soluble organic fertilizers available on the market was tested at the Danish Institute of Agricultural Sciences, Department of Horticulture. In general the nitrate content was low. Among these products a fish blood/fish bone product (Nu-Gro, Brøste A/S, Denmark) was different from the rest. It contained more nitrate and the ammonium content was low (10%) compared to nitrate. A product with a relatively high amount of nitrate and a relatively low ammonium content and acceptable sulphate content would solve the nutritional disorders we saw in this experiment. Nu-Gro is still not certified for organic use in Denmark, but when this happens trials with organic potted plants can be started. Many challenges still remain ahead before an organic production of high quality potted plants can be initiated, but a functional strategy for the nutrition of organic potted plants could be an important step in this direction.

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Increased Cation Content in Recirculating Nutrient Solutions as a Means for Controlling Dissemination and Attack of Root Rot in Glasshouse Crops©

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INTRODUCTION

The use of recirculating nutrient solutions for irrigation and fertilization of greenhouse crops has been gaining importance for Scandinavian potted plant production. The systems utilize the "ebb-flood" principle and they are economically as well as environmentally advantageous, but they introduce a risk for spreading of root pathogens. Pathogenic soil-dwelling organisms, predominantly fungi can be disseminated with zoospores and cause infections in many greenhouse plants. Therefore alternative control measures are needed.

Previous experiments have shown that infections by *Phytophthora cryptogea* in *Gerbera jamesonii* grown in ebb-flood systems could be reduced by increasing salt concentration (EC) in the water (Thinggaard and Andersen, 1995; Toppe and Thinggaard, 1998). Copper ions (Cu) are generally known to act as fungicides toward *Phytophthora* and the purpose of the experiments presented here was to examine the effects of different concentrations of Cu in the recirculating nutrient solutions on the development of root-related diseases in potted plants inoculated with different species of *Phytophthora*.

MATERIALS AND METHODS

Gerbera jamesonii and *Hedera helix* plants were grown in 10-cm pots on 27 separate ebb-flood benches each with their own separate recirculating irrigation system in a greenhouse at Årslev Research Center Denmark. Plants were obtained from commercial growers at the 6-week stage from seeds or cuttings. Irrigation was performed manually when needed and the water was pumped up to 2 cm and left there for 15 min before draining off to the reservoirs. Eight different nutrient solutions with two Cu concentrations (0.07 and 0.28 ppm); two nutrient levels (1.5 and 2.2 $mS \cdot cm^{-1}$), and two sources of iron (FeHEEDTA and $FeSO_4$) plus controls were used. The entire experiment was repeated three times with 40 plants of each species per treatment.

