model including all main effects, two-factor interactions, and three-factor interactions among the four factors. By successive removal of non-significant effects, this full model was then reduced to the following model: $E \cdot [\ln(P_{WEZD} \cdot 10^{-2}/1 - P_{WEZD} \cdot 10^{-2})] = \beta_0 + \beta \cdot D + \beta_{WE} \cdot D + \beta_Z \cdot D$, where P_{WEZD} is the percent dead plants in zone Z on day D (days after the inoculation) when the plants were treated with watering frequency W and electrical conductivity E. β is the average time effect of all treatments and zones, β_0 the intercept, $\beta + \beta_{WE}$ the time effect for the treatment with watering frequency W and electrical conductivity E, and $\beta + \beta_Z$ the time effect for plants in zone Z. All effects are on the logit scale. All effects in the final model are significant ($P = 0.001$). The significance of the model was $P < 0.001$. The expected percent dead plants for the different treatments ($P_{WE.D}$) and distance zones ($P_{..ZD}$) was estimated by the following equations using Catmod procedure: Equation 1: $P_{WE.D} = 100 \cdot EXP(\beta_0 + \beta + \beta_{WE} \cdot D)/1 + EXP(\beta_0 + \beta + \beta_{WE} \cdot D)$ and Equation 2: $P_{..ZD} = 100 \cdot EXP(\beta_0 + \beta + \beta_Z \cdot D)/1 + EXP(\beta_0 + \beta + \beta Z \cdot D)$.

Disease development. The three inoculated plants per bench died between 9 and 27 days after inoculation in all treatments, and they are not included in the statistical analysis. No significant differences among blocks were found in the percent plants killed by *P. cryptogea*. Plant death was strongly affected by both types of treatments (Fig. 1), low WF and high EC both inhibiting the attack. At day 33, the values for treatments WF 0.5/EC 1.5, WF 1.5/EC 2.2, and WF 0.5/EC 2.2 are not significantly different, and the value for treatment WF 1.5/EC 1.5 is significantly different from the other three based on the pairwise t test on logit transformed percent at $P = 0.05$. In control treatments, without inoculation with *P. cryptogea* (12 plots), no plants died or showed symptoms of infection with *P. cryptogea*. In all four combinations, the percent dead plants was highest in zone 1 but lower and equal in zones 2 and 3, respectively, on day 33 (Table 4). The pattern of disease spread was similar in all four combinations, but the extent of damage differed greatly among treatments. No interactions were found among zones, days, and the four treatments (Table 4). In Figure 2, the course of the attack in the three zones is illustrated as a summation of the average of the four treatments from day 19 to day 33.

Nutrient solution samples. Two weeks after inoculation, *P. cryptogea* zoospores could be isolated from the EC 1.5 mS cm^{-1} tank on baits. However, 2 wk later it could no longer be detected on baits. *P. cryptogea* was never detected on baits from the tank with EC 2.2 mS cm^{-1} or in the two control tanks (Table 5).

An additional experiment was done with the same four treatments but on a smaller scale, with one bench for each treatment and no uninoculated controls (results not shown). The experiment showed the same tendency of the four treatments and of the spread of disease in the three zones.

DISCUSSION

The epidemiology of Phytophthora root rot is that of a multiple cycle disease,

Table 4. Percent dead plants with *Phytophthora* root rot 33 days after inoculation with *Phytophthora cryptogea* at different distances from the inoculated plants; watering frequency (WF) 1.5 and 0.5 times per day and electrical conductivity (EC) 1.5 and 2.2 mS cm^{-1}; 20 plants in each zone (zone 1 = 0–132 cm from inoculated plants, zone 2 = 133–264 cm from inoculated plants, zone 3 = 265–396 cm from inoculated plants)

Zone	Percent *Phytophthora* dead plants			
	WF 1.5/EC 1.5	WF 1.5/EC 2.2	WF 0.5/EC 1.5	WF 0.5/EC 2.2
1	85.3	27.1	28.4	17.4
2	61.2	11.9	9.2	2.4
3	66.5	10.2	11.3	2.4

