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Suppression of Fusarium Wilt of Watermelon Enhanced by Hairy Vetch Green Manure and Partial Cultivar Resistance

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Abstract

Hairy vetch (*Vicia villosa* Roth) green manure is a newly-described potential management tool for Fusarium wilt of watermelon, but control is insufficient when watermelon, especially triploid watermelon, is grown in severely infested soils. A field experiment in a split-split-plot design was conducted over two years to evaluate efficacy of hairy vetch green manure alone and in combination with a moderately wilt-resistant (MR) triploid watermelon cultivar for wilt suppression compared with preplant soil fumigants. Either the soil-incorporated hairy vetch winter cover crop or the MR cultivar was effective in reducing wilt incidence, promoting plant vine growth, and increasing fruit yield. However, neither approach alone resulted in disease reductions sufficient to obtain an acceptable level of marketable fruit yield. An additive effect was observed when both treatments were combined and was greater than that obtained with the fumigants methyl bromide or metam sodium. Stem colonization by *Fusarium oxysporum* f. sp. *niveum* was lower following hairy vetch green manure than in fallow treatments, and was lowest in the MR cultivar grown in green-manured plots. The combined use of hairy vetch green manure and a MR cultivar can enhance suppression of Fusarium wilt in triploid watermelon.

Introduction

Fig. 1. Foliar symptoms of Fusarium wilt of watermelon caused by *Fusarium oxysporum* f. sp. *niveum* (upper right).

Fusarium wilt of watermelon (Fig. 1), caused by *Fusarium oxysporum* Schlechtend.:Fr. f. sp. *niveum* (E. F. Sm), is the most important soilborne disease of watermelon in Maryland and Delaware and many other parts of the world. Currently, host resistance is the most common method used to manage Fusarium wilt of watermelon. However, its effectiveness is primarily dependent on the prevalence of specific races of the pathogen. Three races of *F. oxysporum* f. sp. *niveum* (*FON*) have been described: races 0, 1, and 2 (5,12). Race 0 is least aggressive, race 2 is highly aggressive, and race 1 is intermediate. Race 1 is the most frequently-occurring race throughout the United States and the world (12), while race 2 is known to be present in Delaware, Florida, Indiana, Oklahoma, Maryland, and Texas (5,8,12,15). Race 2 also is present in several Mediterranean countries including Cyprus, Greece, Israel, Turkey, and Spain (5). Most commercially-available diploid (seeded) watermelon cultivars have resistance to races 0 and 1 (5,12), while most triploid (seedless) watermelon cultivars are susceptible to race 1 (5,18). All commercially available diploid and triploid cultivars are susceptible to race 2. Due in part to the substantial hectares of triploid watermelon, which represent over 50% of watermelon produced in the northeastern United States and 30% in the United States (5), and the increased prevalence of race 2, losses due to Fusarium wilt are increasing.

There is growing interest in research and application of winter cover crops for disease management in organic and sustainable agriculture systems. Winter cover crops, especially legume cover crops, not only reduce soil erosion, contribute nitrogen to the subsequent cash crops, and improve soil physical and chemical properties, but also suppress weeds, harmful insects and diseases (4). Hairy vetch (*Vicia villosa* Roth) (Fig. 2) is a legume that can be planted as a winter crop throughout most of the eastern and central United States (3,4). It can be killed in the spring and incorporated as a green manure or no-tilled as an organic mulch in production of tomato, cucurbits, and other vegetables in the Mid-Atlantic region of the United States (1,2,3,4,9). Hairy vetch as a green manure produced sufficient amounts of ammonia to reduce soil populations of *Thielaviopsis basicola*, and subsequent incidence of black root rot on cotton in Arkansas (6,14). In Maryland, a killed hairy vetch winter cover crop, when left on the ground as an organic mulch, reduced the severity of powdery mildew (caused by *Podosphaera xanthii*) and Plectosporium blight (caused by *Plectosporium tabacinum*) on pumpkin (9), and also reduced the severity of early blight (caused by *Alternaria solani*) and Septoria leaf spot (caused by *Septoria lycopersici*) on staked fresh market tomato (13). More recently, we found that soil amended with hairy vetch induced suppression to Fusarium wilt in diploid watermelon (17). However, neither a cover crop of hairy vetch incorporated as green manure nor wilt resistance available in commercial triploid watermelon was sufficient to suppress Fusarium wilt under high wilt pressure (*unpublished data*). The benefits of wilt suppression resulting from hairy vetch combined with partial host resistance compared to wilt suppression of soil fumigation have not been previously studied.

