

Northeastern IPM Center – IPM Partnership Grants – 2010 – Proposal

**Project Director: Christine Hoepting, Cornell Cooperative Extension Vegetable Program
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Project Title: Cultural practices to manage bacterial diseases in the small-scale intensive production of fresh market onions

Project Type: IPM Issues

2b. Project summary

Small-scale diversified fresh market vegetable growers who grow onions intensively are constantly challenged by yield losses due to bacterial bulb rots, which greatly compromise the profitability of the crop. If bacterial diseases cannot be managed, the profitability of this industry will not be sustained or expanded. The focus of this project is to evaluate, demonstrate and encourage adoption of cultural tactics to reduce bacterial diseases in small-scale intensive production of fresh market onions. We will evaluate the effects of mulch type and planting configurations on incidence of bacterial disease of onions, yield, bulb size, economic return and grower adoption. This project will be a cooperative effort among the Cornell Cooperative Extension Vegetable Program in New York, Penn State University, Cooperative Extension in Pennsylvania and two grower cooperators in New York and Pennsylvania. Successful demonstration of research-based recommendations to modify planting configuration and/or mulch type will result in 50 to 100% adoption of the 54 onion growers in the Finger Lakes region of NY and Lancaster County, PA. Consequently, losses due to bacterial rot and number of copper bactericide sprays will decrease, while yield, profitability and acreage of intensively managed sweet onions will increase, and more locally grown produce will be available to the consumer, and the small-scale fresh market onion industry will be sustained.

2c. Background and justification

i) Problem: Small-scale diversified fresh market vegetable growers who grow onions intensively are constantly challenged by yield losses due to bacterial bulb rots, which greatly compromise the quantity and quality and thus profitability of this crop. If these bacterial diseases cannot be managed, the profitability of the fresh market onion market will not be sustained or expanded.

Bacterial diseases are draining the profitability of fresh market onions: During the past 5 years, fresh market onion growers in PA and NY have lost \$350 to \$700 per 100 feet of onion row (or \$3500 to \$7000 per acre) as a result of reduced onion quantity resulting from bacterial diseases. In 2008 alone, 34 growers lost a total of \$140,000 to diseases in PA. Unfortunately these losses are occurring just as the “Eat Local” movement gains force throughout the Northeast, and has consumers and wholesale retailers searching for local vegetables throughout the year. In fact, one local vegetable broker in PA indicated that he has the market to sell three times the current volume of onions being produced (Bill Saussaman, personal communication). Despite the favorable market, bacterial diseases are a major deterrent for growers to increase or invest in onion production. In addition, reduced onion storability also prevents growers from being able to market onions locally throughout the winter when prices are higher. Growers in PA

also gain a marketing advantage by buying into and participating in the “PA Simply Sweet Onion Program”, the state’s only trademarked crop.

Bacterial diseases of onions: Onions are plagued by a number of bacterial diseases that cause both bulb and leaf decay. Thanks to funding in part from the PA Vegetable Growers Association (PVGA) and PA Vegetable Research and Marketing Program (PVRMP) in 2009, a survey was conducted in PA to identify the bacterial pathogens associated with symptoms observed in the field. To-date the most frequently isolated bacterial pathogens include: soft rot pathogens, *Pseudomonas marginalis* and *Pectobacterium caratovora*; and center rot pathogens, *Pantoea ananatis* and *P. agglomerans*; *Xanthomonas axonopodis* and *Pseudomonas viridiflava*. In NY, sour skin caused by *Burholderia cepacia*, is the most common cause of bacterial bulb rot, but *Pantoea ananatis* has also been identified. Bacterial diseases first appear as leaf blight symptoms on the center leaves of the plant, resulting in yellowing or bleaching and wilting of these leaves. The infection progresses down the leaves and the neck, and eventually into the bulb. Affected bulb scales eventually become soft and yellowish-brown in appearance. At harvest, the foliage often tears away from the bulb when pulled causing in-field losses. Additional losses can occur during storage when outwardly asymptomatic bulbs at harvest continue to breakdown (Davis, 2008; Gent and Schwartz, 2008). In PA and NY it is not uncommon for growers to harvest 2 to 3 weeks early and sacrifice bulb size in attempt to prevent the bacteria from moving into the bulb and causing rots and additional storage losses.