Source of variation			
Intercept	***[a]	Days	***
WF	*	WF × Days	**
EC	***	EC × Days	**
WF × EC	ns	WF × EC × Days	ns
Zones	***	Zones × Days	ns
WF × Zones	ns	WF × Zones × Days	ns
EC × Zones	ns	WF × EC × Zones × Days	ns
WF × EC × Zones	ns		

[a] * = $P \leq 0.05$, ** = $P \leq 0.01$, *** = $P \leq 0.001$, ns = not significant.

and in contrast to monocyclic diseases, the influences of soil moisture on the multiplication of the fungus may be much more important than initial inoculum concentration (17). For the first time, our experiment shows that ebb-and-flow benches with recirculation of the nutrient solution can provide such beneficial conditions for *P. cryptogea* as Hoitink et al (5) found for *Pythium* in pot plants of poinsettia. They found that the pathogen spread in their system at a distance of 80 cm in 37 days. Our results with *Gerbera* actually show a more efficient dispersion, in particular for the treatments with EC 1.5, where *P. cryptogea* zoospores were found in the tank after 14 days, and infected plants were dying 3 m from the inoculation point 19 days after inoculation. The rapid spread of the disease strongly suggests that zoospores were involved. We found the strongest attack closest to the points of inoculum placement; only 1.3 m from the inoculum point, a reduction in the attacks was observed in all four treatments. The data in Figure 2 indicate for all four treatments that the disease spread was influenced by the inoculum point in zone 1, but not in zones 2 and 3. This corresponds to the results of Sanogo and Moorman (10), who found that the spread of *Pythium* in cucumber grown in an ebb-and-flow subirrigation system with recirculation (300 ppm N and EC 2.0 mS cm^{-1}) was primarily caused by the irrigation water and not by pot-to-pot contact, undrained water, or insects. While no other studies of dispersal of *Phytophthora* in ebb-and-flow systems have been reported, zoospores of *P. parasitica* were dispersed by irrigation water at least 68 m downstream in tomato fields (9). The greatest severity of symptoms on roots was found at the original point of inoculum placement, and severity of root symptoms decreased with increasing distance, especially at distances greater than 8 m downstream from infestation sites (9).

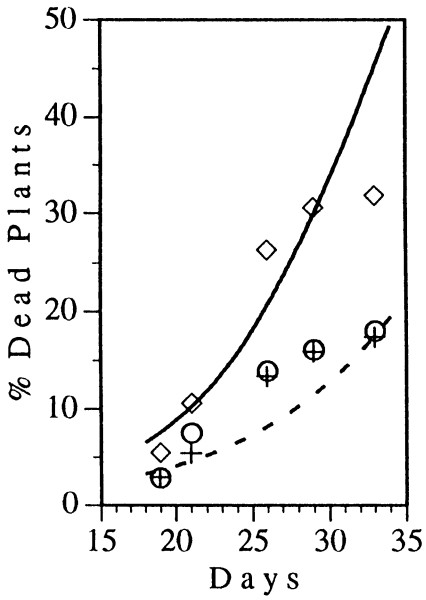

Fig. 2. Observed (symbols) and predicted (lines) percent dead *Gerbera* pot plants caused by *Phytophthora cryptogea* ($P_{.ZD}$) after inoculation with the fungus as a function of zones. The course of the epidemic in the three zones as a summation over the average of the four treatments. Twenty plants were used in each zone (zone 1 = 0–132 cm from inoculated plants, zone 2 = 133–264 cm from inoculated plants, and zone 3 = 265–396 cm from inoculated plants). Model estimations: zone 1 = solid line, zones 2 and 3 = dashed line. Actual data points are presented by: ◇ = zone 1, ○ = zone 2, and + = zone 3. Lines were estimated from equation 2 (see text), and the estimated parameters of $\beta + \beta_z$ were 0.1645 for zone 1, 0.1235 for zone 2, and 0.1236 for zone 3.

