Downy Mildew Impacts and Control Measures on Cucurbits in the United States






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Abstract

This study describes the impact of downy mildew (Pseudoperonospora cubensis) *in high-value cucurbit crops grown in the United States. In 2017, a detailed survey was administered to cucurbits farmers. Results showed that all cucurbit crops were affected by cucurbit downy mildew (CDM) to varying degrees. For instance, pickling and slicing cucumber had the greatest damage followed by squash, watermelon, cantaloupe, and pumpkin. The total dollar loss per crop cycle due to CDM ranged from $50 to $1,425 per acre. The actual economic losses reported by growers caused by CDM are significant relative to growers' profitability and can be used in designing and implementing effective integrated pest management strategies for CDM mitigation.*

INTRODUCTION

Cucurbit downy mildew (CDM) is a foliar pathogen of cucurbit crops caused by *Pseudoperonospora cubensis*. CDM affects economically important crops such as cucumber, watermelon, cantaloupe, zucchini, and squash that are grown worldwide. The destructiveness of CDM can be measured by several methods, which include rating the leaves for infection and calculating loss in harvestable yield. CDM causes economic yield loss up to 100% if left untreated and threatens the long-term viability of cucurbit crop

production (Cohen et al., 2015; Hausbeck and Cortright, 2009; Lebeda and Urban, 2007; Holmes, Wehner, and Thornton, 2006). Even if fungicides are applied after symptom appearance, yield can be reduced between 20% and 50% (Holmes et al., 2015; Zheng et al., 2013; Colucci, Wehner, and Holmes, 2006). CDM foliar symptoms initially include small, angular water-soaked lesions on the abaxial leaf surface that become chlorotic and necrotic over time. Pathogen sporulation occurs on the abaxial leaf surface, resulting in a distinctive purplish-brown moldy appearance. As the lesions coalesce, entire leaves become blighted and necrotic, causing the eventual death of the entire leaf (Call et al., 2013). Favorable conditions for the pathogen include high humidity and warm temperatures (Boso et al., 2014). In northern climates that experience winter months (e.g., freezing temperatures), the pathogen will not survive or overwinter. The pathogen may survive year-round on cucurbits grown in protected or heated greenhouse structures during the winter or when production areas are in the southern regions of the United States (Lebeda and Cohen, 2011).

New CDM pathotypes and mating types have been detected in Israel, the United States, Asia, and Europe in recent years (Cohen et al., 2015; Wallace, D'Arcangelo, and Quesada-Ocampo, 2020). CDM was successfully controlled in cucumber in the United States and elsewhere through host crop resistance until 2004. The cause of this change in the United States is currently unknown; however, it may be due to a difference in the pathogen population (Savory et al., 2011; Wallace, D'Arcangelo, and Quesada-Ocampo, 2020). The 2004 re-emergence of CDM was first observed in North Carolina's cucumber fields, where the pathogen spread quickly; within a week of symptom appearance, fields were abandoned without harvesting. The pathogen spread northward via weather patterns to cucumber fields in New Jersey, Maryland, and Delaware and then infected pumpkin fields in New York. Severe to complete crop losses occurred in Georgia, South Carolina, North Carolina, Virginia, Delaware, Maryland, and New Jersey (Holmes et al., 2015). Innark et al. (2014) found that of the cucumber germplasm tested, one variety was highly resistant, twenty-three were moderately resistant, two were intermediately resistant, seven were moderately susceptible, and six were highly susceptible. The highly resistant and moderately resistant varieties may be combined with fungicides for optimal crop production (Call et al., 2013). The purpose of this study was to evaluate data from a 2017 survey to assess farming activities with a reference to CDM impacts and encourage high-value cucurbit crop production despite disease interference.