Chemical tactics have failed to control bacterial diseases: Attempts have been made by several growers to control bacterial diseases in onions with copper bactericides and other chemicals such as Oxidate. However, it has been reported in PA that weekly sprays of various bactericides starting as early as the second week in May when onion plants have just 5 leaves and continuing until the pre-harvest entry interval of the bactericide still resulted in unacceptably high incidence of bacterial disease (i.e. >30%). In order for bactericides to work, they need to be part of an IPM program that incorporates various cultural tactics.

ii) Address specific needs identified by growers and IPM issues: On a local level, small-scale diversified vegetable growers of onions in PA and NY need to find an integrated approach that will significantly reduce bacterial diseases, or else this industry will not be sustained or expanded. This is demonstrated in our grower support letters and by previous grower funding by the PVGA and PVRMP to support research projects on bacterial diseases of onions. Our project addresses three high priority cross commodity research needs established by the NY Vegetable IPM Program (2007) including, i) cultural practices for yield and quality enhancement, which includes investigation of row spacings, populations and stand establishment, ii) adoption of new marketing opportunities/new crops/new products when they arise, and iii) non-chemical pest management.

On a regional level, this proposal focuses on developing and implementing IPM practices for onion bacterial diseases deemed a priority pest by the Northeast Vegetable IPM Working Group in November 2009. In addition, several of the general needs issues will also be addressed including: i) to expand adoption of IPM through addressing the unique needs of all types of vegetable growers including small or isolated operations and highly diversified farms, and

organic growers, and, ii) to conduct research on how to promote plant health and suppress insect, disease and weed problems through cultural and biological practices.

National IPM issues that will be addressed by this project include the National IPM goals: i) to improve the economic benefits of adopting IPM practices and to reduce potential risks to human health and the environment caused by the pests themselves or by the use of pest management practices, and ii) to improve cost benefit analysis when adopting IPM practices, because if new IPM programs do not appear to be as economically beneficial as practices already in place, they are not likely to be adopted.

iii) Who stands to benefit from your project: Small-scale diversified vegetable growers in the Northeast stand to benefit the most from this project. These growers sell primarily sweet onions, through local produce auctions and direct markets. These lucrative markets pay \$1 or more for jumbo and about \$0.50/lb for colossal sized bulbs. Reducing the losses from bacterial diseases will directly and immediately impact farm profitability. Through this project, as we succeed in controlling bacterial rots through an IPM approach that relies heavily on cultural practices, current growers, both conventional and organic, will increase their acreage and more small-scale diversified vegetable growers will start growing onions thus building the fresh market onion industry in the Northeast. In addition, this project may lead to further research to investigate planting configurations to reduce bacterial rots in large-scale onion production (as in the muck lands of NY, for example) and also benefit large-scale onion growers in the long-term.

iv) Review completed or on-going work: Research conducted by Gitaitis et al., has linked the use of black plastic mulch with increased incidence of center rot (2004). Black plastic absorbs sunlight thus increasing soil temperature, which in turn, promotes early crop development of onions. However, during June and July, the warmer soil temperatures provided by the black plastic may actually create a more favorable environment for bacteria. In 2007, in NY, Reid showed that the daily high soil line temperature during July was approximately 10 °F cooler under reflective silver mulch than it was under black plastic. This could be the difference between optimum and below optimum temperatures for bacterial growth. Growing onions without mulch on bare soil may be another option, provided weeds can be economically controlled and not have a negative effect on yield. Biodegradable black plastic represents a compromise between black plastic and bare ground with the black plastic giving a push to early season growth and then giving way to cooler soil temperatures as it degrades.

In 2009, Hoepting *et al.* evaluated different planting configurations on the incidence of bacterial diseases of onions grown on plastic mulch in NY and PA (see Table 1 in Appendix). In NY, the grower's standard planting configuration (4 rows/bed with 8" plant spacing) resulted in 37% incidence of bacterial disease at harvest compared to the more closely spaced plants, 4 rows and 3 rows with 4" spacing, which had 13% and 14% disease incidence, respectively. Consequently, the highest density plantings also had significantly higher marketable yields and economic return as a result of more jumbo and colossal sized bulbs. In PA, unusually cool weather conditions resulted in very low incidence of bacterial disease negating any treatment differences. We hypothesize that bacterial disease incidence is reduced in higher density planting configurations, because these conditions hasten maturity and produce plants with thinner necks and fewer leaves thus creating a less favorable environment for the pathogen(s); a trend we observed in PA. The

highest planting density (4" plant spacing with 4 rows/bed) had significantly fewer leaves per plant, thinner necks and half as many plants lodged at harvest (see Table 2 in Appendix).

