Great Lakes Fruit, Vegetable & Farm Market EXPO
December 5-7, 2006
DeVos Place Convention Center, Grand Rapids, MI

Pepper

Tuesday afternoon 2:00 pm

Where: Grand Gallery (lower level) Room E-F

Recertification credits: 1 (1A, 1B, Comm CORE, Priv CORE)

CCA Credits: PM(1.5) CM(0.5)

Moderator: Jim Breinling, Regional Vegetable ICM Educator. MSU Extension

2:00 p.m. Damping-off of Pepper Transplants

Sally Ann Miller, The Ohio State University

2:30 p.m. Pepper IPM in New England

Jude Boucher, University of Connecticut

3:00 p.m. Phytophthora Research Update in Peppers

Mary Hausbeck, Plant Pathology Dept., MSU

3:30 p.m. Spacing Studies in Peppers

Sally Ann Miller, The Ohio State University

Damping-Off of Pepper Transplants

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In greenhouse environments, damping-off caused by *Rhizoctonia solani* and *Pythium* spp. can cause significant losses for transplant production. Damping-off is associated with plant crowding, variable temperatures, over-watering, high humidity, and the lack of fungicides highly effective against damping-off pathogens. We evaluated a number of products and tactics to suppress these pathogens and reduce the incidence of *Rhizoctonia* and *Pythium* damping-off in pepper transplants. Pepper is particularly susceptible to damping-off during seedling production.

METHODS

Rhizoctonia damping-off. Nine treatments were evaluated for efficacy against Rhizoctonia damping-off in pepper (cv. California Wonder - organic, non-treated seed) seedlings (Table 1). All treatments were applied at the time of sowing; the center 48 cells of 288-cell trays were filled with *R. solani* 122-infested potting mix (0.5 g inoculum/100 ml Fafard's or peat) and the remaining cells of each flat were filled with non-inoculated potting mix. Treatments were applied to the entire flat, with the exception of the *T. hamatum* 382 treatment, which was only applied to the center 48 cells of each flat. The center 48 cells of each flat were seeded. All flats were placed in the greenhouse in a randomized complete block design with four replications. Greenhouse temperatures were set to 80F daytime and 70F nighttime. Automatic overhead watering was set up for one pass at 4ft/min., three times daily.

Table 1. Treatments and rates of products evaluated for Rhizoctonia damping-off management.

Treatment	**Rate**	**Potting Mix**
Composted cow manure (4% total nitrogen)	10%	Peat
Untreated control without *R. solani* 122	Water drench	Peat
Omega Grow Plus	2% drench	Fafard
Moncut	0.71 lb/A	Fafard
Endorse	1.6 lb/100 gal	Fafard
Endorse	2.0 lb /100 gal	Fafard
Serenade (Rhapsody) ASO	0.5% drench	Fafard
Serenade (Rhapsody) ASO	1% drench	Fafard
Serenade (Rhapsody) ASO	2% drench	Fafard
Thiram	1tsp/1Lb	Fafard
Untreated control + *R.solani* 122	Water drench	Fafard
Untreated control without *R.solani* 122	Water drench	Fafard

Pythium damping-off. Inoculum of *P. aphanidermatum* isolate 349 was prepared on chopped potato/soil medium and incorporated into potting mix at the rate of 0.5 g/100 ml mix. The treatments described above and in Table 1 for Rhizoctonia damping-off, with the exception of Moncut and Endorse, and the addition of Seacide (fish emulsion; 2% drench), *Pseudomonas fluorescens*-Wayne 1R and *P. fluorescens*-Mg1 A2R (biocontrol agents, $10^{5\text{-}6}$ CFU/ml), Mycostop (biofungicide; 0.01% drench), Prestop (biofungicide; 1% drench), Phosphonate (biorational fungicide; 1% drench), and Ranman (fungicide; 3 fl oz/100 gal) were applied as described. Maintenance of plants, evaluations and data analyses were as described above.