Fig. 2. Flowering hairy vetch just before incorporation into soil.

This research was conducted to determine the effects of a hairy vetch winter cover crop as a green manure alone and together with a triploid watermelon cultivar with moderate resistance to Fusarium wilt on incidence of Fusarium wilt, plant growth, and fruit yield, and on soil populations of *F. oxysporum* compared with preplant soil fumigants.

Field Plot Establishment

Experiments were conducted in a field of Nolfolk "A" loamy sand at the University of Maryland's Lower Eastern Shore Research and Education Center, Salisbury. The field had a history of continuous watermelon production and was highly infested with *FON* comprising a mixture of races 0, 1, and 2 (15). The field was not treated with any fumigants the year before the experiment. Plots were single raised beds 25 m long, 0.9 m wide, and 15 cm high.

The experiment was conducted as a split-split-plot design with four replications in 2003 and 2004. The whole plots were winter fallow or a fall planted hairy vetch cover crop that was killed in the spring and disked; subplots were the triploid watermelon cv. Millionaire or Seedless Sangria (susceptible and moderately resistant to race 1 of *FON*, respectively, but both susceptible to race 2); and sub-subplots were a nonfumigated control or fumigated with methyl bromide at 224 kg/ha (2003) or metam sodium (Vapam, Amvac Chemical Corporation, Commerce, CA) at 374 liter/ha (2004). Hairy vetch seeds inoculated with a commercial formulation of *Rhizobium* spp. were sown in early October at 50 kg/ha (2002) or 45 kg/ha (2003). In late May, aboveground biomass of hairy vetch in three areas (0.5 by 0.5 m) at the edges of each plot was sampled, dried, and weighed. Subsequently the remaining hairy vetch (Fig. 2) was then flattened with a cultipacker, sprayed with paraquat (1.2 kg a.i/ha, Gramoxone Extra 2.5SC; Zeneca Agrochemicals, Greensboro, NC), disked three times, and incorporated to a depth of 20 cm. Plot beds were formed by a bed shaper, a single-drip irrigation tube was placed at the center, and the beds were covered with commercial black polyethylene (LDPE). The winter fallow plot areas received the same bed preparation as the hairy vetch treatment. Methyl bromide (98% a.i. formulation, Terr-O-Gas 98; Great Lake Chemical Corp., West Lafayette, IN) in 2003 or metam sodium (42% a.i. formulation, Vapam) in 2004 was injected at a 20-cm soil depth and covered immediately with black polyethylene.

In late June, after a period of 3 to 4 weeks following soil incorporation of hairy vetch, 4-week-old greenhouse-grown seedlings of the triploid watermelon cv. Millionaire or Seedless Sangria were transplanted 0.91 m apart within rows. The diploid watermelon cv. Royal Majesty, highly resistant to races 0 and 1 of *FON* but susceptible to race 2, was transplanted in every third planting site within each row and served as the pollinator.

Based on the results of soil fertility analyses, 18-0-15 N-P-K at 666 kg/ha in 2003 or 34-0-0 N-P-K at 303 kg/ha in 2004 was applied to winter fallow plots before bedding. At 1, 3, and 5 weeks following transplanting, urea was applied at 28 kg/ha to all plots through a drip irrigation system. Irrigation and management of foliar diseases, insects, and weeds were conducted according to local extension recommendations.

Disease Ratings, Plant Growth, and Yield

Development of Fusarium wilt was observed weekly and the incidence of Fusarium wilt determined 56 days after transplant by counting plants that had one or more runners wilted or dead. The length of the primary runners of three randomly-selected plants per plot was measured 21 days after transplant. At maturity, marketable fruit were individually weighed, and sugar content from the center of three arbitrarily selected fruit per plot was measured with a handheld refractometer. Three plants per plot were cut at the soil line, air dried in a greenhouse, and weighed to determine the dry weight of the aboveground plant biomass. Experiments were analyzed as a split-split-plot design with the General Lineal Model (GLM) procedure of SAS (version 8.2; SAS Institute Inc., Cary, NC). Data were subjected to analysis of variance (ANOVA) and means were separated by Fisher's protected least significant difference (LSD) test at $P = 0.05$.