Onion thrips (OT) feeding damage is thought to provide entry for bacterial pathogens into the onion plant, thus increasing incidence of bacterial disease. Gitaitis et al. (2003) demonstrated that tobacco thrips can harbor and transmit *Pantoea* sp. Therefore, improved control of OT may further reduce incidence of bacterial diseases. In 2006 with funding from NE-SARE (ONE06-062), Reid found that fewer OT colonized onions grown on reflective silver mulch compared to those grown on black plastic. This project also demonstrated higher yields and larger bulb sizes in the onions grown on reflective silver mulch, supposedly a result of lower soil line temperatures that are more favorable for bulbing and less favorable for bacterial pathogens. In NY, some growers have adopted the use of reflective silver mulch as a result of this work, however, in PA, black plastic still remains the standard mulch type. The interaction between mulch type, OT, yield and bacterial diseases requires further research.

v) Applicability of proposed research to other regions: Although small-scale intensive onion production occurs primarily in the Northeastern U.S., demonstrated success of adjusting planting configurations to reduce bacterial rot may stimulate research projects in large-scale commercial onion production, not only in NY, but in Georgia and Colorado, and other states where bacterial diseases can be a perennial problem. In NY, bacterial rots are also one of the most important diseases in large-scale onion production, especially in transplanted onions. In 2007, losses due to bacterial rot ranged from 10 to 80% or more throughout the state due to an abnormally wet and very hot July. The results of this research would also be applicable for states such as New Jersey who are looking to build local production to support a process industry that traditionally ships onions from the Pacific Northwest (Tom Orton, personal communication).

Objectives and Anticipated Impacts

1. To evaluate and demonstrate cultural practices including mulch type and planting configurations for managing bacterial diseases in small-scale intensive fresh market onion production.

Anticipated Impacts

- Identification of mulch type and planting configuration to reduce bacterial disease incidence that can be incorporated into an overall IPM program.
2. To determine the economic feasibility of adopting cultural practices for managing bacterial diseases in small-scale intensive production of fresh market onions.

Anticipated Impacts

- Increase the options available for growers to cost-effectively manage bacterial rots.
3. To increase grower knowledge about onion bacterial diseases and their management, and grower adoption of our research-based recommendations to use cultural practices as a component of an IPM program.

Anticipated Impacts

- Fresh market onion growers in the Northeast adopt and integrate the use of cultural practices for managing onion bacterial diseases thus improving profitability, and reducing reliance on copper and other bactericides.
- Northeast growers expand their onion acreage and markets.
- Promote more long-term sustainable onion production.

Approach and Procedures.

Objective 1: To evaluate and demonstrate the impact of plant spacing and mulch type on the incidence of bacterial diseases in small-scale intensive fresh market onion production.

Planting configuration field trials: In Pennsylvania: In year 1(2010) to evaluate the impact of planting configurations on incidence of bacterial diseases in sweet onion, a replicated trial on black plastic mulch will be established on a grower collaborator farm with a history of onion bacterial diseases. Different planting configurations will be achieved by varying both the number of rows across the bed as well as the spacing within each row to attain the following individual bulb areas: 1) standard = 36 inch² per bulb; 2) 24 inch² per bulb; 3) 32 inch² per bulb; 4) 60 inch² per bulb; and 5) 80 inch² per bulb. In year 2, the same trial will be repeated, however the treatments may be modified based on the 2010 results. **In New York:** In previous field trials with pungent yellow onions, the 60 and 80 inch² per bulb treatments resulted in too much bacterial disease so in Year 1 emphasis will be placed on the 4, 6 and 8 inch in-row spacing and include: 1) standard = 48 inch² per bulb; 2) 64 inch² per bulb; 3) 24 inch² per bulb; 4) 32 inch² per bulb; 5) 36 inch² per bulb; and 6) 48 inch² per bulb (different configuration than trt. 1). Note that in NY, a pungent yellow onion variety will be planted to reflect local grower preferences. For this onion type, the jumbo and colossal bulb sizes are not as valuable as they are in the sweet onion market. This trial will also be conducted on standard reflective silver mulch.