RESULTS

All of the treatments, except the low rate of Endorse and all rates of Serenade, significantly reduced Rhizoctonia damping-off of pepper seedling (Table 2). In the non-inoculated control, only 1.6% of seedlings damped-off. Composted cow manure or *T. hamatum* 382 incorporated into the planting mix, and the standard thiram seed treatment were most effective, resulting in the highest number of healthy seedlings. However, neither the compost nor the *T. hamatum* 382 treatment was significantly more effectives than the Thiram treatment. Omega Grow Plus, Moncut and the 2.0 lb/100 gal rate of Endorse were significantly less effective than the best treatment, amendment of the palnting mix with composted cow manure. Serenade ASO drench was not effective in reducing Rhizoctonia damping-off, and the higher rates (1 and 2%) of Serenade appeared to be phytotoxic to pepper seed.

Table 2. Efficacy of treatments against Rhizoctonia damping-off of pepper.

Treatment	Percent Healthy	Percent Damping-off		
		Pre-emergence	Post-emergence	Total
Composted cow manure	95.3 a	4.7 jk	0.0 b	4.7 jk
Untreated control: peat mix without *R. solani*	93.8 ab	6.3 jk	0.0 b	6.3 jk
Trichoderma hamatum 382	89.6 abc	9.4 ijk	1.1 ab	10.4 ijk
Moncut	78.1 de	18.8 ghi	3.1 ab	21.9 ghi
Omega Grow Plus	82.3 cd	16.7 hi	1.1 ab	17.7 hı
Endorse 1.6 lb/100 gal	71.4 ef	26.6 efg	2.1 ab	28.7 efg
Endorse 2.0 lb/100 gal	74.5 de	22.9 fgh	2.6 ab	25.5 fgh
Serenade ASO 0.5%	68.2 efg	30.2 def	1.6 ab	31.8 def
Serenade ASO 1.0%	41.1 h	56.8 b	2.1 ab	58.9 b
Serenade ASO 2.0&	25.5 i	74.0 a	0.5 ab	74.5 a
Thiram - standard	88.5 abc	10.4 ijk	1.1 ab	11.5 ijk
Untreated control + *R. solani*	64.1 fg	33.3 cde	2.6 ab	35.9 cde
Untreated control - *R. solani*	98.4 a	1.6 k	0.0 b	1.6 k

Values are the means of four replicate flats; means followed by the same letter are not significantly different at $p \leq 0.05$.

Pre-emergence damping-off caused by *P. aphanidermatum* was very high in this study (70,3%). Ranman, composted cow manure, Omega Grow, *T. hamatum* 382 and the standard Thiram seed treatment significantly decreased Pythium damping-off of pepper seedlings (Table 3). Ranman was the most effective treatment; Ranman, composted cow manure and Omega Grow treatments were significantly more effective in reducing Pythium damping-off than the standard Thiram seed treatment. Serenade ASO drench, Seacide, Phosphonate, Prestop, Omega Grow Plus, Mycostop and two fluorescent Pseudomonads did not reduce damping-off compared to the untreated, inoculated control.

Table 3. Efficacy of treatments against Pythium damping-off in pepper "California Wonder'.

Treatment	Percent Healthy	Percent damping-off		
		Pre-emergence	Post-emergence	Total
Ranman	77.6 b	22.4 i	0.0 d	22.4 ı
Composted cow manure	59.9 c	39.6 h	0.5 cd	40.1 h
Omega Grow	51.6 d	47.9 g	0.5 cd	48.5 g
Trichoderma hamatum 382	43.3 e	56.8 ef	1.1 bcd	57.8 f
Thiram	42.7 e	54.7 fg	2.6 a-d	57.3 f
Serenade ASO 0.5%	21.9 hi	74.5 abc	3.7 ab	78.1 abc
Serenade ASO 1.0%	30.8 fg	66.7 cd	4.2 a	70.8 cde
Serenade ASO 2.0%	30.7 fg	69.8 bcd	1.6 a-d	71.4 cde
Seacide	24.0 ghi	75.5 ab	0.5 cd	76.1 a-d
Phosphonate	31.3 f	66.7 cd	2.1 a-d	68.8 de
Prestop	32.8 f	64.1 de	3.2 abc	67.2 e
Omega Grow Plus	26.6 fgh	72.9 abc	0.5 cd	73.5 b-e
Mycostop	20.3 hi	77.1 ab	2.6 a-d	79.7 ab
Pseudomonas fluorescens-Wayne 1R	19.8 hi	78.7 a	1.6 a-d	80.2 a
P. fluorescens- Mg1 A2R	19.8 hi	76.1 ab	4.2 a	80.2 a
Untreated control + *Pythium*	29.2 fg	70.3 bcd	0.5 cd	70.8 cde
Untreated control - *Pythium*	93.8 a	6.3 j	0.0 d	6.3 j
Trichoderma hamatum 382 - *Pythium*	93.8 a	6.3 j	0.5 cd	6.8 j

