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Management of *Monosporascus* sudden wilt of melon by soil application of fungicides

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Abstract Sudden wilt (vine decline) of melon caused by *Monosporascus cannonballus* is a problem in arid and semiarid regions worldwide. Preplanting soil disinfestation with methyl bromide, a common treatment for disease management, has been banned in many countries, raising the need for alternative disease-control measures. Soil fungicide application during the growing season is one possible treatment. Twelve fungicides were evaluated in vitro for *M. cannonballus* suppression, seven of those were evaluated under field conditions. The fungicides azoxistrobin, prochloraz and pyraclostrobin + boscalid exhibited high and similar efficacies in controlling sudden wilt disease under field conditions. Fludioxonil applied at high rates was also effective but was phytotoxic. Fluazinam, the first fungicide found capable of suppressing sudden wilt and one which has been used in Israel since 2000, was less effective. The results indicate that two applications of a fungicide during the short fall season should be sufficient for effective control of the disease. In the long spring season, at least three applications are needed to protect the melon crop. Melon fruits were examined for fungicide residues and only boscalid residues were found. This fungicide was therefore limited to the first application before fruit set.

Keywords Azoxystrobin · Melon · *Monosporascus cannonballus* · Prochloraz

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Introduction

Sudden wilt of melon (*Cucumis melo* L.) caused by the soilborne fungus *Monosporascus cannonballus* (Pollack & Uecker) is a destructive disease known in arid and semiarid regions worldwide (Cohen et al. 2000; Martyn and Miller 1996). This devastating disease has been reported and investigated in several regions of the US, including southern California, Arizona, and Texas, as well as in Central America, Japan, Taiwan, Tunisia, Spain, Saudi Arabia and in the Arava Valley of southern Israel (Bruton and Miller 1997; Karlatti et al. 1997; Lobo Ruano 1990; Martyn et al. 1994; Mertely et al. 1993; Pivonia et al. 1997; Watanabe 1979). The disease has occurred in Israel since the early 1980s (Reuveni and Krikun 1983)

In commercial fields in the Arava region of southern Israel, melon and watermelon (*Citrullus lanatus*) crops can be totally destroyed by the disease in the late summer, while disease incidence and severity in crops grown in the same field during the following winter-spring season mostly are lower (Pivonia et al. 2002). A similar phenomenon has been observed in Arizona (Kim et al. 1995) and differences in soil temperature between the two growing seasons have been suggested as a possible explanation for seasonal variations in disease incidence (Pivonia et al. 2002). Wolff (1996) also suggested that disease symptoms in melons are affected by temperature stress in Texas.

Soil disinfestation by fumigation with methyl bromide before planting is, in general, highly effective against sudden wilt of melon and has been a common treatment in Israel (Klein 1996; Ucko et al. 1992). Methyl bromide fumigation can still be used in Israel with special permits; however, the material is very expensive and it is expected that in the near future, this treatment will no longer be available to melon growers. Additional approaches have been suggested for disease suppression. Among them, chemical soil disinfestation methods, cultural practices such as grafting, irrigation methods that increase root development (Cohen et al. 2000), and chemical destruction of the roots at the end of the season for reducing inoculum buildup (Stanghellini et al. 2003).

Fungicide application to existing vegetable crops for soilborne pathogens is used mainly for the management of seedling diseases such as *Pythium* and *Rhizoctonia* damping off. In these pathosystems, host-pathogen interactions occur during a short time window and in a relatively limited soil volume (Pivonia et al. 1997). Chemical control of pathogens that attack the deep root system of older plants, such as the vascular pathogens *Fusarium* and *Verticillium* (Erwin 1981) or the root-and stem-rot pathogen *Macrophomina* and the combined vascular and root-rot pathogen *Monosporascus*, is less common due to the complexity of the plant-environment-fungicide interaction. In laboratory tests conducted in 1998, the fungicides fluazinam and kresoxim methyl both completely inhibited vegetative growth of *M. cannonballus* in vitro (Cohen et al. 1999). Fluazinam was chosen for further testing under field conditions because it also was effective against *Pythium aphanidermatum*, a pathogen frequently found in the Arava melon fields. Fluazinam's efficacy at suppressing sudden wilt was confirmed in the field but results varied (Cohen et al. 1999). In two of the three experiments conducted, disease control at fruit ripening was about 87%, whereas in the third experiment it was only 32%. Fluazinam efficacy at controlling sudden wilt also was demonstrated in commercial fields. This fungicide was approved by the Israeli Ministry of Agriculture for commercial use and has been used since the year 2000. Fludioxonil (Cannonball™) is another fungicide registered in the United States in 2005 for the control of *M. cannonballus* (Syngenta 2008).