METHODOLOGY

A structured questionnaire was used as a tool to collect data on the production of cucurbits. A face-to-face survey of 98 farmers was conducted with support from the field experts, extension agents, and producers in Iowa, Michigan, New York, and Ohio during 2017. Cucurbit crop production in the United States is classified into major classes of crops: cucumber-fresh, cucumber-processing, cantaloupe, pumpkin, squash, and watermelon. Total U.S. field production of all classes of cucurbit crop is about 109 million metric tons on 229,000 hectares, with a value of $1.43 billion. Michigan has been producing significant quantities of cucumber (4.12 million cwt), squash (1.9 million cwt), and watermelon (1.02 million cwt), while New York leads the production of squash (0.81 million cwt) and pumpkin (0.46 million cwt). Ohio also produced a lot of cucumbers (0.29 million cwt) and watermelons (0.67 million cwt) among the different states in 2018 (USDA NASS, 2019). In recent years, the total production of these crops is less than the previous years for comparable states. The purpose of this study was to gather information on field production of high-value cucurbit crops. Baseline information related to crop production and farmer demographics was assessed; however, the survey specifically referenced CDM disease as of particular interest. Surveyors conducted interviews with the person in charge of the farming activity once consent was given. The survey was intended to assess the possibility of encouraging efficient high-value crop production with effective control of CDM management.

Data Limitation

In certain cases, it is possible that the data collected may not be accurate because some of the participants did not keep records. However, in such cases probing questions were asked to get the most possible accurate answers from the cucurbit growers. Asking for details such as land size in acreage and then in square meters also contributed to the difficulty in acquiring accurate data. Details such as income and income sources were provided with reluctance from some farmers, who did not offer the exact information. Some questions were repetitive (same information twice, for two different periods) and hence caused problems in obtaining quality data.

RESULTS AND DISCUSSION

Respondent Demographics

The 98 respondents were from four states: Iowa, Michigan, New York, and Ohio (Table 1). Among these four states, 92 respondents (93.9%) were from Michigan, 3 respondents (3.1 %) were from New York, 2 respondents (2.0 %) were from Ohio, and 1 respondent (1.0%) was from Iowa. Michigan produces almost 18% of the total pickling cucumber in the United States (Lucier and Lin, 2000). In 2005, Michigan covered 33% of the national area planted to cucumbers, which accounted for 14% of the total area planted. However, Michigan has not increased its production efficiency (productivity); the share of the national area is greater than the share of national production (Martinez, Thornsbury, and Nagai, 2006).

Land Ownership and Use

In 2019, there were approximately 20,655 horticultural specialty crop farms across the country, which includes 3,245 farms in the selected states: Iowa (321), Michigan (1,092), New York (978), and Ohio (854) (USDA NASS, 2020). Land parcel sizes were determined by respondent information and were categorized into groups by acreage as illustrated in Table 2. The majority of farms surveyed, 32 responses (32.7%), were over 1,001 acres. The second most prevalent acreage size was less than 50 acres, accounting for 22.5% (22) of the respondents. The third most common acreage size was tied between 50–100 acres and 501–1,000 acres, each with 11.2% (11) of the respondents. The 251- to 500-acre category accounted for 10.2% of the total with 10 respondents. The 101- to 250-acre category accounted for 7.1% (7) of the respondents.

Cucurbit Downy Mildew Impacts

Crop characteristics, including the specific cucurbit crop, a conventional or organic production system, and the prevalence of CDM disease during production, are shown in Table 3. Among the different cucurbits, the primary crops include those that are most commonly grown and are also among the best sellers. Of the crops surveyed, 37 respondents most frequently grew pickling cucumber and 32 respondents (86.1%) reported it as their primary crop. This was followed by pumpkin with 34 respondents and 21 (67.8%) reporting it as their primary crop. The squash crop was grown by 37 respondents but only 18 (48.7%) reported it as their primary crop. Similarly, slicing cucumber was grown by 19 respondents, with 9 of them (47.4%) reporting it as their primary crop. The least frequently mentioned crop was watermelon with 10 respondents but only 2 of them (20.0%) reported it as their primary crop. Of the 86 total responses, 4 crops were organically grown: 3 squash (8.1%), 2 pumpkin (5.9%), 1 cantaloupe (9.1%), and 1 pickling cucumber (2.7%). All of the crops were reported by the respondents as being affected by CDM in some capacity. Pickling cucumber was the most impacted by CDM, with 35 responses accounting for 94.6% of the total. Other crops with responses included cantaloupe (7 responses, 63.6%), slicing cucumber (11 responses, 57.9%), pumpkin (19 responses, 55.9%), squash (17 responses, 46.0%), and watermelon (4 responses, 40.0%).