Values are the means of four replicate flats; means followed by the same letter are not significantly different at $p \leq 0.05$.

CONCLUSIONS

Incorporation of 10% composted cow manure in potting mix was consistently effective in reducing damping-off in pepper caused by *Rhizoctonia solani* or *Pythium aphanadermatum*. This treatment also resulted in taller, healthier plants than other treatments or the controls. Compost amendments increase the organic matter content of planting mixes and also provide additional nutrients, which may contribute to better germination and the production of healthier seedlings. *Trichoderma hamatum* 382 is a biocontrol agent that is known to be effective against Pythium and Rhizoctonia species. In this experiment, *T. hamatum* 382 was relatively more effective in reducing Rhizoctonia than Pythium damping-off. Ranman was the most effective treatment against Pythium damping-off. However, Ranman is not yet labeled for use against Pythium damping-off; it is also not yet labeled for use on peppers. Similarly, neither Moncut nor Endorse are currently labeled for use in peppers against Rhizoctonia diseases.

Pepper IPM in New England

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The key to prioritizing chores and the many possible IPM management options that might be used on your farm, is to realize that there are only five or six major pepper pests that must be dealt with annually. There are also several dozen minor or occasional pests too, but it is rare that you have to deal with more than one or two of these in any particular year. The most successful growers design their pest management plan around the chronic (usually the major) problems and implement the solutions as part of their standard operating procedure.

In New England, the major pepper pests include weeds (as a group, but especially hairy galinsoga), Phytophthora blight (whether or not it is present on your farm), bacterial leaf spot (BLS), the pepper maggot, European corn borer (ECB), and aphids (usually, the green peach aphid). Growers should construct a similar list of management options from IPM literature and manuals for other minor pest (i.e. Pythium) or abiotic disorder (e.g. blossom end rot or sun scald) that dramatically limit production and profits on their farm. Proper pest/damage identification is crucial before this process begins. Consult Extension IPM specialists or diagnostic laboratories for proper identification to avoid wasted efforts by repeating the same mistakes year after year.

Major pests in New England:

1. <u>Weeds</u>. All farmers must successfully manage weeds to produce a pepper crop, particularly, between weeks 2-10 for bare-ground plantings, and weeks 4-10 for plasticulture fields. These are the critical periods for weed management on peppers when direct competition from weeds can reduce the yield for the crop. For peppers on plastic mulch, this means that weeds emerging in week 1 will not produce yield reductions if removed by week 3, and weeds emerging after week 10 will not reduce yields due to direct competition. There may, however, be other reasons to control weeds outside of the critical period, such as when tall weeds late in the season may block spray coverage targeted at major pests (i.e. ECB).

Weed management options include cultural controls (e.g. banded or liquid fertilizers, scouting, site selection, weed-free cover crop seed, cleaning soil from plows and cultivators between fields, rotation, smother crops, low or no-till), mechanical controls (e.g. plastic or organic mulches, cultivation), chemicals (i.e. pre- and post-emergence herbicide applications), or some combination of these. Of course, usually growers use some combination of weed control techniques, such as shielded paraquat applications between plastic-mulched rows and certain cultural practices.

a) Galinsoga seeds are relatively short-lived in the soil. Rotate to fields where triazine herbicides were used in previous years (i.e. on sweet corn or tomatoes).

b) Select sites with lower populations of solanaceous weeds (i.e. black nightshade) that will not be controlled by herbicides registered for use on peppers.