The objectives of the present study were to evaluate additional fungicides that could replace the partially effective fluazinam and to optimize their usage for both the spring and fall melon-growing seasons.

Materials and methods

Growth inhibition of *M. cannonballus* in vitro

The activity of 12 different fungicides on the growth of *M. cannonballus* was determined in vitro (Table 1). Sterile aqueous solutions of fungicide were mixed with melted potato dextrose agar medium to give concentrations of 0.1, 1 and 10 µg a.i./ml. A 10-mm disk of agar with *M. cannonballus* mycelium from a 10-day old culture was placed in the center of the Petri dish containing the test fungicide. The cultures were incubated at 27°C for 5 days, then colony diameter was measured and growth suppression calculated relative to the untreated control. There were four replicates (Petri dishes) for each fungicide and concentration.

Management of *M. cannonballus* in field trials

Disease management trials were conducted in fields naturally infested with *M. cannonballus* at the "Zohar" experimental station at Ein Tamar in the northern Arava Valley, Israel. There are two main cropping season for melon in the Arava: spring and fall. Fall melons are grown in the open field and the growing season is about two and a half months. Spring melons are grown in walk-in tunnels and the season lasts seven to eight months. The fungicides

Table 1 Fungicides evaluated in the laboratory and field experiments (in alphabetical order)

Fungicide	Laboratory test	Field experiments			
		Fall 2006	Spring 2007	Fall 2007	Spring 2008
Azoxystrobin (a.i. 25%)[z]	+	+	+	+	+
Carbendazim	+	–	–	–	–
Famoxadone + mancozeb	+	–	–	–	–
Fluazinam (a.i. 500 g/liter)	+	+	+	–	–
Fludioxonil (a.i. 230 g/liter)	+	+	–	+	–
Fludioxinil + cyprodinil	+	–	–	–	–
Kresoxim methyl (a.i. 50%)	+	–	–	+	–
Metominostrobin	+	–	–	–	–
Prochloraz (a.i. 45%)	+	+	+	+	+
Pyraclostrobin +boscalid (a.i. 6.7%+26.7%)	+	+	–	–	–
Tebuconazole	+	–	–	–	–
Trifloxystrobin (a.i. 50%)	+	–	-	+	-

[z] a.i.—Active ingredient in the commercial product, given only for fungicides that inhibited mycelial growth in culture at a concentration of 0.1 μg/ml and were evaluated later in the field. The fungicides carbendazim, famoxadone + mancozeb, metominostrobin, fludioxonil + cyprodinil, and tebuconazole were not tested in the field.

azoxystrobin and prochloraz were the most effective in reducing disease incidence in preliminary studies and were tested four times in this present study; during the fall season of 2006 and 2007 and in the spring of 2007 and 2008. The fungicide fluazinam has been used in Israel since the year 2000 to control *M. cannonballus* and was tested twice in the current experiment: fall 2006 and spring 2007 (Table 1). The three most effective fungicides in the in vitro test, Fludioxonil, Kersoxin methyl and Trifloxystrobin also were evaluated under field conditions (Table 1).

Fall season trails

In 2006 five fungicides were evaluated in the field; azoxystrobin, prochloraz, fluazinam, fludioxonil, and pyraclostrobin + boscalid (Table 2). Approximately 2-wk-old melon (cv. Malika, Nunhems B.V.) plants were transplanted to the field on Sep 6, 2006. Intra-row spacing was 40 cm and beds were 160 cm apart. The experiment was conducted in a complete randomized design, with four replicates of 25 plants each. The plants were grown prostrate in the open field. All fungicides were applied three times during the growing season: first by root dipping at transplanting (except for prochloraz), and then twice in the field, 3 and 5 weeks after transplanting. Prochloraz was applied in the field 1 week after transplanting instead at transplanting because it may cause some phytotoxicity when applied to young transplants. The fungicides were applied through the drip irrigation system.