Table 3 also lists two methods for controlling CDM. The first method is the use of an integrated pest management program along with a regular fungicide application program. The second method is the inclusion of CDM-resistant or tolerant cucumber varieties. Some cucurbits, such as watermelon, squash, cantaloupe, and pumpkin, don't have resistant cultivars against CDM; as such, their options are far more limited. Pickling cucumber had 37 responses (100%) for using a fungicide program alone and 18 responses (48.7%) for the use of resistant varieties; slicing cucumber had 15 responses (79.0%) indicating the use of a fungicide program and 11 responses (57.9%) for using resistant varieties. However, we observed that the majority of producers relied on fungicides to protect their crops. Specifically, squash had 24 responses (64.9%) for using a fungicide program, followed by pumpkin with 24 responses (70.6%), cantaloupe with 9 responses (81.8%), and watermelon with 7 responses (70.0%) for using a fungicide program to overcome CDM. Among the U.S. states, Michigan alone spends about $8 million annually on fungicides to manage CDM in cucurbit crops. This value does not take into account related expenses associated with disease management, such as labor and equipment costs (Hausbeck, Cortright, and Glaspie, 2006).

The most important chemical fungicides used in the production of each cucurbit crop surveyed and the cost of the chemical control per acre are shown in Table 4. Overall, the two most commonly used fungicides reported for all crops were Bravo (chlorothalonil) and Kocide 3000 (copper hydroxide). Other commonly reported fungicides included Zing (zoxamide + chlorothalonil), Ranman (cyazofamid), Zampro (ametoctradin + dimethomorph), and Orondis (oxathiapiprolin). The highest cost of fungicide control was for slicing cucumber at $142.50 per acre. Fungicide costs associated with CDM control for other cucurbits were as follows: cantaloupe at $135.00 per acre, pickling cucumber at $53.90 per acre, pumpkin at $50.00 per

acre, and squash at $46.70 per acre. The crop that cost the least amount in fungicide control was watermelon at $23.00 per acre.

Crop Loss from Cucurbit Downy Mildew

The extent of cucurbit crop loss caused by CDM varied by crop (Table 5). Pickling cucumber and slicing cucumber had the greatest damage with 41% to 60% crop loss for each as reported by 1 respondent. The responses for all crops indicate the most frequent loss was 1% to 20%. Pickling cucumber received 32 responses for 1% to 20% loss for 86.5% of the total and 21% to 40% loss with 2 responses and 5.4% of the total. Slicing cucumber reported 8 responses of 1% to 20% loss for 42.1% of the total and 4 responses of 21% to 40% loss for 21.1% of the crop total. Watermelon reported 4 responses for 1% to 20% loss for 40.0% of the total and 1 response for 21% to 40% loss for 10.0% of the crop total. Squash reported 24 responses for 1% to 20% loss with 64.9% of the total and 4 responses for 21% to 40% loss and 10.8% of the crop total. Cantaloupe had 8 responses for 1% to 20% loss with 72.7% of the total and 1 response for 21% to 40% loss and 9.1% of the crop total. Lastly, pumpkin had 25 responses for 1% to 20% loss with 73.5% of the total and 2 responses for 21% to 40% loss for 5.9% of the crop total. The total crop percentages do not equal 100% because some producers saw no loss from CDM.

Total Dollar Loss per Acre

The total value loss due to the impact of CDM is considerable and varied by crop (Table 6). The survey results indicate that the largest loss in value occurred among slicing cucumber producers with $1,425 per acre. This was followed by pumpkin with $255 per acre loss, squash with $250 per acre loss, cantaloupe with $200 per acre loss, and pickling cucumber with $136 per acre loss. Watermelon had the least amount of value loss from CDM at $50 per acre.

CDM Occurrence Over Time

The surveyed farmers' observations regarding CDM occurrence in 2017 were compared to observations five years prior and are illustrated in Figure 1. The most common responses were that CDM occurrence remained the same and that the occurrence was more compared to five years prior. Each of these two categories had 23 responses accounting for 23.5% and a total of 47.0%. Fourteen respondents (14.3%) indicated that they did not know how the current occurrence compared to that of five years prior. The fewest respondents (7), 7.1% of the total, answered that CDM occurrence was less than it was five years prior.

