Project Description:

Problem, background and justification

In the mid-Atlantic region (NJ, MD, VA, DE, PA) of the United States approximately 221, 000 A of fresh-market and processing vegetable crops are grown each year (NASS, 2003-4). Over the past decade, a number of new fungicide chemistries for use in vegetable production have been released in the US. Many of these fungicides have specific modes-of-action (MOA) that target pathogen development at a single site (McGrath, 2001). Fungicides with a single-site MOA are often considered at- or high-risk fungicides because the chances for fungal resistance to develop are much higher than fungicides with multiple MOA's (McGrath, 2001). In recent years, fungicide resistance in important diseases of vegetable crops, such as gummy stem blight and powdery mildew in cucurbits and phytophthora in bell pepper, has been detected in the mid-Atlantic region. Unfortunately, some growers become concerned about managing resistance only after it has developed. They (ie. growers) do not recognize that the primary goal of resistance management is to delay its development rather than to manage resistant strains (McGrath, 2001). The vast number of fungicide chemistries available and differences in mode-of-actions can make it very difficult for vegetable growers to develop and follow fungicide resistance management programs on their farms.

In 2002, the NAFRAC (North American Fungicide Resistance Action Committee) was established to i) coordinate and identify resources for contact between government, universities, and the public on fungicide resistance management issues, ii) assist in the creation of new working groups in North America for other areas of chemistry, as they are needed and iii) serve as a spokesman for the industry view on fungicide resistance management issues by providing an outlet for comments and position papers from members. Each year the FRAC group publishes a list FRAC codes for most fungicides and fungicide chemistries. FRAC codes group fungicide chemistries according to class, mode-of-action and resistance-risk. To date, there are 42 numbered and 3 lettered FRAC groups for 61 listed chemical groups and 179 common names of fungicides (FRAC code, 2006). Accordingly, fungicides listed within a given FRAC group share a similar mode-of –action, therefore, have i) similar risks for resistance development, ii) similar use patterns on multiple crops and iii) exhibit the potential for cross-resistance development.

Fortunately, most fungal pathogens can be controlled by more than one fungicide chemistry and rotations between fungicides with different modes-of-action can easily be accomplished. However, in many cases, fungicides within a given FRAC group are listed for control of the same pathogen. Unfortunately, this can lead to serious confusion by vegetable producers when it comes to developing a seasonal fungicide application program for specific diseases. For example, Gummy stem blight is an important disease in cucurbit crops in the mid-Atlantic region, as well as, the rest of the US. In the mid-Atlantic region, fungicide chemistries such as azoxystrobin and pyraclostrobin are listed as recommended options for Gummy stem blight control. Unfortunately, both fungicides belong to the same FRAC group, FRAC group 11, and each has a high-risk for fungicide

resistance development. The development of fungicide resistance in the field can be very difficult to detect. Unknowingly, a cucurbit grower without the proper knowledge could be selecting for a resistant fungal population with the overuse of any of these chemistries. Importantly, with highly mobile pathogens, such as cucurbit powdery mildew, successful management may require regional implementation. Otherwise, growers using an at-risk fungicide exclusively may select resistant strains and thereby thwart efforts of growers using a resistance management program (McGrath, 2001). More so, cross-resistance can develop in fungicides in FRAC group 11. Cross-resistance occurs when a fungal population that develops resistance one fungicide chemistry can develop resistance to other fungicide chemistries in the group, even if, only one fungicide chemistry has been applied. Unfortunately, resistance to the FRAC group11 fungicides, as well as, others has already been detected for important vegetable pathogens in the northeast (McGrath, 2001).

Because of the vast number of fungicides available and the potential difficulty in understanding FRAC groups and their importance, vegetable producers need a simplified reference tool for the management of fungicide resistance in their farm operation. In the mid-Atlantic region, five states (NJ, MD, DE, PA and VA) share the use of a common commercial vegetable productions guide which is developed by university personnel from multiply disciplines on an annual basis. Each year over 3,500 copies of the production guide are distributed to growers who plant 221,000 acres of vegetable crops throughout the region on an annual basis. Although the recommendations guide includes FRAC groupings, a simplified version is necessary to help vegetable growers understand FRAC groupings and their importance in fungicide resistance management.

Objectives and anticipated impacts

The objective of this project is to develop a grower reference guide for fungicide resistance management in vegetable crops in the mid-Atlantic region. The anticipated impacts of this project are to i) promote the importance and understanding of FRAC groupings in fungicide resistance management ii) prevent the misuse of specific fungicides with a high-risk for resistance development and iii) provide the tools and knowledge to allow growers to develop vegetable disease control programs with an emphasis towards fungicide resistance management.