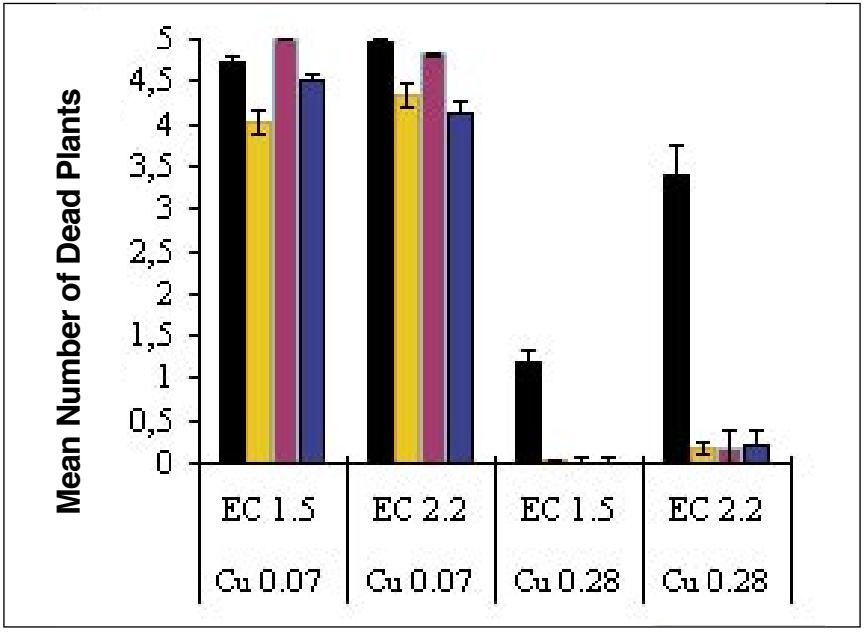

Figure 1. Mean number of dead plants (out of 5) of *Gerbera* per pot with different concentrations of Cu ion, different EC, and different zoospore loads (*P. cinnamomi*). Bars represent std. error.

The plants were inoculated with zoospores of *P. cryptogea (Gerbera) and P. cinnamomi (Hedera)*. Spores were added directly to the reservoirs. Two hours after addition the first irrigation was carried out. In the *Gerbera* experiment four different concentrations of zoospores were used (Fig. 1). In the *Hedera* experiment only two concentrations were used (5 and 125 spores per ml).

Weekly tests of the nutrient solution for presence of the pathogens were done on 200-ml samples from each reservoir. Samples were tested by filtration and by baiting. The experiments were terminated 17 days after inoculation for *Hedera* and after 28 days for *Gerbera*. Data collected were: number of infected plants and root quality (grading on a 0-5 scale). Statistical analysis was done with a factorial analysis of variance (glm, SAS-pc).

RESULTS

In *Gerbera* inoculated with *P. cryptogea* the attack was reduced considerably for plants grown in a nutrient solution containing 0.28 ppm Cu when $FeSO_4$ was used as iron source (Fig 1). No effect of increased Cu concentration was evident with FeHEEDTA in the solution. Change of the total ion concentration from 1.5 to 2.2 $mS \cdot cm^{-1}$ without changing the Cu concentration did not affect the development of the disease.

Similar results (not shown) were obtained with *Hedera:* fewer plants died at all levels of inoculum, when they were grown at 0.28 ppm Cu. The disease index the effect of increased Cu was significantly better at the lower EC.

DISCUSSION

These results indicate that increasing the concentration of Cu at least to 0.28 ppm in the nutrient solution can become a potential strategy for growing healthier potted plants that are subjected to infections by *Phytophthora* through the irrigation systems. In all treatments the higher Cu concentration reduced the disease significantly over the lower concentration. This fungus has previously been shown to be sensitive towards Cu (Thingaard and Andersen, 1998).

It is also clear that the beneficial effect of Cu is reduced markedly when iron chelates (Fe- HEEDTA) are present in the nutrient solution. The binding of Cu ions to the chelating moiety probably causes this. Also the use of $FeSO_4$ reduces the efficiency of the Cu by promoting the binding of Cu ions to humic substances in the soil. The original concentrations of .07 and .28 ppm were reduced to .01 and .06 ppm respectively, but the reduction of fungal attacks was still significant at the higher concentration.

Change in EC from 1.5 to 2.2 $mS \cdot cm^{-1}$ without modifying the Cu concentration had no influence on the disease. These results indicate that the previously reported findings of disease reduction by high EC (Thinggaard and Andersen 1995) must be explained by the higher level of specific ions in the solution rather than the generally higher salt concentration.

Symptoms of copper toxicity in the treated plants or significant accumulation of copper in the peat, the nutrient solution, or in the extracts of soil were not found during the 28 days the experiment lasted. Further experiments are, however, necessary to find out whether such copper treatment will lead to accumulation over time and thus possible danger of toxicity or environmental pollution. Nevertheless it is possible on the basis of the present evidence to recommend an increased Cu concentration as means for reducing fungal infections in potted plant production and add to the faster modification of recirculating nutrient solutions by reducing the risk for spread of zoospore producing organisms through the solution.

ADDITIONAL READING

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