In 2003, the aboveground dry weight of the hairy vetch cover crop ranged from 7.5 to 8.0 tons/ha, with an average of 7.9 tons/ha. The results of variance analyses indicated that there was significant ($P < 0.05$) interaction of green manure by cultivar by fumigation for wilt and significant interaction between green manure and cultivar for fruit yield (Table 1). However, no significant ($P > 0.05$) interactions among green manure, cultivar, and fumigation were observed on vine length, aboveground dry weight of plants, or sugar content in watermelon fruit. Compared to the control treatment (Fallow + 'Millionaire' + No fumigant), hairy vetch green manure alone (Vetch + 'Millionaire' + No fumigant) and planting with the moderately-resistant (MR) cv. Seedless Sangria alone (Fallow + ‘SS’ + No fumigant) significantly ($P < 0.05$) decreased the incidence of Fusarium wilt (Table 2). The MR cultivar alone (50% wilt reduction) reduced wilt to a greater extent than the green manure alone (26% wilt reduction). Combining the green manure with the MR cultivar (Vetch + ‘SS’ + No fumigant) (68% wilt reduction) produced significantly lower wilt incidence than the green manure alone or the MR cultivar alone (Table 2, Fig. 3). This effect was even greater than that obtained with the soil fumigant methyl bromide (Fallow + ‘Millionaire’ + Fumigant) (21% wilt reduction) (Table 2). However, the soil fumigant added to the combined treatment of hairy vetch with the MR cultivar (Vetch + ‘SS’ + Fumigant) resulted in the least incidence of Fusarium wilt (88% wilt reduction). The combined treatment of the green manure with the MR cultivar (Vetch + ‘SS’) also resulted in significantly higher fruit yield than the green manure alone (Vetch + ‘Millionaire’) and the MR cultivar alone (Fallow + ‘SS’) (Table 3). Fumigation increased fruit yield compared to no fumigation, 15 to 11 tons/ha, respectively (Table 1). Vine length of plants was significantly increased by hairy vetch green manure, the use of the MR or the soil fumigant (Table 4). Aboveground dry weight of watermelon plants was significantly increased by the use of the MR cultivar or the soil fumigant, but not by hairy vetch green manure. Green manure significantly ($P < 0.05$) increased sugar content in fruit but use of the MR cultivar or the soil fumigant did not.

Table 1. Variance analysis for the effects of hairy vetch green manure, cultivar resistance, and soil fumigation on incidence of Fusarium wilt, plant growth, and fruit yield and sugar content of watermelon in 2003 and 2004.

		Plant growth		**Marketable fruit**	
Source	**Wilt**	**Vine length**	**Dry weight**	**Yield**	**Sucrose**
2003					
Manure	<0.000*	0.0217	0.3238	<0.0001	0.0001
Cultivar	<0.0001	<0.0001	0.0001	<0.0001	0.0522
Fumigation	<0.0001	0.0446	0.0097	0.0169	0.3633
Manure x Cultivar	0.5484	0.9730	0.1827	0.0016	0.5299
Manure x Fumigation	0.0147	0.2578	0.5273	0.8289	0.9030
Cultivar x Fumigation	<0.0001	0.8807	0.0678	0.0655	0.5588
Manure x Cultivar x Fumigation	0.0477	0.3730	0.6523	0.7862	0.5588
2004					
Manure	0.0404	0.0003	0.0801	0.0145	0.0061
Cultivar	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fumigation	<0.0001	<0.0001	0.3941	0.0005	0.0015
Manure x Cultivar	0.0161	0.4371	0.8633	0.0001	0.2542
Manure x Fumigation	0.2875	0.4506	0.6086	0.9310	0.1256
Cultivar x Fumigation	0.6149	0.5348	0.7310	0.1101	0.1809
Manure x Cultivar x Fumigation	0.1132	0.3039	0.4954	0.8839	0.9159

* *P*-values smaller than 0.05 indicate statistical significance at the 5% level.

Fig. 3. Field plots showing differences in severity of Fusarium wilt and plant growth between watermelon cv. Seedless Sangria (left) and Millionaire (right) grown in green-manured beds.

Table 2. Effects of hairy vetch green manure, cultivar resistance, and soil fumigation on incidence (% wilt) of Fusarium wilt of watermelon in 2003 and 2004[t].