Alternative mulch field trials: In Pennsylvania in Year 1 (2010): A replicated on-farm trial will be established to evaluate the effect of mulch type on onion bacterial disease incidence. The treatments will consist of 1) standard black plastic; 2) reflective silver plastic; 3) biodegradable black plastic; and 4) bare soil (no mulch) and will be planted with onion transplants cv. "Candy" at a standard planting configuration (36 inch² per bulb, 6" plant spacing, 4 rows/bed with 6" in-row spacing). Field design will be the same as described for the planting configuration trial. Hobo® Onset pendant temperature sensors will be placed both at the soil line under the plastic mulch and within the onion crop canopy. **In Year 2 (2011):** A replicated multi-factorial trial will be designed to evaluate the effect of mulch type and planting configuration on the incidence of bacterial rot of onion. Treatments will be selected based on the results of the previous trials conducted in Year 1. There will be a total of 9 to 12 treatments arranged in a randomized complete block factorial design.

Procedures: For all on-farm small-plot trials, the grower cooperator will secure the onion transplants and lay out the mulch in 3 ft wide beds with drip tape. Each trial will be arranged as a complete randomized block design with 4 replications (unless otherwise indicated) and each replicate will be 15 ft long with 1 ft between replicates. The different plant spacings will be arranged using fabricated hole punching tools and transplants planted by hand. The trials will be maintained by the grower cooperators using their standard practices throughout the season.

Data Collection: In all trials, plant height and number of leaves will be quantified on 10 randomly selected plants per replicate 3 weeks after transplanting and every 3 weeks thereafter until harvest. As plants approach maturity, percent lodging will be estimated and neck diameter measured. Visual assessment of bacterial disease incidence, and number of OT per plant will be counted or OT damage rated, as appropriate, during these assessments. The entire trial will be harvested and, yield, grade, and incidence of bulb rot quantified. Bacterial pathogens will be isolated and identified from select samples representing different types of bacterial rot symptoms

by Gugino using morphological and molecular techniques. In NY, onions will be stored and graded again after 3 months in storage to reflect typical local production practices. **Statistical Analysis:** All continuous variables within each year will be analyzed using an ANOVA and means separated using Fisher's least significant difference test (LSD) (SAS 9.2, SAS Institute, Cary, NC). All rating and count data within each year will be analyzed using non-parametric ordinal data analysis. Repeated measures analysis will be used to compare data across years for trials conducted in the same field location. In year 2, the multi-factorial trial will be analyzed using a MANOVA to test for treatment effects and interactions.

Objective #2: To determine the economic feasibility of adopting cultural practices for controlling bacterial diseases in small-scale intensive production of fresh market onions.

With the growers' assistance, we will conduct an economic analysis on a per 100 ft of row basis of the different mulch and planting configurations by taking into consideration the costs of transplants, mulch and weed control, marketable yield and grade, labor and market prices.

Objective #3: To increase grower knowledge about onion bacterial diseases and their management, and grower adoption of our research-based recommendations to use cultural practices as a component of an IPM program.

Extension fact sheet: The developed cultural practices for managing onion bacterial diseases as well as economic feasibility analysis will be integrated with more basic information about onion bacterial diseases and onion physiology, and laid out as a multi-state best management practices fact sheet. This resource will be made available at grower meetings in the later part of Year 2 of the project. It will also be made accessible via the Cornell and Penn State Cooperative Extension websites. With the increased interest in the production of fresh market onions, this fact sheet will be an important resource for both new and experienced onion growers.

Field days and winter educational meetings: During years 1 and 2, on-farm trials will be showcased and preliminary data presented at grower field meetings in PA and NY. Results and recommendations will be presented at local and statewide grower winter educational meetings in both NY and PA, and written up as articles for grower newsletter articles. Project directors will also participate in each other's field days and twilight meetings.