2. <u>Phytophthora blight</u>. This is the toughest pepper pest to manage, and once established, can kill all plants in a wet year. Phytophthora is forever; there is no cure. This disease can cause stem lesions that girdle and kill the plants, branch lesions that help produce and spread spores to neighboring plants, and fruit infections that cause severe losses from post-harvest rot. It produces three types of spores. Oospores are long-term resting spores that produce sporangia. Sporangia spread between plants by splashing rain and/or produce zoospores. Zoospores have two sperm-like tails and can swim between soil particles towards the roots of adjacent plants. Zoospores can swim through flooded soils to initiate plant infections in wet holes, and later move uphill to infect and kill all the plants in a row, or adjacent rows. All management plans must attempt to prevent the introduction or further accumulation of spores in the soil, and limit destruction from this disease if it is already present on the farm at high levels. This pest has only one weak link in its life-cycle that we can exploit to help provide control. Phytophthora requires 24 to 48 hours of soil saturation (standing water) before zoospores are released to start the disease cycle.

WATER MANAGEMENT IS CRUCIAL IN PREVENTING THIS DISEASE AND TO MINIMIZE THE DESTRUCTION IT CAUSES.

Manage Phytophthora <u>before</u> it is a problem on your farm!

a) Do not compost culls from your stand in your fields to prevent introduction of spores.
b) Do not irrigate from infested sources (use well or clean river water).
c) Clean soil off borrowed equipment (i.e. muddy tires that have been in infested fields).
d) Crop rotation: two years without solanaceous and cucurbit crops or beans.

Water management starts with site selection.

e) Plant susceptible crops on well-drained soils/fields.
f) Plant rows down the slope so that the water leaves the field.
g) Avoid planting low, wet areas prone to flooding.

Improve drainage with site modifications.

h) Fill low areas/level fields.
i) Create swails or drainage ditches to remove water from fields.
j) Break up plow pans by V-ripping or chisel-plowing every few years.
k) Plant on domed-shaped raised beds to help shed water away from plants.
l) Break beds by ditching through them in low areas, so that water can move across and out

Continue site modifications after planting.

m) Chisel plow or V-rip between beds.
n) At the ends of the rows, remove soil dams to let water drain from between rows.
o) Fix leaky irrigation pipes the first time they operate.
p) Rogue the diseased plants in the area of initial infection to prevent spread.

Managing moderate to high levels of Phytophthora.

q) Use only Phytophthora-resistant varieties in infested fields (i.e. Paladin, etc.).
r) Clean soil from plows and cultivators between fields: work infested fields last.
s) Use fungicides to limit spread.

3. <u>Bacterial leaf spot</u>. This is the most common disease of peppers and can be very destructive during prolonged periods of hot, humid weather or during wet seasons when nitrogen levels are depleted. Disease development is favored by high night temperatures (>70-75°F) and high relative humidity (>85%). Defoliation, leaf and fruit spotting, and delayed and reduced yields are common symptoms. Six distinct races of this pathogen have been identified to date.

a) If available, use only BLS-resistant plants unless the field is highly infested with Phytophthora (see previous pest).
b) Use a three-year crop rotation.
c) Choose site with good air and soil drainage; avoid foggy locations, if possible.
d) Control solanaceous weeds.
e) Use hot-water seed treatment (122°F for 25 minutes).
f) Produce and use clean transplants or inspect and reject infected seedlings if purchased.
g) Maintain proper pH and fertility levels (especially N & Mg).
h) Minimize leaf wetness time when irrigating, or use trickle.
i) Do not work field while foliage is wet.
j) Scout plants weekly to detect disease in early stages.
k) Rogue plants in initial area of infection and work infected areas last, to slow disease spread.
l) Spray susceptible varieties with copper bactericide on 7 to10-day schedule if disease is detected.
m) Lengthen spray interval by one day for each night below 60° F.
n) Avoid using high-pressure air-blast sprayers which wound plants and spread disease.
o) Discontinue spraying once the temperature is below 60° F on most nights during late summer.
p) Disk or plow after final harvest to hasten decomposition of crop residue.

