Beneficial Bacteria Suppress Pythium Root Rot and Enhance Growth of Hydroponic Sweet Peppers at Moderate and High Temperatures

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Introduction

Root rot caused by *Pythium* spp. is economically important in almost all hydroponic crops including sweet peppers (*Capsicum annuum* L.). Symptoms of the disease include root browning and necrosis, wilting, reduced growth, and decreased yield. Environmental stress factors increase host susceptibility to Pythium root rot (PRR), especially when the stress occurs prior to infection (predisposition). Epidemics of PRR often progress rapidly because zoospores of *Pythium* spp. are dispersed quickly in the circulating nutrient solution and the density and diversity of microbial communities in hydroponic systems usually are low and antagonize *Pythium* spp. only weakly.

Management of PRR in hydroponic systems is difficult. Several microbial agents have been reported to give good control of PRR in various crops and their use is increasing worldwide. The microbes, in some instances, also promote plant vigour and productivity. In the present research, quantitative relationships between duration of high temperature and predisposition of sweet peppers to PRR, and remediation of PRR by the bacterium *Pseudomonas chlororaphis* 63-28, were investigated.

Figure 1. Commercial production of hydroponic sweet peppers.

Figure 2. Progression of root browning following inoculation with *P. aphanidermatum*. Non-inoculated roots shown on extreme left.

Materials and Methods

Plants: Sweet peppers were grown from seed in rockwool plugs in a growth room maintained at 23 °C (moderate temperature). Four week-old seedlings were transferred to individual 500 ml plastic hydroponic units with aerated nutrient solution.

***Pythium* inoculation.** Roots (8-10 week-old plants) were immersed in 5 X 10^3 zoospores mL^{-1} water of *P. aphanidermatum*. for 30 minutes (controls in water).

High temperature treatment: Hydroponic units were placed in insulated plastic tubs containing water (Figure 3) that was heated to 33 °C with aquarium heaters. The nutrient solution was allowed to cool to 23 °C prior to inoculation. The duration of the treatment ranged from 8 - 144 h and was 72 h for the microbial remediation studies.

Figure 3. High temperature treatment of pepper roots

Beneficial microbe treatment: *Pseudomonas chlororaphis* 63-28 was added to the nutrient solution at a final density of 1 X 10^7 CFU mL^{-1} 7 days prior to high temperature treatment.

Development of PRR. Percent root browning was estimated visually using a standardized scale.

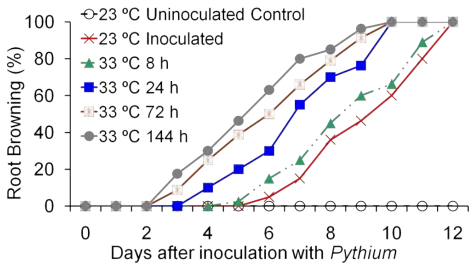
Growth analysis. Plant height was measured from the surface of the rockwool plug to the top of the canopy. Dry weights were measured on tissue dried at 80 °C for 48h. Leaf area was measured using a LI-COR LI-300 area meter.

Results and Discussion

1. Effects of pre-inoculation high temperature (Fig.4).

- High temperature predisposed the pepper plants to PRR.
- Root rot increased progressively earlier as the duration of pre-inoculation high temperature was increased. Example: root browning reached 50% 4 days earlier in plants kept at 33 °C for 144 h than in plants kept continuously at 23 °C.
- As few as 8 h at 33 °C were sufficient to predispose the plants to PRR.

Figure 4. Relationship of pre-inoculation high temperature (33 °C) duration to the progression of root browning (%) in *Pythium*- inoculated hydroponic sweet peppers.



2. Effects of *Pythium* and *Ps. chlororaphis* on plant growth (Figs. 5 and 6).

- *Pythium* caused severe root browning and stunting of growth within 12 days.
- In the absence of *Pythium, Ps. chlororaphis* promoted growth of the roots and shoots during 22 days after treatment with the bacterium (12 h shown In photo).
- Root and shoot growth in plants treated with *Ps. chlororaphis* and subsequently inoculated with *Pythium* was similar to, or greater than, in the untreated, non-inoculated control plants, and markedly higher than in the *Pythium* controls.