	2003				2004[u]	
	'Millionaire'		'SS'			
Manure	**No fumigant**	**Fumigant[v]**	**No fumigant**	**Fumigant**	**'Millionaire'**	**'SS'**
Fallow	92[w]	73	46	12	65	35
Vetch	68	56	29	11	49	19
LSD[x]	10.0				9.1	
LSD[y]	10.0				9.2	
LSD[z]	15.0					

[t] The triploid watermelon cvs. Millionaire and Seedless Sangria (SS) were, respectively, susceptible and moderately resistant to race 1 of *Fusarium oxysporum* f. sp. *niveum*.

[u] Means represent the combined data across fumigation treatments (see Table 1).

[v] Fumigants applied in 2003 and 2004 were, respectively, methyl bromide (224 kg/ha) and metam sodium (374 liter/ha).

[w] Data were the means of four replicate plots.

[x] LSD (least significant difference) to compare cultivars within same manure treatment (P = 0.05).

[y] LSD to compare manure treatments within same or different cultivars (P = 0.05).

[z] LSD to compare fumigation treatments within same manure and cultivar treatment (P = 0.05).

Table 3. Effects of hairy vetch green manure and cultivar resistance on marketable fruit yield (tons/ha) of watermelon in 2003 and 2004[w].

Manure	2003		2004	
	'Millionaire'	'SS'	'Millionaire'	'SS'
Fallow	2[x]	16	5	19
Vetch	4	29	6	47
LSD[y]	3.4		7.0	
LSD[z]	3.2		7.0	

[w] The triploid watermelon cvs. Millionaire and Seedless Sangria (SS) were, respectively, susceptible and moderately resistant to race 1 of *Fusarium oxysporum* f. sp. *niveum*. Means represent the combined data across fumigation treatments (see Table 1).

[x] Data were the means of four replicate plots.

[y] LSD (least significant difference) to compare cultivars within same manure treatment ($P = 0.05$).

[z] LSD to compare manure treatments within same or different cultivars ($P = 0.05$).

Table 4. Effects of hairy vetch green manure, cultivar resistance, and soil fumigation on plant growth and fruit sugar content of watermelon in 2003 and 2004[x].

Main effect	2003			2004		
	Plant growth			Plant growth		
	Vine length (cm)	Dry weight (g/shoot)	Sucrose (%)	Vine length (cm)	Dry weight (g/shoot)	Sucrose (%)
Manure						
Fallow	133 a[z]	89 a	10.8 a	117 a	69 a	10.2 a
Vetch	148 b	98 a	11.9 b	133 b	83 a	10.9 b
Cultivar						
Millionaire	132 a	73 a	11.5 a	107 a	45 a	10.9 a
SS	149 b	115 b	11.2 a	143 b	107 b	10.3 b
Fumigation[y]						
No fumigant	137 a	81 a	11.3 a	111 a	74 a	10.3 a
Fumigant	144 b	107 b	11.4 a	138 b	78 a	10.8 b

[x] The triploid watermelon cvs. Millionaire and Seedless Sangria (SS) were, respectively, susceptible and moderately resistant to race 1 of *Fusarium oxysporum* f. sp. *niveum*.

[y] Fumigants applied in 2003 and 2004 were, respectively, methyl bromide (224 kg/ha) and metam sodium (374 liter/ha).

[z] Data were the means of four replicate plots. Means within same column and main effect followed by the same letter are not significantly different ($P = 0.05$) according to Fisher's LSD test.

In 2004, the aboveground dry biomass of hairy vetch was estimated at 4.7 to 5.7 tons/ha, with an average of 5.2 tons/ha. In general, the effects observed in 2003 also were observed in 2004 (Table 1).

However, there was no significant ($P > 0.05$) interaction of green manure by cultivar by fumigation for wilt. The interaction between green manure and cultivar was significant ($P < 0.05$) for both wilt and fruit yield (Table 1). Hairy vetch green manure alone (Vetch + 'Millionaire') and the MR cultivar alone

(Fallow + 'SS') significantly ($P < 0.05$) reduced wilt by 25% and 46%, respectively. When combined these treatments (Vetch + 'SS') resulted in a further wilt suppression (71% reduction) relative to the control treatment (Fallow + 'Millionaire') (Table 2). Fumigation reduced wilt compared to no fumigation, 50% to 34%, respectively (Table 1). The use of the green manure in combination with the MR cultivar (Vetch + 'SS') produced an average of 47 tons/ha of marketable fruit yield, which was higher yield than those obtained with the green manure or the MR cultivar (Table 3). Fumigation increased yield; 25 tons/ha compared to no fumigation, 13 tons/ha (Table 1). Vine length of plants and sugar content in fruit were significantly ($P < 0.05$) increased by the green manure, the use of the MR, or the soil fumigant (Table 4). Dry weight of watermelon plants was significantly increased by planting the MR cultivar, but not by the green manure or soil fumigation.