Implementation/Grower adoption: After year 1, we will be able to make research-based recommendations with respect to modifying planting configurations to reduce bacterial diseases, and in year 2, there will be growers implement our recommended cultural practices. In NY, Reid, Hoepting and Klotzbach will identify approximately 20 onion growers in the Finger Lakes region via their local winter educational meetings and grower visits, when they will share our research results and recommendations. During the growing season, they will be available to assist those growers as well as other interested growers with the implementation of our recommended cultural practices in 2011. In the fall of year 2, Reid and Klotzbach will re-visit with these growers for an in-depth interview and request information regarding yield, bulb size, incidence of bacterial diseases, use of bactericide sprays, increased sales and new market opportunities. Similarly, in PA, Stolfus will provide assistance to any of the 34 growers in Lancaster County who are interested in implementing our recommended cultural practices, and conduct season-end interviews.

Project Time Table

Year	Task and Objective	Completed by
April 2010	Establish planting configuration trials in NY & PA, and mulch trial in PA (<i>Obj. 1</i>)	NY: Hoepting, Klotzbach, Reid, grower cooperators.; PA: Gugino, Mansfield, Stoltzfus, grower cooperators
May - August 2010	In-season data collection and harvest field trials (<i>Obj. 1</i>); grower field meetings (<i>Obj. 3</i>) in both NY and PA.	NY: Hoepting, Klotzbach, Reid; PA: Gugino, Mansfield, Stoltzfus
September - October 2010	Collect economic data in NY and PA (<i>Obj. 2</i>)	NY: Reid, grower coop.; PA: Stoltzfus, grower cooperators
Dec. 2010	Storage evaluation of onions in NY (<i>Obj. 1</i>)	NY: Hoepting, Klotzbach
Nov 2010 – March 2011	Present results and make recommendations at educational meetings in PA and NY (<i>Obj. 3</i>)	NY: Hoepting, Reid, Klotzbach; PA: Gugino, Stoltzfus
April 2011	Set up field trials in PA (<i>Obj. 1</i>); Assist growers implement recommended cultural practices, NY & PA (<i>Obj. 3</i>)	NY: Hoepting, Klotzbach, Reid, grower cooperators; PA: Gugino, Mansfield, Stoltzfus; grower cooperators
May - August 2011	In-season data collection and harvest field trials (<i>Obj. 1</i>); grower field meetings (<i>Obj. 3</i>) in both NY and PA.	NY: Hoepting, Klotzbach, Reid; PA: Gugino, Mansfield, Stoltzfus
September - October 2011	Collect economic data in NY and PA (<i>Obj. 2</i>); Season-end in-depth interviews (<i>Obj. 3</i>)	NY: Reid, grower coop.; PA: Stoltzfus, grower cooperators
Nov 2011 – March 2012	Final results presented to growers at local and statewide meetings and development and publication of extension fact sheet (<i>Obj. 3</i>)	NY: Hoepting, Reid; PA: Gugino, Stoltzfus

Management Coordination

Project directors will have phone conferences no less than twice annually to discuss project work plans in the spring (prior to establishing the trials) and in late summer (after harvest). In addition, they will be participating in each other's field days and winter meetings when appropriate.

Evaluation plans

In addition to the previously described statistical data analysis for the on-farm field trials, economic feasibility, and documentation of grower implementation and adoption, we will evaluate change in grower knowledge about onion bacterial diseases and their management by administering a survey immediately following our presentations at our winter educational grower meetings in years 1 and 2. Growers will answer 5-10 simple questions about bacterial diseases, plant physiology and how cultural practices can reduce bacterial disease. Hoepting and all co-CPDs have had formal training and experience conducting project evaluation including survey design. They also have resources available at their respective universities for assistance. Survey and interview questions will be consistent for all growers. Survey data will be statistically analyzed using categorical data analysis. Although beyond the scope and resources of this project, a long-term evaluation would be worthwhile to document grower adoption, changes in

marketable yield, pesticide sprays and profitability, development of new markets, and new onion growers in 2012 and beyond. See the logic model in the appendix.

References

- Davis, R.M. 2008. Sour Skin. In: Compendium of Onion and Garlic Diseases and Pests, 2nd ed. The American Phytopathological Society, St. Paul, MN, pp. 63-64.
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Cooperation, institutional units and key personnel involved.