Fungicide Resistance

The frequency and percentage of respondents that have or have not observed fungicide resistance in their previous production cycle are shown in Table 7. The survey indicated that 32 respondents observed fungicide resistance in their previous production cycle while 66 did not.

Fungicide Usage Over Time

Fungicide usage to control CDM compared to past years in terms of percentages is illustrated in Figure 2. The largest response was 1 year ago, with 23.9% of producers using less or the same amount of fungicide compared to the previous year. This was followed by 2 years ago with 22.9%, 3 years ago with 20.8%, and 5 years ago with 13.7% of the total. Finally, 18.8% of producers reported that they used less or the same amount of fungicide compared to 12 years ago. This indicates that the fungicide usage to control CDM has not increased over time. We presume this is partially due to the inclusion of resistant varieties (e.g., with cucumbers) as well as improved and more effective fungicides, early pathogen detection, and disease forecasting—and not due to a decrease in the presence of the disease.

Conventional Fungicides

The most commonly used conventional fungicides included the following: Previcur Flex (propamocarb), Omega (fluazinam), Zampro (ametoctradin + dimethomorph), Zing (zoxamide + chlorothalonil), Curzate (cymoxanil), Orondis (oxathiapiprolin), Presidio (fluopicolide), Mancozeb (mancozeb), Quadris (azoxystrobin), Ranman (cyazofamid), potassium phosphite–based products (Fosphite, K-Phite, ProPhyt, Fungi-Phite, Rampart), Revus (mandipropamid), Ridomil Gold (mefenoxam), Tanos (famoxadone + cymoxanil), Aliette (fosetyl-Al), Bravo (chlorothalonil), Reason (fenamidone), Gavel (zoxamide + mancozeb), and others (Table 8). The use of a surfactant, OSO, as an additive to the fungicide was also indicated. The most commonly used conventional fungicide for pickling cucumber was Ranman with 28 responses accounting for 14.9% of the total. The most commonly applied fungicide for slicing cucumber was Previcur Flex and Presidio with 9 responses (11.3%) each. The most commonly sprayed fungicides for watermelon were Presidio and Tanos with 3 responses each accounting for 15% of the crop total. For squash, the most commonly used fungicide was Ridomil Gold with 12 responses for 11.4% of the total. The most commonly used fungicides for cantaloupe were Zampro, Presidio, and Tanos with 4 responses each for 11.1% of the crop

total. Bravo was the most commonly used fungicide for pumpkin with 8 responses for 13.3% of the total.

Biorational Products

The most commonly used biorational product for pickling cucumber was OxiDate (hydrogen dioxide) with 3 responses (16.7% of crop total) (Table 9). The most commonly applied product for slicing cucumber was Sonata ASO (*Bacillus pumilus* strain QST 2808) with 3 responses (18.8% of crop total). Neem Oil (hydrophobic extract of neem oil) was the most commonly used product for watermelon, based on 2 responses (25.0%). The most common fungicides for squash were Neem Oil, Regalia (extract of *Reynoutria sachalinensis*), and Serenade AX (*Bacillus subtilis* strain QST 713) with 3 responses for 12.5% each of the crop total. The most common fungicides for pumpkin were Neem Oil and OxiDate with 3 responses for 15.8% each. Overall, the most common organic fungicides reported by survey participants were OxiDate, Sonata ASO, and Neem Oil.

CONCLUSION

The presence of a more virulent strain of the CDM pathogen on cucumber in the United States has resulted in major economic losses. Results of the survey showed that the application of fungicides to limit CDM has contributed to an increased cost of $23 to $143 per acre depending on the crop. This finding is consistent with Savory et al. (2011). The total dollar loss due to yield reduction per crop cycle because of CDM ranged from $50 to $1,425 per acre. Pickling cucumber and slicing cucumber had the greatest damage of up to 41% to 60% crop loss, whereas squash, watermelon, cantaloupe, and pumpkin reported maximum damage up to 21% to 40% loss. The total crop percentages do not equal 100% because some producers saw no loss from CDM. The majority of producers surveyed had not observed crop failure due to fungicide resistance in their last cropping cycle. This could be a result of being alerted by extension educators and university specialists as to which fungicides were no longer working against CDM in their research plots (Goldenhar and Hausbeck, 2019; Cohen et al., 2015). The results also indicate that the use of fungicide to control CDM has not increased over time. With regard to cucumbers, this may be partially explained by the inclusion of resistant varieties; for the other cucurbits, it is most likely due to more effective fungicide chemistries and improved integrated pest management programs, early pathogen detection systems, and disease forecasting—and not due to a decrease in the presence of the disease.