4. <u>Pepper maggot</u>. Pepper maggots are not on all farms, but are very common on the East Coast, south of the MA/NH border. Eggs are laid in fruit and hatching maggots tunnel through the flesh and seed heads. Pepper maggot exit holes allow soft rot bacterium to enter and produce fruit rot. At present, there are no selective insecticides available that will control or suppress pepper maggots. Whole-field sprays with broad-spectrum insecticides can cause secondary pest outbreaks (i.e. aphids). Sprays must be targeted to control the adult fly before and during the oviposition (egg laying) period. Adult flies can be monitored with (liquid) ammonia-baited, yellow, sticky traps, placed within the canopy of nearby maple trees, or by planting hot cherry pepper plants in the outer rows and watching for the first fruit stings (egg-laying scars).

a) Eliminate the alternate host, horse nettle, from fields and borders.
b) Plant 1 or 2 rows of trap crop (hot-cherry peppers) all around field
c) Treat only the perimeter (cherry-peppers) after the first adult fly is captured or oviposition scars begin to appear on fruit.
f) Discontinue spraying after 1-3 applications/weeks that covers the period of fly emergence and oviposition.

5. <u>European corn borer</u>. Second generation larvae attack fruit annually. European corn borer is the most common cause of fruit soft rot in New England. Monitor for the second-generation moth flight using two Scentry Heliothis traps, baited with either the NY (E) or IO (Z) pheromone lures, and placed in the tall weeds on the edge of field. Initiate insecticide applications one week after a combined trap capture of $\geq$ 7 moths per week. Discontinue spraying one week after $\leq$ 21 moths are captured in traps.

a) Use selective/microbial insecticides to preserve beneficial arthropods.
b) Alternate between insecticides to prevent pest resistance.

6. <u>Aphids</u>. Aphids are induced secondary pests on peppers, usually caused by early or frequent use of broad-spectrum chemical pesticides (both insecticides and fungicides) or excess nitrogen. They can stunt or kill plants if extremely abundant, or will cause cosmetic damage to the fruit by excreting honeydew, which renders the fruit unmarketable.

a) Preserve natural enemies by delaying and minimizing pesticide use for other pests through the use of scouting, monitoring, action thresholds and alternative management strategies.
b) Use of plastic mulches (especially reflective silver) reduces aphid populations.
c) Preserve natural enemies by using selective/microbial pesticides for other pests.
d) Scout 4 leaves/plant, 25 plants/field, weekly.
e) Spray <u>prior</u> to fruit set only if you find an average of 5 to 10 aphids/leaf for $\geq$ two weeks, or immediately <u>after</u> fruit set if more than 5 aphids/leaf.
f) In needed, use selective aphicides and alternate between insecticides to prevent pest resistance.

Occasional pest(s):

Create a list of management options for other minor pests that limit profits and/or production on your farm here:

Reference:

Boucher, T. J. and R Ashley (eds.). 2001. *Northeast Pepper Integrated Pest Management (IPM) Manual*. University of Connecticut Cooperative Extension System Pub. p. 136.

More details are available in the ***Northeast Pepper Integrated Pest Management (IPM) Manual***. This full-color, soft-cover manual has 23 chapters, over 200 color pictures, and many easy-to-read tables and figures. It offers detailed information on all major and most minor pepper pests and comes with a pesticide supplement that rates products for their effectiveness.

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Phytophthora Research Update in Peppers

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Michigan has over 79,000 acres of vegetables that are vulnerable to root, crown, and fruit rot caused by the soilborne fungus, *Phytophthora capsici*. *P. capsici* has two mating types that allow for the production of long term survival spores (oospores) and development of genetic adaptations that foster fungicide resistance. The oospores can survive in soil up to ten years without a susceptible crop, and both mating types needed for oospore production have been found in every field sampled in Michigan. This pathogen is favored by rain and warm temperatures that occur during the Michigan growing season and has recently been found in irrigations ponds and other surface water sources. The most effective control measures are to avoid planting in infested soil and limit the spread of the pathogen to clean fields. Crop rotation is difficult as infested acreage and urban pressure is increasing across the major growing areas of the state. Properly constructed raised beds can be helpful as they keep vulnerable plants from saturated soil conditions. Foliar applications of preventive fungicides can be effective if proper coverage and timing of applications can be achieved. Certain fumigants are also available that can help lower crop losses. A combined approach of all available control techniques is more effective than using just one control measure.