Christine Hoepting is a Vegetable Specialist with the Cornell Cooperative Extension Vegetable Program and specializes in onions. As the project director, she will coordinate all aspects of the project, conduct the NY field trial and assist with harvest of the PA trials, present results at grower meetings, write all reports and newsletter articles, and assist Gugino in writing the fact sheet. **Judson Reid** is Hoepting's team mate and specializes in small-scale diversified low-input vegetable production. He will assist with the NY field trial and harvest of the PA trials, collect economic and grower adoption data, and coordinate field and winter educational meetings in NY. **Kathryn Klotzbach** is a Program Assistant for this team and will assist Hoepting and Reid.

Beth Gugino is an Assistant Professor at Penn State with statewide research and extension responsibilities for vegetable pathology. She will be involved in the overall coordination of the field trials in PA and the development of the fact sheet. She will also work with other PDs to analyze data and conduct grower meetings. **Michele Mansfield**, research technician, has experience with the morphological and molecular identification of bacteria isolated from onion and will also help conduct the on-farm trials. **Jeff Stolfus** is an Adult Agriculture Instructor for the Eastern Lancaster County School District. He works with mostly "plain sect" farmers in the area of vegetable production, marketing and coop development. In PA, he will coordinate and assist with field trials, collect economic and grower adoption data, and organize local grower field and winter meetings.

Amos Lapp grows 10A of mixed vegetables including 2A of onions in New Holland, PA. He is a Board member of the Lancaster County Vegetable Growers Cooperative. **Eli Stolfus** grows 15A of produce, with approximately 1500 row ft of onions, in Interlaken, NY. Both growers have hosted university research trials in the past. For this project, they will procure the onion transplants, lay the mulch with drip irrigation, maintain the trial plots throughout the season, and host field meetings, if appropriate.

Table 1. Evaluation of planting configurations of small-scale pungent yellow fresh market onions on marketable yield and grade, quality and economic return, Interlaken, NY 2009 (Hoepting 2009).

<i>Onion Spacing</i>				<i>Total Marketable Yield</i>	<i>Onion Grade (pounds per 100 ft of bed)</i>				<i>Bacterial Bulb Rot</i>	
<i>Planting Density (inch²/bulb)</i>	<i>Number Rows per Bed¹</i>	<i>Row Spacing (inch)</i>	<i>Plant Spacing (inch)</i>		<i>Pounds per Foot of Bed</i>	<i>Small <2.5''</i>	<i>Medium 2.5-3''</i>	<i>Jumbo 3-4''</i>	<i>Colossal >4''</i>	<i>Pounds per 100 ft Bed</i>
24 inch ²	4	6	4	5.1 a ²	10.0 a	36.0 a	330 a	130 b	70	13.3 b
32 inch ²	3	8	4	4.6 a	2.00 b	10.0 b	190 b	270 a	70	13.8 b
48 inch² Standard	4	6	8	3.3 b	0.00 b	6.00 bc	50.0 c	270 a	180	37.3 a
60 inch ²	4	6	10	2.2 bc	1.00 b	0.00 c	20.0 c	200 ab	170	41.5 a
80 inch ²	3	8	10	1.6 c	0.00 b	1.00 c	10.0 c	130 b	190	53.6 a
<i>P Value:</i>				<i>0.0001</i>	<i>0.0046</i>	<i>0.0000</i>	<i>0.0000</i>	<i>0.0352</i>	<i>NS</i>	<i>0.0064</i>
<i>Economic Return:</i>					<i>\$ per size class (per 100 ft of bed)</i>				<i>Total \$ per 100 ft bed</i>	
					<i>Small \$0.20/lb</i>	<i>Medium \$0.40/lb</i>	<i>Jumbo \$0.50/lb</i>	<i>Colossal \$0.55/lb</i>		
24 inch ²	4	6	4		\$2	\$14.40	\$165	\$71.50	\$252.90	
32 inch ²	3	8	4		\$0.40	\$4	\$95	\$148.50	\$247.90	
48 inch² Standard	4	6	8		\$0	\$2.40	\$25	\$148.50	\$175.90	
60 inch ²	4	6	10		\$0.20	\$0	\$10	\$110	\$120.20	
80 inch ²	3	8	10		\$0	\$0.40	\$5	\$71.50	\$76.90	

¹bed width = 3 ft. ²numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, p > 0.05.