The most commonly used conventional fungicides included the following: Previcur Flex, Omega, Zampro, Zing, Curzate, Orondis, Presidio, Mancozeb, Quadris, Ranman, Fosphite, K-Phite, ProPhyt, Fungi-Phite, Rampart, Revus, Ridomil Gold, Tanos, Aliette, Bravo, Reason, and Gavel to protect crops from CDM. Growers also used the following biorational fungicides: Actinovate AG, Neem Oil, Kaligreen, Milstop, OxiDate, Regalia, Trilogy, Serenade AX, and Sonata ASO. Against this background, we recommend that a well-defined integrated pest management strategy includes CDM observant systems, resistant cultivars (when available), and best management practices coupled with a sustainable fungicide program to safeguard the economic viability of cucurbit production. An effective disease management approach for CDM by collective partnerships between the public/academic sectors and industry, with support from funding agencies, to balance the need for both applied and fundamental research would appear to be a sustainable approach to generate long-term solutions for the U.S. cucurbit industry.

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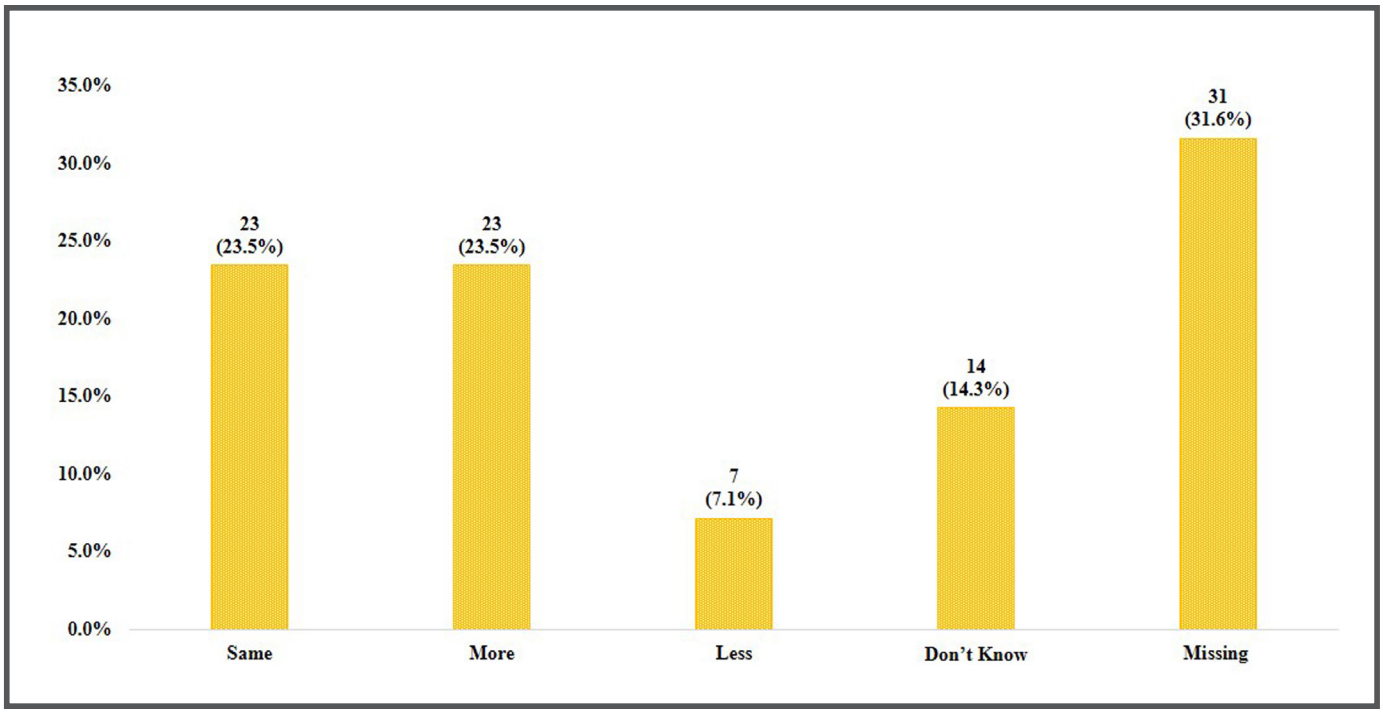