Fungicide Trial

New products and one registered fungicide were tested (Table 1). The field was prepared by forming 6-inch raised beds covered with black plastic, with one drip tape per bed. Drip tape emitters were spaced 8 inches apart, calibrated to deliver 0.4 gal/min/100 ft, and operated for 45-minute periods. Preplant drip treatments were applied on 28 May (7 days before transplant). Pepper 'Camelot' transplants were planted 24 inches apart into the beds on 4 Jun. Drip treatments were applied on 4 Jun (at transplant), 13 Jul (32 days after transplant), and 25 Jul (29 days before harvest). Foliar sprays applied at 7-day intervals were initiated on 20 Jun. The experiment was harvested on 23 Aug.

Table 1. Products tested

Product	Active ingredient	Labeled
IR6141 50WP	kiralaxyl	no
Remedier 40WP	*Trichoderma* spp.	no
Ridomil Gold 4EC	mefenoxam	yes
Ridomil Gold Bravo 76WP	mefenoxam + chlorothalonil	no
V-10162 5.73FL	fluopicolide + propiconazole	no

Disease pressure was high at the test site with 25% of the pepper plants showing *P. capsici* symptoms on 13 Jul. Plant death continued to develop throughout the summer with 68% of the untreated plants being dead at the last evaluation date (Table 2). Plants treated with IR6141 50WP 0.21 lb + Remedier 4WP 2.2 lb and V-10162 5.73FL 1.75 pt had significantly less plant death than the untreated control on 18 Aug. Only V-10162 5.73FL 1.75 pt had significantly higher yield than the untreated control.

Table 2. Evaluation of fungicides and applications for management of Phytophthora blight of pepper.

Treatment and rate/A	Application	Plant death (%) 8/18	Yield (lb/30 ft of row)
Untreated..	--	68.8 a*	7.4 b
V-10162 5.73FL 1.75 pt...................	6/4 drench at transplant 6/20 7-day foliar spray	3.8 c	29.5 a
Ridomil Gold EC 1.6 pt .... Ridomil Gold Bravo 76WP 2 lb.......	6/4 drench at transplant 6/20 7-day foliar spray	47.5 ab	9.6 b
IR6141 50WP 0.21 lb + Remedier 4WP 2.2 lb....................	5/28 drench 7 days before transplant 6/4 drench at transplant	27.5 bc	8.8 b
Remedier 4WP 2.2 lb.......................	5/28 drench 7 days before transplant 6/4 drench at transplant	57.5 ab	13.0 b
Ridomil Gold EC 25.6 fl oz	6/4 drench at transplant	47.5 ab	12.9 b
IR6141 50WP 2.1 lb	7/13 drench 32 days after transplant 7/25 drench 29 days before harvest	63.8 a	4.2 b
Ridomil Gold 4EC 25.6 fl oz	7/13 drench 32 days after transplant 7/25 drench 29 days before harvest	56.3 ab	7.1 b
IR6141 50WP 2.1 lb	6/4 drench at transplant	51.3 ab	13.3 b

*Column means with a letter in common are not significantly different (LSD; *P*=0.05).

Cultivar Trial

A pepper variety trial was established in a commercial pepper field located near Fremont, MI in a field that has a history of *Phytophthora capsici* infection. Eleven different cultivars were arranged in a randomized complete block design and replicated four times. Existing pepper plants were pulled from 20 ft sections and replaced by 7 week old transplants grown in 128-cell plug trays on 14 Jun. Plants were planted every 12 in. and rows were 24 in. apart. Plots were maintained by the grower cooperator until harvest on 29 Sep. Fruit from the inner 10 ft was collected, weighed, and evaluated for a silvering fruit defect.