In 2007 five fungicides were evaluated; azoxystrobin, prochloraz, fludioxonil, trifloxystrobin, and kresoxim-methyl (Table 3, Fig. 1). The melon cultivar was 1625 (A.B. Seeds, Teradion, Israel) and plants were transplanted to the field on Sep 5, 2007. The experimental design was as described above. Fungicides were applied three times during the growing season: first by root dipping at transplanting (except for prochloraz), and then twice in the field, 2 and 5 weeks after transplanting.

In addition, azoxystrobin was evaluated for the most effective number of applications (Fig. 1). The fungicide was applied in four schemes: 1. as root dipping at transplanting, 2. root dipping and drip application after 2 weeks, 3. root dipping and drip application after 5 weeks and 4. all three applications (root dipping, three and five drip applications). The amount of each fungicide applied is indicated in Table 3 and Fig. 1.

Spring season trails

In Spring 2007 three fungicides were evaluated, azoxystrobin, prochloraz and fluazinam (Table 4). Melon (cv. 6003, HaZera Genetics, Mivhor, Israel)

Table 2 Effect of fungicide applications on yield and disease incidence in melons grown in *Monosporascus cannonballus*-infested soil. Fungicides were applied three times. The first time by root dipping at transplanting and twice during the growing season, 3 and 5 weeks after transplanting. The experiment was conducted in the fall of 2006. Melons were transplanted on Sep, 6, 2006 and final disease incidence was evaluated on Nov 12, 2006. Yield and disease incidence values followed by the same letter are not significantly different

Fungicide treatment in the field[y]	Fungicide concentration for root dipping at transplanting (%)	Yield (kg/h)	Final disease incidence (%)
Untreated control	None	14,470 c	80 a
Azoxystrobin 3,000	0.1	31,810 a	0 b
Fludioxonil 750	0.1	21,090 bc	7 b
Fluazinam 1,500	0.1	17,070 c	65 a
Pyraclostrobin + boscalid 2,000	0.1	28,720 a	6 b
Prochloraz 2,500 [z]	None	28,110 ab	3 b

[y] Fungicide rate in ml/ha or g/ha of commercial product.

[z] Since prochloraz can be toxic to young seedlings, the first treatment was given in the field 1 week after transplanting

plants were transplanted on Dec 5, 2006. Intra-row spacing was 40 cm and beds were 160 cm apart. The experiment was conducted in complete randomized design, with four replicates of 25 plants each. The plants were grown trellised in a walk-in tunnel covered with polyethylene sheeting. All fungicides were applied four times during the growing season: first by root dipping at transplanting (except for prochloraz), and then 40, 88 and 134 days after transplanting. The fungicides were applied through the drip irrigation system. Azoxystrobin also was tested for the most effective number of applications (Fig. 2) and was applied in four schemes: 1. as root dipping at transplanting , 2. root dipping and then drip application after 40 days, 3. root dipping and drip applications after 40 and 88 days and 4. all four application schemes as described above. The amount of each fungicide applied is indicated in Table 4 and Fig. 2.

Table 3 Effect of fungicide applications on yield and disease incidence in melons grown in *Monosporascus cannonballus*-infested soil. Fungicides were applied three times: first by root dipping at transplanting and then 2 and five weeks after transplanting. The experiment was conducted in the fall of 2007. Melons were transplanted on Sep 5, 2007 and final disease incidence was evaluated on Nov 7, 2007. Yield and disease incidence values followed by the same letter are not significantly different