Figure 1. Downy mildew disease in 2017 compared to five years prior

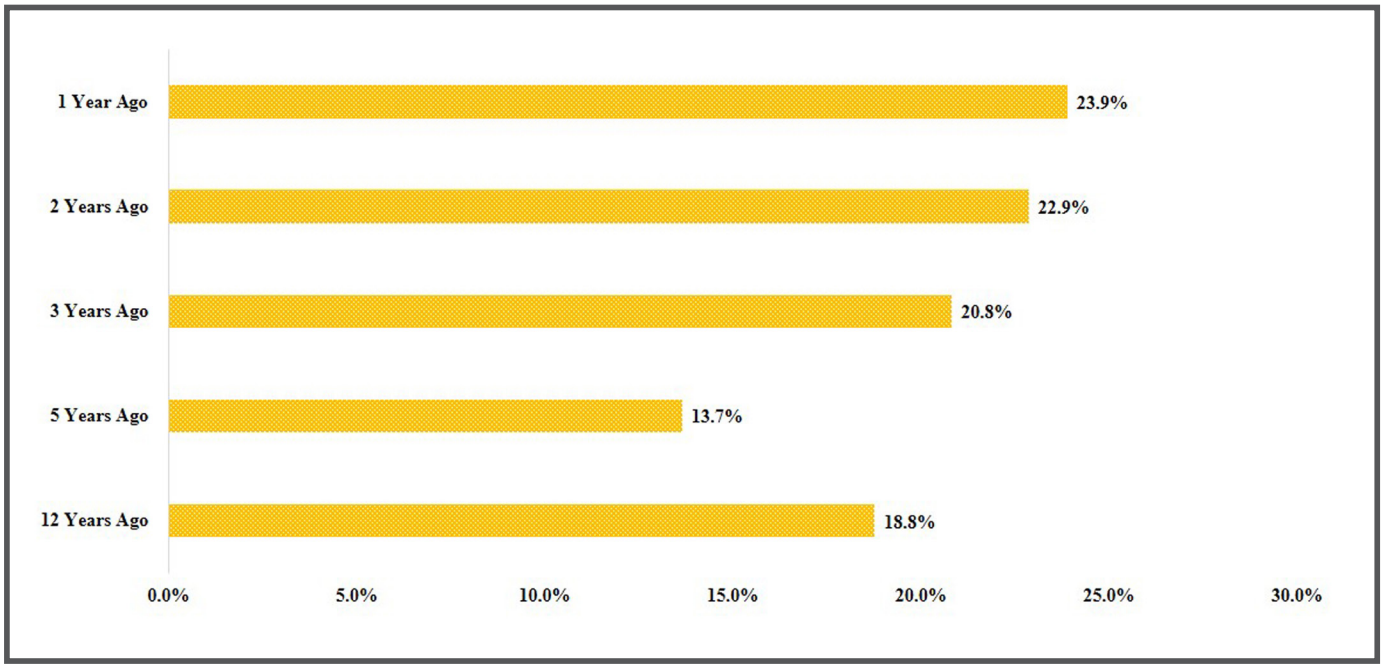

Figure 2. Producers who used less or the same amount of fungicide compared to the past

Table 1. Breakdown of Study Respondents

State	Frequency	Percent (%)
Iowa	1	1.0%
Michigan	92	93.9%
New York	3	3.1%
Ohio	2	2.0%
Total	98	100.0%

Table 2. Responses by Land Parcel Size

Farm Size, in Acres	Frequency	Percent (%)
<50	22	22.5%
50–100	11	11.2%
101–250	7	7.1%
251–500	10	10.2%
501–1,000	11	11.2%
>1,001	32	32.7%
Not Reported	5	5.1%
Total	98	100.0%