Watering frequency was an important factor in the spread of *P. cryptogea* in our experiment. Kuan & Erwin (6) found that water conditions are more important than the inoculum concentration. *Eucalyptus* trees were only susceptible to attacks of *P. cinnamomi* when dry periods were followed by rain; 2 days after rain, the activity of *P. cinnamomi* could increase 128-fold (2). Thus, the low infection efficiency in the WF 0.5 treatments could have been the result of a combination of factors, including a reduced rate of fungal growth and multiplication resulting in fewer infective propagules and fewer periods of wetness for the fungal propagules to be effectively dispersed.

With an EC value of 2.2 mS cm^{-1} in the nutrient solution, inhibition of the pathogen occurred in our experiment. With in vitro experiments made (data not shown), EC 2.2 mS cm^{-1} did not reduce zoospore production or viability of our *P. cryptogea* isolate compared with soil extract. One explanation could be an increase of specific ions in the nutrient solution. Slade and Pegg (12) found Cu^{2+} to be toxic in very low concentration to zoospores of *Phytophthora*; here, LD_{50} for Cu^{2+} was 1.84 μM (0.117 ppm). In safflower seedlings, Halsall (4) was able to decrease attacks of *Phytophthora drechsleri* by watering with 1 μM $CuSO_4$ frequently over the critical period for infection, and they suggested that an inhibition either of the zoosporangial production and/or of the process of infection could possibly explain the decrease of attacks. In our nutrient solutions, the concentrations of Cu^{2+} were 0.07 ppm and 0.12 ppm, respectively (1.1 μM and 1.8 μM $CuSO_4$ $5H_2O$). The higher content of Cu^{2+} in the nutrient solution with EC 2.2 mS cm^{-1} could possibly explain the decrease in attack of *P. cryptogea* if Cu^{2+} was not bound by HEEDTA, as pointed out by Halsall (4). Also, high nutrient levels in solutions or in soil extract tend to reduce the degree of zoospore formation of *Phytophthora parasitica* in soil (14). The nitrogen levels in our nutrient solution were moderate, with the highest nitrogen level at 232 ppm (16.6 mM), but we observed high EC values in the pots in the experiment. The high values in the pots could be one explanation of the tendency to lower attacks at EC 2.2 and a slowdown of the attack in all treatments at the end of the experiments, but Sanogo and Moorman (10) did not find a relationship between high levels of nutrients, caused by salt accumulation in the pots, and disease development.

It is possible that low WF and/or high EC might harm the plants, upsetting any benefits obtained from inhibition of the fungus. However, the reduction in plant size in the WF 0.5 treatments did not affect flowering and thus actually improved the quality. Using the combination of EC 2.2 and WF 0.5, it should be possible to prevent serious attacks of *P. cryptogea* in *Gerbera* pot plants grown in ebb-and-flow systems with recirculation of the nutrient solution. In addition, the method benefits the environment in two ways. First, the method reduces the need for fungicides and makes it possible to continue recirculating the nutrient solution. Second, it reduces the discharge of excess nutrients. To get a better understanding of the influence of EC level and WF on the development of *P. cryptogea* and to optimize this method of disease prevention, experiments should be done to determine the mechanisms involved. It is also possible that the principle of changing WF and EC levels could be applied to other crops.

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Table 5. Water samples (1 L each) from the four tanks with recirculated nutrient solution examined for *Phytophthora cryptogea* zoospores in the period from 25 March to 6 May

	Days before/after inoculation (Date)					
Tank no./electrical conductivity (EC)	**−8 1/4**	**0 8/4**	**7 15/4**	**14 22/4**	**20 28/4**	**28 6/5**
1/EC 1.5 mS cm^{-1}/+ inoc.	−[a]	−	−	+	+	−
2/EC 1.5 mS cm^{-1}/− inoc.	−	−	−	−	−	−
3/EC 2.2 mS cm^{-1}/+ inoc.	−	−	−	−	−	−
4/EC 2.2 mS cm^{-1}/− inoc.	−	−	−	−	−	−

[a] + = *P. cryptogea* isolated from baits; − = *P. cryptogea* not isolated from baits.

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