Fungicide treatment in the field	Fungicide concentration for root dipping at transplanting (%)	Yield (kg/h)	Final disease incidence (%)
Untreated control	None	21,140 a	80 c
Azoxystrobin 250[z]	0.2	34,570 bcd	49 abc
Azoxystrobin 500	0.2	39,340 cd	20 ab
Azoxystrobin 1,500	0.2	42,920 d	8 ab
Azoxystrobin 3,000	0.2	38,170 bcd	6 ab
Fludioxonil 250	None	35,240 bcd	38 ab
Fludioxonil 500	None	35,990 bcd	40 abc
Fludioxonil 750	None	31,620 bc	21 bc
Kresoxim-methyl 1,500	0.2	34,340 bcd	54 bc
Prochloraz 750	None	34,110 bc	30 ab
Prochloraz 1,500	None	34,640 bcd	8 ab
Prochloraz 3,000	None	35,650 bcd	4 a
Trifloxystrobin 1,500	0.2	32,210 bc	46 abc

[z] Fungicide rate of commercial product: ml/ha or g/ha for kresoxim-methyl and trifloxystrobin

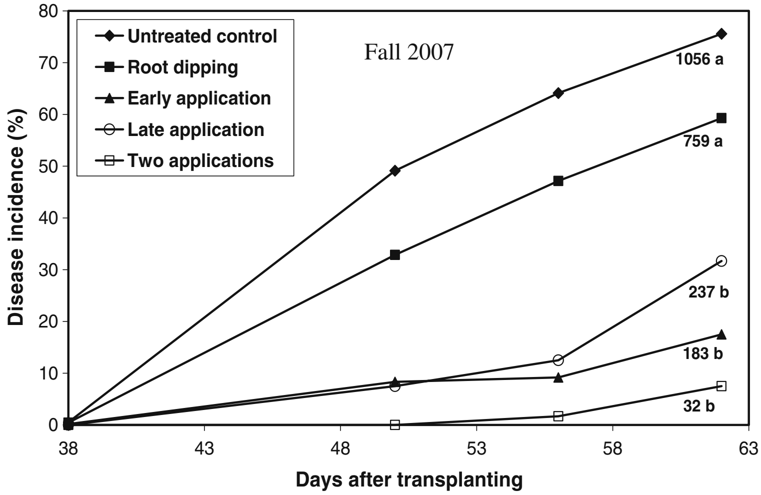

Fig. 1 Effect of the number of azoxystrobin (1,500 ml/ha) applications on disease progress in melons grown in *Monosporascus cannonballus*-infested soil in 2007 fall season. Treatments were: Untreated control, root dipping at planting, root dipping + field application 2 weeks after planting (early application), root dipping + field application 5 weeks after planting (late application) and root dipping + two field applications. AUDPC is indicated as numbers on the curve. Numbers followed by the same letter are not significantly different

In 2008, the efficacy of the two most effective fungicides from the 2007 trails, azoxystrobin and prochloraz was further tested. The melon cultivar and experimental design were as described previously. Plants were transplanted on Dec 20, 2007 and the two fungicides were applied three times during the growing season: 45, 89 and 130 days after transplanting. The amount of each fungicide applied was 1500 ml/ha commercial formulation.

Table 4 Effect of fungicide applications on yield and disease incidence in melons grown in *Monosporascus cannonballus*-infested soil. Fungicides were applied four times during the growing season: first by root dipping at transplanting, and then 40, 88 and 134 days after transplanting. The experiment was conducted in the spring of 2007. Melons were transplanted on Dec 5, 2006 and final disease incidence was evaluated on May 31, 2007. Yield and disease incidence values followed by the same letter are not significantly different

Fungicide treatment in the field[y]	Yield (kg/h)	Final disease incidence (%)
Untreated control	41,790 a	64 b
Azoxystrobin[z] 1,500	70,500 bcd	0 a
Azoxystrobin 3,000	89,070 d	2 a
Fluazinam 1,500	57,660 ab	54 b
Fluazinam 3,000	67,780 bc	42 b
Prochloraz 1,500	66,080 bc	6 a
Prochloraz 3,000	78,690 cd	5 a

[y] Fungicide rate in ml/ha of commercial product.

[z] First application at transplanting. Plants roots of both azoxystrobin treatments were dipped in 0.1% fungicide suspension

Disease incidence evaluation

The experimental plots were evaluated once a week for disease incidence. Plant wilting was evaluated visually in all experiments. A plant was considered dead when the whole plant exhibited irreversible wilting symptoms. The percentage of wilted plants was used to calculate wilt incidence.