Soil Populations of *F. oxysporum*

Prior to and at 4 weeks after hairy vetch incorporation, 200-g soil samples comprising three subsamples taken from each plot were evaluated. A 10-g (dry weight equivalent) subsample was placed in a sterile Erlenmeyer flask with 90 ml sterile water and stirred on a rotary shaker for 10 min. The suspension was serially diluted with 0.1% sterilized water agar and a 1-ml aliquot of the resulting suspensions was spread onto each of two plates filled with Komada's medium (10). After 7 to 10 days at room temperature, *F. oxysporum* colonies were counted. The average of counts on eight plates was used as the soil population of *F. oxysporum* for each treatment.

Prior to hairy vetch incorporation in 2003 and 2004, the population of *F. oxysporum* was high in all treatments and there were no significant ($P > 0.05$) differences between both treatments of green manure, cultivar, or fumigation (Table 5). At 4 weeks after incorporation, soil populations of *F. oxysporum* were not affected by green manure or cultivar. However, soils receiving hairy vetch green manure tended to have slightly higher population densities of *F. oxysporum* than those following winter fallow although these differences were not statistically different ($P > 0.05$). Soil fumigation with methyl bromide (2003) or metam sodium (2004) both greatly reduced soil populations of *F. oxysporum*.

Stem Colonization Assay

At fruit harvest, three plants were randomly selected from the remaining live watermelon plants, and their lower stem sections (10 cm in length starting at the crown node) were sampled. Colonization in the stem tissue by *FON* was assayed by the procedure described previously (16). Colonies on Komada's medium were counted and counts converted into CFU/g of fresh tissue. There were four plates for each replicate plot.

At fruit harvest, the CFUs of *FON* in stem tissues of the cv. Millionaire or Seedless Sangria were lower following hairy vetch green manure than in the winter fallow treatment in either year (Table 6). There was a 2- to 4-fold difference between each cultivar grown in hairy vetch amended vs. non-amended plots. The MR cv. Seedless Sangria had much lower pathogen densities in stem tissues compared with the susceptible cv. Millionaire. The numbers of CFU in the stem tissues of 'Seedless Sangria' grown in hairy vetch-incorporated soil were least among all the four treatments evaluated.

Table 5. Effects of hairy vetch green manure, cultivar resistance, and soil fumigation on population density (CFU/g dry soil) of *Fusarium oxysporum* in field plot soil in 2003 and 2004[w].

Main effect	2003		2004	
	PRE	**POST**	**PRE**	**POST**
Manure				
Fallow	1,875 a[z]	1,438 a	1,956 a	1,332 a
Vetch	2,056 a	1,725 a	2,266 a	2,625 a
Cultivar[x]				
Millionaire	1,944 a	1,600 a	2,122 a	1,813 a
SS	1,988 a	1,563 a	2,010 a	2,144 a
Fumigation[y]				
No fumigant	1,944 a	1,581 a	2,109 a	1,978 a
Fumigant	1,988 a	38 b	2,113 a	147 b

[w] Soil samples were collected at pre-incorporation (PRE), or 4 weeks post-incorporation (POST) of hairy vetch.

[x] The triploid watermelon cvs. Millionaire and Seedless Sangria (SS) were, respectively, susceptible and moderately resistant to race 1 of *F. oxysporum* f. sp. *niveum*.

[y] Fumigants applied in 2003 and 2004 were, respectively, methyl bromide (224 kg/ha) and metam sodium (374 liter/ha).

[z] Data were the means of four replicate plots. Means within same column and main effect followed by the same letter are not significant different ($P = 0.05$) according to Fisher's LSD test. There were no significant ($P > 0.05$) interactions among green manure, cultivar resistance and fumigation in either year. Prior to analysis, data were transformed to $\log_{10}$ (CFU/g of soil + 1).

Table 6. Colonization (CFU/g of fresh tissue) by *Fusarium oxysporum* f. sp. *niveum* in lower stems of two watermelon cultivars grown in hairy vetch green manured or nonmanured field plots in 2003 and 2004[x].