Table 3. Cucurbit Crop, Frequency of Production, Importance of Downy Mildew, and Use of Strategies to Limit Disease

Cucurbit Crop		Primary Crop	Organically Grown	Downy Mildew Considered a Problem	Strategies to Limit Downy Mildew[a]		Total Respondents
					Fungicide Program	Resistant Cultivars	
Pickling Cucumber	Frequency	32	1	35	37	18	37
	Valued %	86.5%	2.7%	94.6%	100.0%	48.7%	100.0%
Squash	Frequency	18	3	17	24	Not Available	37
	Valued %	48.7%	8.1%	46.0%	64.9%	—	100.0%
Pumpkin	Frequency	21	2	19	24	Not Available	34
	Valued %	67.8%	5.9%	55.9%	70.6%	—	100.0%
Slicing Cucumber	Frequency	9	0	11	15	11	19
	Valued %	47.4%	0.0%	57.9%	79.0%	57.9%	100.0%
Cantaloupe	Frequency	4	1	7	9	Not Available	11
	Valued %	36.4%	9.1%	63.6%	81.8%	—	100.0%
Watermelon	Frequency	2	0	4	7	Not Available	10
	Valued %	20.0%	0.0%	40.0%	70.0%	—	100.0%

[a]Multiple responses.

Table 4. Chemical Fungicides and Cost of Control by Cucurbit Crop per Acre in 2017

Crop Name	Key Chemical Fungicides	Cost of Control/ Acre
Pickling Cucumber	Bravo, Kocide 3000, Presidio, Zing, Ranman, Zampro, Orondis	$53.90
Squash	Bravo, Kocide 3000, Astirstor, Copper, Previcur Flex, Ranman, Ridomil, Torino, Quintec	$46.70
Pumpkin	Bravo, Kocide 3000, Ranman, Zampro, Orondis, Zing, Previcur Flex, Presidio, Astirstor, Copper, Torino, Quintec	$50.00
Slicing Cucumber	Bravo, Kocide 3000, Ranman, Zing, Zampro, Presidio, Orondis,	$142.50
Cantaloupe	Bravo, Kocide 3000, Orondis, Presidio, Zing, Ranman, Zampro	$135.00
Watermelon	Bravo, Kocide 3000, Orondis, Zing, Previcur Flex	$23.00

Table 5. Crop Loss to Cucurbit Downy Mildew in 2017 Production Cycle

Crop Name		1% to 20%	21% to 40%	41% to 60%	61% to 80%	81% to 100%	Not Responded	Total Respondents
Pickling Cucumber	Frequency	32	2	1	0	0	2	37
	Valued %	86.5%	5.4%	2.7%	0.0%	0.0%	5.4%	100.0%
Squash	Frequency	24	4	0	0	0	9	37
	Valued %	64.9%	10.8%	0.0%	0.0%	0.0%	24.3%	100.0%
Pumpkin	Frequency	25	2	0	0	0	7	34
	Valued %	73.5%	5.9%	0.0%	0.0%	0.0%	20.6%	100.0%
Slicing Cucumber	Frequency	8	4	1	0	0	6	19
	Valued %	42.1%	21.1%	5.3%	0.0%	0.0%	31.6%	100.0%
Cantaloupe	Frequency	8	1	0	0	0	2	11
	Valued %	72.7%	9.1%	0.0%	0.0%	0.0%	18.2%	100.0%
Watermelon	Frequency	4	1	0	0	0	5	10
	Valued %	40.0%	10.0%	0.0%	0.0%	0.0%	50.0%	100.0%

Table 6. Total Monetary Loss per Acre from Cucurbit Downy Mildew in 2017 Production Cycle

Crop Name	Total Monetary Loss per Acre
Pickling Cucumber	$136.40
Squash	$250.00
Pumpkin	$255.00
Slicing Cucumber	$1,425.00
Cantaloupe	$200.00
Watermelon	$50.00