Fungicide residues in melon fruits

Melon fruits collected from plants treated with azoxystrobin, fluazinam, fludioxonil, prochloraz and pyraclostrobin + boscalid were examined for fungicide residues at an accredited contract laboratory (Bactochem Ltd., Nes Tziona, Israel) using methods based on the Manual of Food Quality Control 13 (FAO 1992) and the Pesticide Analytical Manual (USFDA 1995). Briefly, the fungicide residues were extracted as a bulk from 8 fruits sample with acetone, partitioned into a second phase for clean-up and drying and then analyzed in a gas chromatograph (GC) equipped with a mass spectrometry (MS) detector and a capillary DB-5 column. Quantification was carried out with external standard

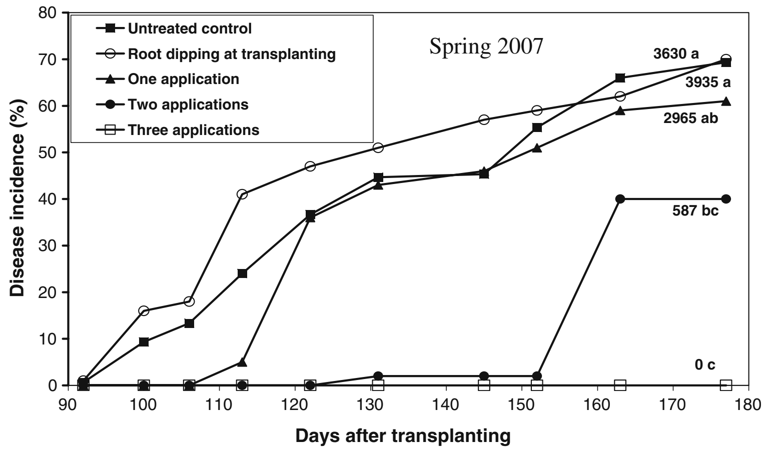

Fig. 2 Effect of number of azoxystrobin (1,500 ml/ha) applications on disease progress in melons grown in *Monosporascus cannonballus*-infested soil in 2007 spring season. Treatments were: Untreated control, root dipping at planting with 0.1% azoxystrobin, root dipping + field application 40 days after planting (one application), root dipping + field application 40 and 88 days after planting (two applications) and root dipping + three applications 40, 88 and 134 days after planting (three applications). AUDPC is indicated as numbers on the curve. Numbers followed by the same letter are not significantly different. The experiment was conducted in spring 2007

solutions in a matrix. Peaks were identified by their retention times and by the masses of the characteristic ions of the analyzed components.

Statistical analysis

Fruit yield and disease incidence values (expressed as area under the disease progress curve - AUDPC) were statistically analyzed by one-way analysis of variance (ANOVA) using JMP software (SAS Institute Inc., Cary, NC). The Tukey-Kramer honestly significant difference test (P=0.05) was used to compare means.

Results

Inhibition of *M. cannonballus* in culture

Of the 12 fungicides tested in the laboratory, eight: fluazinam, fludioxonil, prochloraz, fludioxonil + cyprodinil, kresoxim methyl, trifloxystrobin, azoxystrobin and pyraclostrobin + boscalid (Table 1), completely suppressed mycelial growth in culture at a concentration of 0.1 μg a.i./ml. The fungicides tebuconazole, carbendazim, famoxadone + mancozeb and metominostrobin also were effective in inhibiting mycelial growth, but at higher concentrations and complete inhibition was obtained at 1 to 10 μg a.i./ml. Therefore these fungicides were not evaluated in the field experiments.

Management of *M. cannonballus* in field experiments

Fall season trials

In 2006, slight phytotoxic symptoms were observed on transplants treated with fluazinam and fludioxonil after transplanting. However, those symptoms disappeared rapidly with plant growth. Additional phytotoxic effects of fludioxonil were observed later in the season, including leaf rigidity and eventually yield reduction.