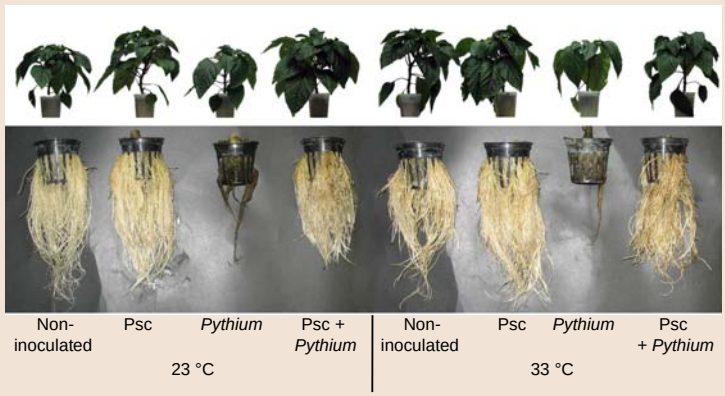


Figure 5. Appearance of pepper plants and their roots that were either treated with *Ps. chlororaphis* (Psc) or not and inoculated with *Pythium* or not and maintained at 23 °C or heat treated (33 °C for 72h). Photos taken 12 days after inoculation with *Pythium.*

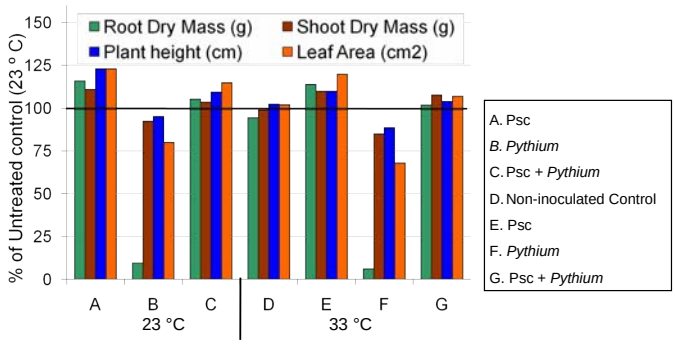
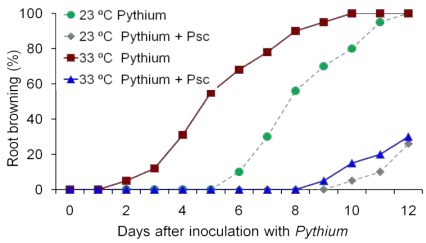


Figure 6. Growth responses of peppers that were treated with *Ps. chlororaphis* (Psc) alone or followed by *Pythium* and maintained at 23 °C or exposed to 33 °C for 72 h. plants. Data collected 12 days following *Pythium* treatment.

3. Effects of *P. aphanidermatum* and *Ps. chlororaphis* on root browning (Fig. 7).

- No root browning developed in non-inoculated control plants. Root browning progressed in sigmoidal curves in plants inoculated with *Pythium*, and more rapidly in plants exposed to 33 °C for 72 h than in plants kept continuously at 23 °C.
- *Ps. chlororaphis* markedly delayed and reduced progress of root browning in plants inoculated with *Pythium*.

Figure 7. Effect of treating sweet pepper roots with *P. chlororaphis* (Psc) alone or followed by *Pythium* on progress curves for percent root browning in plants maintained at 23 °C or exposed to 33 °C for 72 h.



Conclusions

- We demonstrated for the first time that high temperature in the root zone predisposes pepper roots to PRR.
- Predisposition to PRR was related quantitatively and positively to duration of pre-inoculation high temperature.
- *Pythium* markedly reduced shoot and root growth (dry mass, height, total leaf area).
- The beneficial microbe enhanced root and shoot growth and controlled PRR effectively throughout the experiment regardless of temperature treatment.
- Maintaining moderate temperature of the nutrient solution is important for controlling PRR.
- Monitoring of root zone temperature has value for predicting severity of PRR and for timing management practices such as use of beneficial bacteria.