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Short communication

Effectiveness of whey against zucchini squash and cucumber powdery mildew

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ABSTRACT

The effectiveness of whey against powdery mildew (*Podosphaera xanthii*) of cucumber and zucchini squash was tested in greenhouse experiments. Plants were sprayed once or twice a week with whey at concentrations of 0, 5, 10, 15, 20, 25, and 30% in water. Severity of powdery mildew was estimated weekly by visual assessment of individual leaves and scored as percentage of leaf area affected. Effectiveness of treatments did not differ significantly when applied weekly compared to twice a week. In each instance, powdery mildew severity correlated negatively with whey concentration. For cucumber, the rate of the disease progress in the control ranged from 0.45 to 0.75. Disease progressed more slowly in plants treated with 25–30% whey than when lower concentrations were used. The rate of disease progress varied from 0.12 to 0.33 in plants treated once a week and from 0.13 to 0.17 when applied twice a week. Similar tendencies were observed for zucchini, but disease progressed more rapidly and the final disease severity was higher than in cucumber. Effectiveness of whey applied twice a week at concentrations of 15–30% did not differ significantly among treatments; in these treatments the rate of disease progress was about 0.23 and significantly higher than the value for the water controls (about 0.80). Plants treated with 30% whey often exhibited symptoms of phytotoxicity. The data indicated that whey effectively controlled powdery mildew in cucumber and zucchini. Further studies are needed to optimize the concentration and timing of whey applications for mildew management in commercial crops.

1. Introduction

Powdery mildew, caused by *Podosphaera xanthii* [syn. *P. fusca* (Castagne) U. Braun & Shiskoff, *Sphaerotheca fuliginea* (Schlecht.) Pollacci], is a serious disease affecting the leaves, stems and fruits of cucumber and zucchini squash grown in greenhouses and in the field. The disease is controlled in commercial cucurbit crops by means of frequent applications of fungicides (Kimati et al., 1997). Heavy fungicide use, however, has resulted in the development of *P. xanthii* populations that are resistant to fungicides (McGrath, 1996; McGrath et al., 1996), and have raised public concerns over contamination of the environment and foods. The identification of biocompatible products for managing cucurbit powdery mildew with low animal toxicity and low potential risk to the environment would be a valuable contribution to disease management (McGrath and Shiskoff, 1999).

Bettiol et al. (1999) demonstrated that fresh cow milk is an effective alternative for the control of powdery mildew in zucchini squash. The effectiveness of the fresh milk was dose-dependent, and the control of the disease improved with the increase in the concentration applied. The authors recommended 5 or 10% whole milk in water for use in commercial crops. The activity of fresh milk against squash powdery mildew or zucchini squash is considered to involve several mechanisms. Milk may act directly on the pathogen due to its germicidal properties (Salle, 1954) and/or the presence of salts (Reuveni et al., 1993, 1995; Pasini et al., 1997). Indirect effects may include induction of host resistance and stimulation of antagonistic microorganisms on leaf surfaces. Stadnik and Bettiol (2001) observed the stimulation of microorganisms, especially bacteria, on the phylloplane of cucumber sprayed with milk. Enhanced development of saprophytic fungi such as *Cladosporium* and *Fusarium* was also observed, but did not affect germination or penetration the leaf by conidia of *P. xanthii*.

Application of fresh milk was reported to suppress powdery mildew in several crops. It has been commercially used by organic and conventional growers for the control of powdery mildew in cucumber, zucchini squash, pepper, grapevine and other agricul-

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tural species (Bettiol, 2003; Bettiol et al., 2005; Zatarim et al., 2005; Crisp et al., 2005, 2006).

Whey is a by-product of the processing of fresh milk and can be an environmental problem if not adequately disposed of by the dairy industry. Studies were initiated in 1999 to evaluate the potential of whey as a cheaper alternative to fresh milk for the control of powdery mildew in various crops, and, in this way make effective use of this organic resource. Preliminary findings that whey suppresses powdery mildew in zucchini squash were reported by Bettiol (2001). Crisp et al. (2005, 2006) reported that whey reduces the severity of powdery mildew in grapevines. The objective of the present study was to evaluate the effectiveness of whey for controlling powdery mildew in zucchini squash and cucumber under greenhouse conditions.