Initial wilting symptoms were observed in the untreated control plots 45 days after planting and reached 80% by the end of the experiment (Table 2). Wilt incidence in plants treated with azoxystrobin, prochloraz, fludioxonil and pyraclostrobin + boscalid ranged from 0 to 7%. The fluazinam treatment was not effective in reducing symptoms as disease incidence did not differ significantly from the untreated control (Table 2). Melon yield in the untreated control was significantly lower comparing to the effective fungicide treatments (Table 2). The highest yield was harvested from the azoxystrobin treaded plots and was 2.2 fold higher than the untreated control. At the end of the experiment, four plants from each treatment were uprooted and examined for the appearance of *M. cannonballus* fruiting bodies (perithecia) on the roots. Diagnostic perithecia were evident on the roots of untreated plant and on roots of those of two of the fluazinam-treated plants. Additionally, a low number of perithecia was observed on the roots of one of the pyraclostrobin + boscalid-treated plants. Perithecia were not detected on the roots of other fungicide-treated plants.

In 2007, the application of azoxystrobin by root dipping at transplanting was not effective in controlling the disease and did not differ significantly from the untreated control. A single azoxystrobin treatment applied 2 or 5 weeks after transplanting was less effective than two applications. Although no significant difference was observed between these two single-application treatments, early application gave somewhat better results; 18% diseased plants as compared with 32% in the late treatment. Final disease incidence in plants treated twice at 2 and 5 weeks after transplanting was only 8% (Fig. 1).

The strobilorin fungicides trifloxystrobin and kresoxim-methyl, which were highly effective in the laboratory evaluation, did not suppress wilting under field conditions. Azoxystrobin applied at 250 ml/ha was not effective and a rate of 500 ml/ha gave only slightly better results (Table 3). Plants treated with azoxystrobin and prochloraz at 1500 and 3000 ml/ha exhibited low disease incidence, ranging from 4 to 8%. Marketable yield was positively correlated with disease suppression (Table 3).

Spring season trials

In the 2007 experiment, root dipping at transplanting along with one additional azoxystrobin application was not effective in controlling the disease and did not differ significantly from the untreated control. Root dip application and two additional drip applications reduced disease incidence to 40%, as compared to 70% in the untreated control. Root dipping and three additional drip applications completely suppressed disease symptoms (Fig. 2). The disease control efficacies achieved by three field applications of azoxystrobin, fluazinam and prochloraz are compared in Table 4. First wilt symptoms were evident in the untreated control plants about 100 days after transplanting. Wilting in the fluazinam-treated plants started about 1 month later. Disease control achieved by azoxystrobin and prochloraz was similar and melon yields of plants treated with these fungicides were significantly higher than the untreated control (Table 4).

The efficacy of azoxystrobin and prochloraz was also confirmed in a trial conducted in 2008. Disease incidence by the end of the experiment was 3, 10 and 55% in the azoxystrobin, prochloraz and untreated control treatments, respectively.

Fungicide residues in melon fruits

A bulk sample of 8 melon fruits from the first harvest of the fall 2006 experiment were examined for fungicide residues. Only residues of boscalid (0.7 ppm), from the pyraclostrobin + boscalid treatment, were found. Interestingly, an unexpected effect on foliar disease was observed. By the end of the experiment, all plants were highly infected with powdery mildew except for the plants treated with azoxystrobin and pyraclostrobin + boscalid, probably due to these two fungicides' systemic action and the ability of azoxystrobin and boscalid to suppress powdery mildew.

Discussion

The fungicides azoxystrobin, prochloraz and pyraclostrobin + boscalid exhibited high and similar efficacies in the control of sudden wilt disease under field conditions. High rates of fludioxonil also were effective, but were phytotoxic. Fluazinam, the first fungicide found capable of suppressing sudden wilt (Cohen et al. 1999) and used in Israel since 2000, was less effective than the other fungicides tested. Since some boscalid residue was detected in the fruits, emphasis was given to study the effective and non-toxic fungicides; azoxystrobin and prochloraz. Nevertheless, pyraclostrobin + boscalid may be used as part of a treatment scheme, when applied before fruit set.