None of the plants in the trial died as a result of *P. capsici* infection. All of the cultivars had some level of the silvering defect which is a separation of the outer cuticle from the fruit (Table 3). The cultivar Red Knight had over 25% affected fruit and was blemished enough to be unmarketable. The *P. capsici* tolerant cultivar 'Alliance' was least affected by the defect and all the fruit harvested were marketable. The cultivars 'Camelot', 'Aristotle', and the germplasm line 'C85XC86' had defect levels below 10%. There was no significant difference in yields.

PRO5-C71x72

Red Knight

Revolution

Aristotle

Camelot

Palladin

C85xC86

PRO3-13x14 R-4

PRO3 15x16 R-5

Table 3. Evaluation of bell pepper cultivars for resistance to Phytophthora blight.

Cultivar	Yield (lb/10 ft of row)	
	Fruit with silvering (%)	Total
Camelot	9.4 a-c*	12.2
Red Knight	26.8 d	9.9
Aristotle	8.6 ab	13.4
C85xC86	8.7 ab	13.7
Revolution	12.1 a-c	8.4
Alliance	7.8 a	13.3
Palladin	17.2 bc	10.9
PRO3-13x14 R-4	15.7 a-c	13.0
PRO3-15x16 R-5	14.1 a-c	14.0
PRO5-C71x72	18.4 cd	12.7
PRO5-C81x82	13.1 a-c	14.2

*Column means with a letter in common or with no letter are not significantly different (Fisher LSD Method; *P*=0.05).

Spacing Studies in Peppers

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The health and productivity of peppers are affected by many factors, including climate, fertility, cultivars, plant population density, pest management practices, pesticide application technology, and pests. The impact of stand density on yield has been studied for bell and non-bell peppers, but very little information exists regarding implications on pesticide efficacy. Although greater pepper fruit yields usually result from higher plant stand densities, increasing crop canopies might diminish the amounts of spray deposits reaching the surface of fruits and leaves at middle or low plant elevations. The use of different pepper cultivars, spray application technologies, and plant stand densities may produce diverse outcomes in fruit yield and insect pest or disease damage. The objective of these studies was to determine the effect of plant population density and pesticide application techniques on fruit yield and control of key insect pests and diseases of peppers in Ohio. Plant population density was investigated at different within-row spacing for single and twin rows.

METHODS

Three trials were conducted on commercial Ohio farms in 2004 to evaluate the effect of plant stand density on yield and pest management efficacy in bell and jalapeño peppers. All on-farm trials were conducted using a randomized complete block design with six replications; crop and pest management inputs were provided according to the standard practices at each farm. The Greene county trial was conducted in a 70 A field of plastic-mulched, drip irrigated bell 'Colossal' peppers. Plant stand densities tested were 13,583, 12,676, and 9,004 plants/A, equivalent to 14, 15, and 24 in. within-row spacing, respectively. The Wood county trial was conducted in a 16 A non-irrigated field of jalapeño pepper ('Ixtapa X3R'), comparing a stand density of 8,896 plants/A to a standard density of 11,368 plants/A. The Henry county experiment was conducted in a 60.8 A, non-irrigated bell pepper ('North Star') field to compare the grower's traditional density of 11,860 plants/A to an experimental density of 9,688 plants/A. The data from all the trials conducted in commercial farms were analyzed with the general linear models procedures in SAS.