2. Materials and methods

Zucchini squash (*Cucurbita pepo,* cv. Caserta) and cucumber (*Cucumis sativus,* cv Safira) plants were grown in 5.0 L plastic pots containing soil and composted cattle manure (3:1, v/v) amended with 10 g of NPK fertilizer (4-14-8) in a greenhouse free from *P. xanthii.* The plants were transferred to a greenhouse with high density of *P. xanthii* inoculum when they had developed two fully expanded true leaves. Inoculum was dispersed in the greenhouse atmosphere by placing plants of zucchini squash and cucumber bearing sporulating colonies of *P. xanthii* beneath ventilation fans of the greenhouse. The plants were sprayed to runoff once or twice a week with one of the following concentrations of whey: 0, 5, 10, 15, 20, 25, and 30% in water (v/v). The whey treatments were applied by means of a compressed air paint sprayer at 0.7 kg/cm^2. The first application was made immediately after the plants were transferred to the greenhouse with *P. xanthii* inoculum. Experiments were set up in a randomized design with five replicates per treatment. Each replicate consisted of one pot containing one plant for zucchini squash and two for cucumber plants. The pots were randomly arranged on the greenhouse bench at the beginning of the experiment and were re-randomized at weekly intervals thereafter. Air temperature in the greenhouse during the experiments varied between 20 and 35 °C.

The severity of powdery mildew was evaluated visually on all individual leaves at weekly intervals and scored as percentage of area affected (Garibaldi et al., 1994; McGrath and Shiskoff, 1996). Statistical analyses were performed in 'R' (R Development Core Team, 2005). Effects of the whey concentrations were compared using generalized linear model, followed by analysis of the residuals to check for the distribution error and model adjustment. A minimal adequate model (MAM) was obtained by extracting non-significant terms ($p > 0.05$) from the full model and difference between levels of treatments (whey) were tested through a posteriori contrast procedure (Crawley, 2002).

3. Results and discussion

The percent leaf area with powdery mildew symptoms correlated negatively with the whey concentration (Fig. 1). Whey sprayed twice a week at concentrations >10% reduced severity of cucumber powdery mildew by 71–94% and zucchini powdery mildew by 81–90%. Severity of powdery mildew exceeded 40 and 50%, respectively, in control plants of cucumber and zucchini squash at 15 days after the first spray was applied (Fig. 1).

Leaves senesced more slowly on plants treated twice a week with whey, due to the control of powdery mildew. Disease control was directly proportional to the whey concentrations, except for the treatment of 5% whey in zucchini sprayed weekly. These results agree with those of Crisp et al. (2003), who found that the disease