Approach and procedures

FRAC tables for the 30 crop groups listed in the 2007 Commercial Vegetable Productions Recommendations Guide for the mid-Atlantic region will be developed for a new fungicide resistance management reference guide. Each table will consist of all fungicides recommended for a particular crop (or crop group) in the 2007 recommendations guide along with FRAC and risk management codes, diseases for that particular crop or crop group and fungicide resistance management guidelines for each particular FRAC group. A table for fungicide resistance management guidelines for pumpkin and winter squash crops grown in the mid-Atlantic region, such as the one in Appendix A, has already been constructed. From Appendix A, 18 labeled fungicides that

include 11 different FRAC groups are listed with risk management codes (L, M, H) for eight common pumpkin and winter squash diseases in the mid-Atlantic region. Fungicide, chemical names, FRAC groups and risk management guidelines will be color-coordinated by group to help distinguish differences based on FRAC group. The far right-hand column of each table will include fungicide resistance management guidelines for each particular FRAC group with specific instructions on risk assessment and/or application instructions. Each reference guide will be spiral-bound so it can be placed in a pesticide shed or weighing area for easy reference. Additionally, each individual table will have the ability to be removed and hung individually, since, in many cases large growers only produce a handful of crops. Included in each guide will be a space where notes on applications, specific FRAC group use and dates can be recorded for specific crops (Appendices B and C). An example of the table is presented in Appendix B with an example of a production schedule for disease control in a pumpkin crop in Appendix C. Although growers are required by law to keep a record of applications, little if any emphasis is put in keeping track of specific fungicide chemistry use in terms of resistance management. Without keeping track of such information, growers could unknowingly apply fungicides against label restrictions. A simple-to-use reference guide and method for keeping track of FRAC group use would help growers i) learn the importance of FRAC codes, ii) apply different fungicide chemistries appropriately, iii) reduce the potential for fungicide resistance development and iv) reduce the potential for economic losses due to fungicide resistance development.

Spring 2007	Summer 2007	Fall 2007
Develop master tables for fungicide resistance management guide	Promote use of guide during field days, twi-light meetings, etc	Promote use of guide during field days, twi-light meetings, etc
Develop text for guide introduction, etc.	Demonstrate importance of FRAC groups and guide to vegetable growers	Demonstrate importance of FRAC groups and guide to growers
Make final edit for printing	Grower surveys on their use of guide	Grower surveys on their use of guide
Print fungicide resistance management guide		Compile information collected from grower surveys
Distribute guide – late spring		Make improvements for future guide

Evaluation plans

The fungicide resistance management reference guide will be available to growers in the mid-Atlantic region in late spring, summer and fall of 2007. The guide will be distributed for free to vegetable growers in the mid-Atlantic states (NJ, DE, MD, PA and VA) during the 2007 production season and be used as a promotional tool for twi-light meetings, fields days and on-farm tours. During these meetings, collaborators from each

state will promote the use of the fungicide resistance management reference guide. Each collaborator will help to i) explain the importance of learning and knowing how to use FRAC groups ii) help explain the FRAC tables and resistance management guidelines and iii) answer any related questions related to the resistance management reference guide from vegetable growers. Between the cooperators and the number of twi-light tours, field days and regional meetings given each year in each state it is estimated that between 1,000 and 1,500 growers from the region will be exposed to the importance of learning and knowing how to use FRAC groups in fungicide resistance management. After each talk at each meeting growers will be briefly questioned on i) their prior knowledge of FRAC groups ii) if FRAC groups are used in development their fungicide programs iii) their use of the reference manual iv) how the use of the reference guide has changed their management programs and v) their thoughts on improving the reference guide. Results of all surveys will be compiled at the end of the production season to help determine i) growers prior knowledge of and the importance of knowing FRAC groups ii) how the reference guide has changed disease management programs for fungicide resistance development in the mid-Atlantic region and iii) how to improve the reference manual for future editions. Results of the project surveys will be used to complete a regional report on fungicide resistance management and to improve future versions of the reference guide. Subsequent copies of the guide (after 2007) will then be sold at-cost (or for a nominal fee) on an annual basis for vegetable growers in the mid-Atlantic region and distributed with the mid-Atlantic commercial vegetable recommendations production guide.

LITERATURE CITED:

McGrath, M.T 2001. Fungicide resistance in cucurbit powdery mildew: experiences and challenges. *Plant Dis.* Vol 85 No 3: 236-245.

		Pumpkin and Winter Squash										
Fungicide	Chemical	FRAC grouping	Risk Management	Damping-off	Angular leaf spot	Plectosporium blight	Scab	Phytophthora blight	Gummy stem blight	Powdery Mildew	Downy mildew	Fungicide Resistance Management Guidelines
Sulfur	sulfur	M1	L							x		Multi-site MOA, use in tank mixes with high risk and in rotations with other FRAC groups
fixed Copper	copper	M1	L		x							
Maneb	EBDC	M3	L			x					x	
chlorothalonil	chlorothalonil	M5	L			x	x		x	x	x	
Nova	myclobutanil	3	H							x		High risk, always tank mix, and alternate with other groups
Procure	triflumizole	3	H							x		
Ridomil Gold	mefenoxam	4	H	x				x				Hisk risk, Mefenoxam resistance in mid-Atlantic
Ultra Flourish	mefenoxam	4	H	x				x				
Amistar / Quadris	azoxystrobin	11	H						x			High Risk, Possible PM and DM resistance in NJ. Use in tank mixes with M1,M3, M5 and alternate with 15,22 + M3, 28. No consecutive applications.
Cabrio	pyraclostrobin	11	H			x			x			
Flint	trifloxystrobin	11	H			x						
Pristine	pyraclostrobin + boscalid	11 + 7	H						x	x		
Tanos	famoxadone + cymoxanil	11 + 27	M					x			x	
Ranman	cyazofamid	21	M					x			x	Risk unknown
Curzate	cymoxanil	27	M								x	Always tank mix with a protectant
Previcur Flex	propomocarb HCL	28	L								x	
Forum	dimethomorph	40	M					x				