Table 7. Fungicide Resistance in the Previous Production Cycle

Response	Frequency	Percent (%)
No	66	67.4%
Yes	32	32.7%
Total	98	100.0%

Table 8. Most Commonly Used Conventional Fungicides in 2017 Production Cycle

	Pickling Cucumber		Squash		Pumpkin		Slicing Cucumber		Cantaloupe		Watermelon	
Fungicide	**Freq.**	**(%)**	**Freq.**	**(%)**	**Freq.**	**(%)**	**Freq.**	**(%)**	**Freq.**	**(%)**	**Freq.**	**(%)**
Ranman	28	14.9%	6	5.7%	7	11.7%	7	8.8%	3	8.3%	2	10.0%
Orondis	27	14.4%	6	5.7%	2	3.3%	6	7.5%	2	5.6%	0	0.0%
Zing	26	13.8%	5	4.8%	5	8.3%	4	5.0%	2	5.6%	1	5.0%
Zampro	22	11.7%	5	4.8%	4	6.7%	7	8.8%	4	11.1%	1	5.0%
Previcur Flex	16	8.5%	8	7.6%	5	8.3%	9	11.3%	3	8.3%	2	10.0%
Bravo	14	7.5%	10	9.5%	8	13.3%	4	5.0%	2	5.6%	1	5.0%
Mancozeb	12	6.4%	7	6.7%	4	6.7%	6	7.5%	1	2.8%	0	0.0%
Presidio	8	4.3%	8	7.6%	3	5.0%	9	11.3%	4	11.1%	3	15.0%
Tanos	7	3.7%	8	7.6%	4	6.7%	8	10.0%	4	11.1%	3	15.0%
Gavel	7	3.7%	1	0.9%	1	1.7%	3	3.8%	2	5.6%	0	0.0%
Quadris	6	3.2%	9	8.6%	2	3.3%	4	5.0%	2	5.6%	1	5.0%
Ridomil Gold	5	2.7%	12	11.4%	4	6.7%	4	5.0%	1	2.8%	1	5.0%
Omega	2	1.1%	1	0.9%	0	0.0%	0	0.0%	1	2.8%	1	5.0%
OSO	1	0.5%	1	0.9%	1	1.7%	2	2.5%	1	2.8%	1	5.0%
Fosphite, K-Phite, ProPhyt, Fungi-Phite	1	0.5%	4	3.8%	2	3.3%	1	1.3%	0	0.0%	0	0.0%
Rampart	1	0.5%	1	0.9%	0	0.0%	1	1.3%	1	2.8%	0	0.0%
Revus	1	0.5%	7	6.7%	1	1.7%	2	2.5%	0	0.0%	0	0.0%
Aliette	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Curzate	0	0.0%	1	0.9%	2	3.3%	0	0.0%	0	0.0%	0	0.0%
Reason	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Others	4	2.1%	5	4.7%	5	8.3%	3	3.8%	3	8.3%	3	15.0%
Total	188	100.0%	105	100.0%	60	100.0%	80	100.0%	36	100.0%	20	100.0%

Table 9. Most Commonly Used Organic Fungicides in 2017 Production Cycle

Fungicide	Pickling Cucumber		Squash		Pumpkin		Slicing Cucumber		Cantaloupe		Watermelon	
	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)
Neem Oil	2	11.1%	3	12.5%	3	15.8%	2	12.5%	1	8.3%	2	25.0%
OxiDate	3	16.7%	0	0.0%	3	15.8%	2	12.5%	1	8.3%	0	0.0%
Sonata ASO	2	11.1%	1	4.2%	1	5.3%	3	18.8%	1	8.3%	1	12.5%
Trilogy	1	5.6%	1	4.2%	1	5.3%	0	0.0%	0	0.0%	0	0.0%
Serenade AX	1	5.6%	3	12.5%	2	10.5%	2	12.5%	2	16.7%	1	12.5%
Actinovate AG	1	5.6%	1	4.2%	1	5.3%	1	6.3%	0	0.0%	0	0.0%
Milstop	1	5.6%	1	4.2%	1	5.3%	1	6.3%	1	8.3%	1	12.5%
Kaligreen	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Regalia	0	0.0%	3	12.5%	2	10.5%	1	6.3%	1	8.3%	1	12.5%
Others	7	38.9%	11	45.8%	5	26.3%	4	25.0%	5	41.7%	2	25.0%
Total	18	100.0%	24	100.0%	19	100.0%	16	100.0%	12	100.0%	8	100.0%