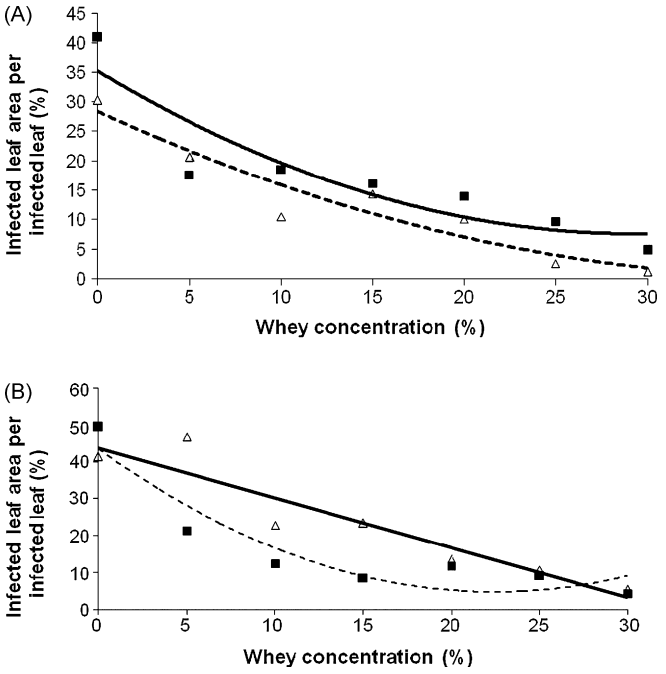

Fig. 1. Relationships of powdery mildew (*Podosphaera xanthii*) severity on leaves (%) of cucumber (A) and zucchini squash (B) and the concentration of whey sprayed once (—) or twice (—) a week. The severity values were measured 15 days after the first spray. Cucumber: sprayed once a week $y = 0.0319x^2 - 1.8759x + 35.174$; $R^2 = 0.8185$; sprayed twice a week $y = 0.018x^2 - 1.4242x + 28.315$; $R^2 = 0.9081$. Zucchini squash: sprayed once a week $y = -1.3473x + 43.669$; $R^2 = 0.883$; sprayed twice a week $y = 0.0768x^2 - 3.4513x + 43.524$; $R^2 = 0.8712$.

severity was inversely proportional to the concentration of whey sprayed to control the powdery mildew in grapevine (*Uncinula necator*).

For cucumber, the rate of disease progress in controls varied from 0.45 to 0.75. Final disease severity after 20 days varied from 26 to 30%. A decrease in severity of disease progression was observed treated with 25–30% whey (Fig. 1). When these treatments were applied once a week, the rate of disease progress varied from 0.12 to 0.33 and the final severity after 20 days varied from 9.2 to 10.6%. When applied twice a week, the rate varied from 0.13 to 0.17 and the final severity after 20 days varied from 2.6 to 1.2%.

For zucchini, the same trend was observed, but, the rate of disease progress and the final disease severity was higher then in cucumber. When applied twice a week, no difference was observed among the treatments with 15–30% whey. In these treatments, the rate of disease progress was about 0.23 during all the experiment and the final disease severity varied from 9 to 4%. These values were highly significant in relation to the control (rate 0.80 and final severity of 55%).

The effects of whey against powdery mildew zucchini squash and cucumber may involve more than one mode of action as was found for fresh milk. Stadnik and Bettiol (2001) and Medeiros et al. (2006) observe that milk increased the bacterial population on leaf surfaces of cucumber and zucchini, and that these bacteria were able to suppress the pathogen. Crisp et al. (2006) found that application of fresh milk or whey to grape leaves colonized by *Erysiphe necator* caused the hyphae of the pathogen to collapse and the conidia to appear damaged within 24 h after treatment. The authors hypothesized that the observed effects on the pathogen were related to increased production of free radicals and to the action of lactoferrin (an antimicrobial component of milk). Ravensberg et al. (2006) observed that lactoperoxidase, an anti-

microbial system active in bovine milk, was active in the control of powdery mildew in cucumber, tomato, sweet pepper and rose. Other components of milk and whey may also contribute to for the control of powdery mildew. The implementation of milk-based products requires a better understanding of their modes of action.

According to Medeiros (2006) and Crisp and Bruer (2001), the use of milk and whey is, in general, less expensive than fungicides, and has the advantage of achieving the same level of control. The economic viability of whey in disease control will depend on cost and benefits for the grower, which in turn will depend on the availability of the product and transportation costs from the dairy industries to the farm. Crisp et al. (2006) suggested that milk, whey, lactoferrin, and mixtures of oil plus bicarbonate are potential alternatives to sulfur and synthetic fungicides for the control of powdery mildew in grapevines.

This present work provides relevant information about the potential of whey to control powdery mildew in zucchini and cucumber. The results show the ability of whey to prevent the build-up of powdery mildew when applied directly to the plants. However, complementary studies are needed to characterize the modes of action of whey, and to establish the ideal concentrations and application frequency of whey in zucchinis and cucumbers grown under commercial conditions. It is recommended that growers who wish to use whey against mildew should conduct initial tests on a small scale in the target crop. As noted by Bettiol (2001) other characteristics of whey such as electrical conductivity and pH need to be considered in order to avoid phytotoxicity. Whey may also have value for controlling other pathogens and pests, including virus vectors. In addition, the effects in other non-target organisms such as the natural microflora of the phylloplane should be considered.

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