Fungicide resistance management guidelines for Pumpkin and Winter Squash crops grown in mid-Atlantic - 2007

FRAC group: M = multi-site MOA, numbered groups = chemistries with similar mode-of-action, specific site (MOA)
Risk management: L = low risk, M = moderate risk or H = high risk for fungicide resistance to develop
Fungicides with similar MOA (ie. same FRAC group number) should not be sprayed consecutively

APPENDIX B

2007 Fungicide Application Schedules

Crop:	Applications										
	1	2	3	4	5	6	7	8	9	10	Notes:
Date											
Farm/Block											
FRAC group											
Chemical											
Rate(s)											
Sprayed for:											

Crop:	Applications										
	1	2	3	4	5	6	7	8	9	10	Notes:
Date											
Farm/Block											
FRAC group											
Chemical(s)											
Rate(s)											
Sprayed for:											

Crop:	Applications										
	1	2	3	4	5	6	7	8	9	10	Notes:
Date											
Farm/Block											
FRAC group											
Chemical(s)											
Rate(s)											
Sprayed for:											

Crop:	Applications										
	1	2	3	4	5	6	7	8	9	10	Notes:
Date											
Farm/Block											
FRAC group											
Chemical(s)											
Rate(s)											
Sprayed for:											

2007 Fungicide Application Schedules

Crop: Pumpkin	Applications										
	1	2	3	4	5	6	7	8	9	10	Notes:
Date	7/15	7/22	7/31	8/7	8/14	8/23	9/1	9/8	9/18		
Farm/Block	RAREC	RAREC	RAREC	RAREC	RAREC	RAREC	RAREC	RAREC	RAREC		
FRAC group	M5 + M1	M5	M5+M3	11	4+M5	11+7	M5+3	M5+M1	M5		
Chemical	Bravo+S	Bravo	Bravo+coppe	Amistar	RidG+Bravo	Pristine	Bravo+Nova	Bravo+S	Bravo		
Rate(s)	2pt+2lb	3 pt	2pt ea	4 oz	2 lb	15 oz	2 pt + 5 oz	2pt+2 lb	3 pt		
Sprayed for:	PM	PM	PM,ALS	PM	PM,DM	PM,DM	PM	PM,DM	PM		

Crop:	Applications										
	1	2	3	4	5	6	7	8	9	10	Notes:
Date											
Farm/Block											
FRAC group											
Chemical(s)											
Rate(s)											
Sprayed for:											

Crop:	Applications										
	1	2	3	4	5	6	7	8	9	10	Notes:
Date											
Farm/Block											
FRAC group											
Chemical(s)											
Rate(s)											
Sprayed for:											

Crop:	Applications										
	1	2	3	4	5	6	7	8	9	10	Notes:
Date											
Farm/Block											
FRAC group											
Chemical(s)											
Rate(s)											
Sprayed for:											

Key Personnel

Andy Wyenandt, Extension Specialist in Vegetable Pathology, Rutgers University, Rutgers Cooperative Research and Extension

Dr. Wyenandt will act as production manager and developmental (senior) editor to help coordinate the development and dissemination of the resistance management guide. Dr. Wyenandt will help distribute and promote use of reference guide at field days, twi-light tours and regional meetings in NJ and regional meetings in mid-Atlantic.

Kathryne L. Everts, Associate Professor of Plant Pathology, Department of Plant Sciences and Landscape Architecture, University of Maryland

Dr. Evert will act as a content advisor and writer of the resistance management guide. Dr. Everts will help distribute and promote use of reference guide at field days, twi-light tours and regional meetings in DE, MD and regional meetings in mid-Atlantic.

Robert P. Mulrooney, Extension Plant Pathologist, Department of Plant and Soil Sciences, University of Delaware

Mr. Mulrooney will act as a content advisor and writer of the resistance management guide. Mr. Mulrooney will help distribute and promote use of reference guide at field days, twi-light tours and regional meetings in DE and regional meetings in mid-Atlantic.

Steven L. Rideout, Assistant Professor, Department of Plant Pathology, Physiology, and Weed Sciences, Virginia Polytechnic Institute and State University

Dr. Rideout will act as a content advisor and reviewer of the resistance management guide. Dr. Rideout will help distribute and promote use of reference guide at field days, twi-light tours and regional meetings in VA and regional meetings in mid-Atlantic.