Melons are grown during two agro-technologically different seasons in the Arava Valley of southern Israel. The spring season is cooler and longer than the fall growing season. Recommendations for disease control strategies differ accordingly. Our results indicate that during the short fall season, when disease progress is very rapid (Pivonia et al. 2002), two fungicide applications in a 3-week interval are needed for effective control of the disease. In the spring, the disease progress is slower and therefore three or four fungicide applications with a 6-week interval are sufficient to protect the melon crop throughout the 7 to 8 month growing season.

The fungicides found to be effective in this study (azoxystrobin, fludioxonil, prochloraz, pyraclostrobin + boscalid) are characterized by relatively slow degradation rates, as evidenced by their long half-lives, and intermediate to high absorption to the soil, as evidenced by their medium to high organic-based soil sorption coefficients (Table 5). These characteristics allow long-term protection of the plant roots and prevent leaching of the chemicals out of the soil rhizosphere. Furthermore, when fungicides are applied via drip irrigation, their intermediate to high sorption ensures that the rhizosphere will always contain an amount of the fungicide (Gerstl and Yaron 1983a, b). Unlike pre-planting soil fumigation, which aims to kill the fungal survival structures (ascospores) in the soil before planting, we hypothesize that *M. cannonballus* could be controlled during its biologically active stages. Ascospores of *M. cannonballus* might germinate and penetrate into melon roots throughout the season according to the environmental conditions and fungus-root interactions. The longer a fungicide persists in the soil, the fewer number of applications would be needed to obtain significant disease control. The relatively low efficacies of fluazinam, trifloxystrobin and kresoxim-methyl in the field vs their high efficacy in in vitro growth tests, appears to stem from their short persistence in the soil and, consequently, these fungicides might be more effective with more frequent applications. Fungicide application by root dipping at time of transplanting was a minor contributing factor to the overall control regime. Moreover, it exposed the transplant to potential phytotoxicity. Therefore, root-dipping transplants in the fungicide immediately before transplanting is not a recommended practice for the control of *M. cannonballus*.

Table 5 Half life and sorption of the evaluated fungicides

K_{oc}[z] (g/ml soil organic carbon)	$T_{1/2}$[y] (days)	Fungicide
423	70	Azoxystrobin
16,430	11	Fluazinam
75,000	125	Fludioxonil
308	16	Kresoxim-methyl
2,225	120	Prochloraz
11,000	32	Pyraclostrobin
809	200	Boscalid
2,377	7	Trifloxystrobin

[y] Half-life of the pesticide in soil.

[z] Organic carbon-based sorption coefficient.

Source: Footprint (2008)

Azoxystrobin and prochloraz excelled in suppressing disease caused by *M. cannonballus*. Azoxistrobin also is active against other soil-borne pathogens that may threaten melons in the Arava region, such as *Myrothecium roridum* and *Didymella bryoniae* (Syngenta 2008). It also is effective at controlling downy and powdery mildews (Ishii et al. 2001), which cause damage to melons during the relatively humid winters in the Arava. Indeed, effective powdery mildew control was evident in azoxystrobin-treated plants in this present study, mainly in the fall experiments (data not shown). The fungicide fludioxonil (Cannonball™,) is a commercial product registered by Syngenta for controlling *M. cannonballus* (Syngenta 2005). This fungicide was tested as well but it was less effective than the azoxystrobin and in certain cases was phytotoxic to plants. The effective fungicides found in this study enable the design of a control scheme in which azoxystrobin is used to control *M. cannonballus* and other soil-borne diseases in the early spring season, followed by prochloraz, later in the season when *M. cannonballus* becomes the major threat to the melon crop. Alternation of fungicides during a season would enable long-term use of this control measure, as it might reduce the risks of selecting for resistant pathogen biotypes and, or the development microbial populations in the soil that possibly could accelerate degradation of the fungicides.

In summary, the technology described in this study is different from other chemical treatments since it is applied during the growing season and not as a pre-plant or post-harvest soil treatment (Ucko et al. 1992; Stanghellini et al. 2003). Fungicide application during the growing season offers the grower an effective, easy to apply and inexpensive method for the control of sudden wilt of melons caused by *M. cannonballus*. Azoxystrobin was recently registered in Israel for the control of *M. cannonballus* in melons and is applied by the majority melon growers in the Arava.

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