Two additional trials were established in 2005 on the OSU-OARDC North Central Agricultural Research Station (NCARS) in Fremont, OH to test the interaction between plant stand density and pesticide application technology in bell and banana peppers. Treatments were factorial combinations of two row arrangements, three plant population densities, and three levels of pesticide application technology. Applications were made using half the recommended rates of insecticides and fungicides by a conventional boom sprayer. Row arrangements were twin and single rows. Plant population densities were low, medium, and high, corresponding to 22, 15, and 11 in. within-row spacing in single rows and to 30, 20, 15 in. within-row spacing in twin rows, respectively. In all trials, fruit were harvested from the center of each plot in two or three harvests. All fruit were inspected for external damage (sunscald, blossom end rot, bacterial spot, and bacterial soft rot) and then cut open to inspect for internal browning, likely due to *Alternaria* sp., and to determine the presence of, or damage by, larvae of European corn borer (ECB), fall armyworm, corn earworm (CEW), or beet armyworm (BAW). Total yield was the total weight of all harvested fruit per plot. Marketable yield was the total weight of all the harvested fruit per plot with a good external appearance. The estimated clean yield was obtained by multiplying the total yield by the percentage of clean fruit per plot. Both trials were terminated early due to heavy damage by *Phytophthora capsici*. Therefore, in the final harvest, bell pepper green fruit with a diameter larger than 5 cm were collected in addition to red fruit. Green and red fruit from this harvest were evaluated separately.

RESULTS

On-farm trials. Clean yields were not significantly affected by plant population densities in bell peppers at the Henry County site. However, at the Greene County site, bell peppers planted at the second highest stand density had the greatest marketable and clean yields, while sustaining the least amount of sunscald damage. At the Greene Co. site, sunscald damage was most prevalent at the lowest plant stand density. At the Wood Co. site, total, marketable, and clean yields of jalapeño peppers were greater at 11,368 plants/A than those obtained at 8,896 plants/A. Average weight per fruit was not significantly affected by plant stand density in bell or jalapeño peppers.

On-station trials. Yield was higher in single-row than in twin-row bell pepper plots. However, peppers in twin rows were less damaged by caterpillars than those in single rows. Bell peppers planted at low stand density produced lower clean yield than peppers at the middle and high plant population densities. Weight per red fruit was lower at the high plant stand density than at middle or low plant densities. Numbers of sunscald-damaged fruit were generally higher in single rows than in twin rows; except for plants at the highest stand density. Untreated plots sustained more sunscald damage than treated plots, except for the untreated plots at the highest stand density. Sunlight at ground level under the crop canopy was more intense in single than in twin rows and less intense at the highest than at the middle and lowest plant stand densities.

The incidence of Phytophthora blight was higher in twin than in single row plots. Although the total number of infected plants was less at the lowest stand density than at the medium and high stand density, no significant differences in the percentage of infected plants were found among plant stand density levels. The number of total plants per plot (apparently healthy plus showing blight symptoms) were generally greater in twin than in single rows at all plant stand density levels.

For banana peppers, total, marketable, and clean yields were greater at high and medium than at low plant stand density. Weight per fruit remained unaffected by plant stand density. Caterpillar damage or presence was more abundant at medium than at high plant stand densities.

CONCLUSIONS

Bell pepper fruit yield increased proportionally with plant stand density in the trial conducted at the OSU-OARDC NCARS. Weight per bell pepper red fruit was lower at the highest than at the middle or lowest stand densities at the research station, but remained unaffected at tested stand densities on commercial farms. Most other workers have reported that bell pepper fruit size or quality is not affected by stand density. On commercial bell pepper farms, the relationship between fruit yield and plant stand density was not clearly determined, but on the commercial jalapeño farm, greater yield was obtained at the higher stand density. A broader range of stand densities evaluated on commercial farms should have resulted in more pronounced yield differences. In banana peppers, stand density did not influence weight per fruit.

Sunscald damage to bell pepper fruit was greater at low stand densities, especially in single row plantings. This is to be expected because a denser crop canopy should provide better protection against direct sun exposure to fruits. It is likely that in the NCARS trial, greater bell pepper yields obtained in single rows than in twin rows, at equivalent plant stand densities, corresponded to Phytophthora blight damage because Phytophthora was more prevalent in twin rows than in single rows. Additionally, early trial termination due to Phytophthora blight might have influenced results by underestimating the cumulative insect and disease damage that might have been produced in a longer field season and minimized yield differences among treatments. Greater bell pepper fruit damage by caterpillars in single vs. twin rows might have been related to greater amounts of fruit in single rows rather than pest levels or pesticide spray efficacy.