Table 2. Evaluation of planting configurations on small-scale fresh market sweet onions (cv. Candy) for plant size and lodging at maturity, New Holland, PA, July 16, 2009 (Hoepting, 2009).

<i>Planting Configuration</i>				<i>Plant Size⁴</i>		<i>Maturity</i>
Planting Density (inch²/bulb)	Number Rows per Bed¹	Row Spacing (inch)	Plant Spacing (inch)	Number Leaves per Plant	Neck Diameter (inch)	% Lodging³
24 inch ²	4	6	4	7.86 b ²	0.66 d	86.4 a
32 inch ²	3	8	4	8.16 b	0.69 cd	68.3 ab
36 inch² Standard	4	6	6	8.83 a	0.74 bc	44.3 b
60 inch ²	4	6	10	9.16 a	0.78 ab	7.5 c
80 inch ²	3	8	10	9.18 a	0.81 a	7.0 c
<i>P value:</i>				0.0001	0.0001	0.0004

¹bed width = 3 ft. ²numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, $p > 0.05$. ³percent lodging was estimated visually.

⁴number of leaves per plant and neck diameter were counted and measured, respectively from 10 randomly selected plants per replicate.

Logic Model: Cultural practices to manage bacterial diseases in small-scale intensive production of fresh market onions.

INPUTS	AUDIENCE ACTIVITIES	IMPACTS		
		Short term (Knowledge Change)	Intermediate (Action Change)	Long-term (Condition Change)
<p>People:</p> <ul style="list-style-type: none"> • Hoepting • Gugino • Reid • Stolfus • grower cooperators <p>Money:</p> <ul style="list-style-type: none"> • NE IPM Partnership grant • PA Veg. Marketing & Research Program <p>Interagency Cooperation:</p> <ul style="list-style-type: none"> • Cornell Cooperative Extension Vegetable Program • PA Cooperative Extension/ELANCO School District • Penn State University <p>In-kind resources:</p> <ul style="list-style-type: none"> • Grower cooperators for on-farm research trials • Infrastructure for information delivery 	<p>Audience:</p> <ul style="list-style-type: none"> • Small-scale diversified fresh market growers of onions • Future onion growers • Organic onion growers • Large-scale onion growers • Extension educators & other ag service providers <p>Activities:</p> <ul style="list-style-type: none"> • On-farm small-plot replicated research trials • Showcase trials and preliminary data at field meetings in NY and PA • One-on-one consulting • Educational grower meetings in NY and PA • Newsletter articles in Extension publications and websites • Articles in trade journals • Distribution of developed fact sheet 	<p>Indicators:</p> <ul style="list-style-type: none"> • Increase target audience (TA) awareness and knowledge of: 1) how cultural practices can reduce bacterial diseases in onions, 2) general plant physiology and how plant spacing affects maturity and yield, and 3) biology and epidemiology of onion bacterial diseases. <p>Possible Measures:</p> <ul style="list-style-type: none"> • Collect baseline data to assess KASI changes using surveys at summer field and winter educational grower meetings. 	<p>Indicators:</p> <ul style="list-style-type: none"> • TA adopt new mulch type and/or planting configurations as part of an IPM program • TA use fewer sprays of copper bactericides after adopting new cultural practices • TA increase their sales with higher yields, better quality onions and new customers <p>Possible Measures:</p> <p>Via in-person survey in year 2:</p> <ul style="list-style-type: none"> • measure number of growers that adopted a different mulch type or planting configuration • Document change in incidence of bacterial rots, marketable yield and profitability • Document reduced use of copper bactericides 	<p>Indicators:</p> <ul style="list-style-type: none"> • TA has increased market share • TA extended marketing season because of prolonged storage life of onions. • TA gain new customers • New growers get into fresh market onion production in the Northeastern US. • New research is initiated to investigate planting configurations to reduce bacterial rot in large-scale onion production • Reduced environmental impact from reduced use of copper bactericides <p>Possible Measures:</p> <p>Compare values of Northeastern US onion industry between 2007 and 2015.</p>