Cultivar[y]	Manure	2003	2004
Millionaire	None	33,888 a[z]	26,125 a
	Hairy vetch	15,238 a	11,625 b
SS	None	88 b	1,750 c
	Hairy vetch	25 c	625 d

[x] Stem tissue samples from three plants per plot were collected at fruit harvest and assayed for vascular colonization in lower stems (10 cm in length from the crown node) by *F. oxysporum* f. sp. *niveum*.

[y] The triploid watermelon cvs. Millionaire and Seedless Sangria (SS) were, respectively, susceptible and moderately resistant to race 1 of *F. oxysporum* f. sp. *niveum*.

[z] Each value was the mean of four replicate plots and of four plates for each plot. Means within same column and cultivar followed by the same letter are not significantly different ($P = 0.05$) according to Fisher's LSD test. Prior to analysis, data were transformed to $\log_{10}$ (CFU/g of tissue + 1).

Discussion and Implications for Disease Management

The results of this study demonstrated that both hairy vetch green manure and the MR cv. Seedless Sangria when used alone significantly reduced the incidence of Fusarium wilt and increased fruit yield, but that the MR cultivar reduced wilt and increased fruit yield to a greater extent than hairy vetch green manure. However, neither approach alone resulted in disease reductions sufficient to obtain an acceptable level of marketable fruit yield, which is within the normal range of fruit yield achieved in commercial watermelon production.

An additive effect on wilt and yield was observed when hairy vetch green manure and the MR cultivar were combined. On an average over two years, hairy vetch green manure alone reduced wilt by 26%, the MR cultivar reduced wilt by 48%, and when combined, they resulted in a wilt reduction of 70%. The combined approach achieved an average of over 29 tons/ha in marketable fruit yield. These yields approach yields typically obtained in commercial production in the northeastern United States. This result suggests that the combined use of green manure and partial cultivar resistance can provide adequate suppression of Fusarium wilt. However, the best control was achieved when combining all three approaches; green manure, the MR cultivar, and fumigation. 'Seedless Sangria' was considered to be the only seedless cultivar that had the moderate level of resistance against race 1 of *FON* in a previous field evaluation (18). Additionally, the approach of combining the green manure with the MR cultivar also was more effective than the single use of the preplant soil fumigants methyl bromide or metam sodium in terms of wilt suppression and yield gain. These results provide critical information for design of management programs in highly *Fusarium*-infested fields.

The extent of watermelon stem tissue colonization by *FON* has recently been reported to be closely correlated to host resistance to Fusarium wilt, and a stem colonization assay proposed as a tool to evaluate cultivar resistance (16). Through employing this assay, either hairy vetch green manure or cultivar resistance significantly reduced stem colonization by *FON* and the combination of both treatments was most effective in reducing the numbers of *FON* in stem tissue. The reductions in tissue colonization resulting from the use of green manure and cultivar resistance were much greater than the effects on soil populations of *Fusarium oxysporum*. This suggests that the reduction in tissue colonization may be responsible for the disease suppression and contributed to enhanced plant growth and watermelon yield.

Although the combination of the green manure and the MR cultivar consistently resulted in the lowest stem colonization, the least wilt incidence, and the highest fruit yield compared with either treatment alone, a significant decrease in soil population density of *F. oxysporum* from this combination or from the green manure alone was not observed. In contrast, there was a trend toward increased populations of *F. oxysporum* in the soil amended with hairy vetch in either year. *F. oxysporum* isolates from soil were not tested for pathogenicity and the percentage of the soil population that was pathogenic to watermelon is not known (i.e., that was *FON*). A portion of the total increased populations of *F. oxysporum* likely was nonpathogenic forms. Part of these nonpathogenic populations of *F. oxysporum* may have been responsible for suppression to Fusarium wilt. The soil populations of microbes including bacteria, saprophytic *F. oxysporum*, and other fungi often are increased following soil incorporation of hairy vetch and other nonhost green manure crops (7,14). These increased microbial populations may play an important role in suppressing Fusarium wilts and other soilborne diseases (7,11).

In conclusion, under high wilt pressure, hairy vetch green manure or partially resistant cultivars can provide some degree of suppression to Fusarium wilt, but the combined use of hairy vetch green manure and a partially resistant cultivar such as the MR cv. Seedless Sangria can offer a practical alternative for the control of Fusarium wilt in triploid watermelon crops.

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