Report submitted to the Pennsylvania Vegetable Marketing and Research Program
Pennsylvania Vegetable Growers Association
December 7, 2014

Title: Continued evaluation of the effects of inoculum pressure and onion maturity at harvest on harvest and post-harvest losses due to bacterial diseases.

PRINCIPAL INVESTIGATORS

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INTRODUCTION

Bacterial diseases of onion may account for 50% or more yield loss from individual fields in a given year, but these losses are often variable between farms. The major bacterial pathogens of onion in PA are the center rot pathogens, *Pantoea agglomerans* and *P. ananatis,* and the soft rot pathogens, *Pectobacterium carotovorum* and *Pseudomonas marginalis,* with some farms experiencing losses due to slippery skin, caused by *Burkholderia gladioli*. Research funded through the Northeast Regional IPM program has identified on-farm factors most closely associated with high bacterial disease incidence and severity. Extensive on-farm field data were collected and analyzed from both PA and New York, for a total of 108 fields over two years. From these data, positive relationships between soil temperatures at bulbing and bacterial disease were identified, that is, the higher the soil temperature at bulbing, the higher the level of bacterial disease. Negative relationships between foliar nutrients at midseason, particularly foliar N, and bacterial disease were suggested in PA, that is, as midseason foliar N increased in the dataset, bacterial disease decreased. Positive relationships between pre-harvest soil nitrate and bacterial disease incidence were also suggested in both states. Supported by the PA Specialty Crop Block Grant Program, further research investigating the type and timing of application of nitrogen fertilizer will be conducted in 2015 and 2016 to more thoroughly describe relationships between nitrogen and bacterial disease, in addition to onion variety trials and a plastic mulch removal trial.

Each year, growers must decide the most appropriate time to harvest their onions, and may base their decision on several criteria, such as the calendar date, the proportion of plants with lodged foliage, or average onion bulb size. Some growers choose to harvest earlier than initially planned as a result of perceived bacterial disease pressure in the crop. This logic stems from the understanding that once the neck of the onion is dried down, bacterial pathogens can no longer move from the leaves into the bulb. However, onion bulbs put on the majority of their size in the last four weeks of the season, and even a few additional days in the field may result in significantly greater yields over the span of an entire field. The identification of a bacterial disease severity rating threshold would provide another integrated management tool for growers to use as they negotiate the interplay between marketable yields and bacterial disease.

Through a PVMRP/PVGA trial on plant defense-inducing products, funded in 2012, a visual disease severity scale (0 = healthy to 7 = ≥ 50% of leaves bleached and collapsed) was developed to rate foliar bacterial disease progression in the research trial (Fig. 1). This scale was further used in PVMRP/PVGA replicated field trials on two Penn State research farms in 2013 (Figs. 2a and 2b), where plots with different levels of bacterial pathogen pressure were rated and harvested once per week for five weeks from mid-June to mid-July. Estimates of the highest marketable yields per acre, calculated based on the yields from the small plots, were determined, regardless of inoculum pressure, to be 64,649 and 41,519 lb/A, for the trials at Rock Springs (RS13) and Landisville (LNDS13), respectively. These marketable yields were then compared to foliar disease severity curves, which indicated threshold average ratings of 2.6 and 3.6 for RS13 and LNDS13, respectively (Figs. 2a and 2b). These estimates begin to suggest a foliar disease severity rating threshold of 3 (= approx. ½ of a leaf chlorotic/bleached), however, additional research is necessary to verify these results. The goal in 2014 was to conduct another replicated trial at Rock Springs and also scout several commercial fields at relate disease severity to marketable yield at harvest.

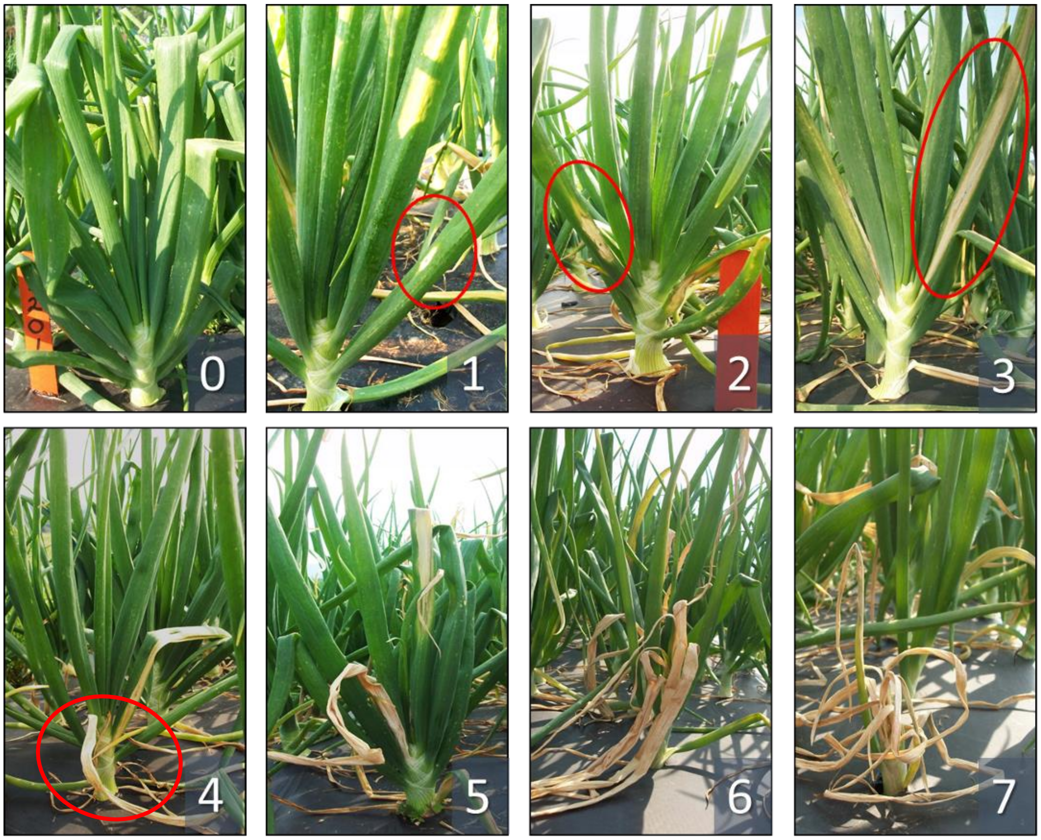
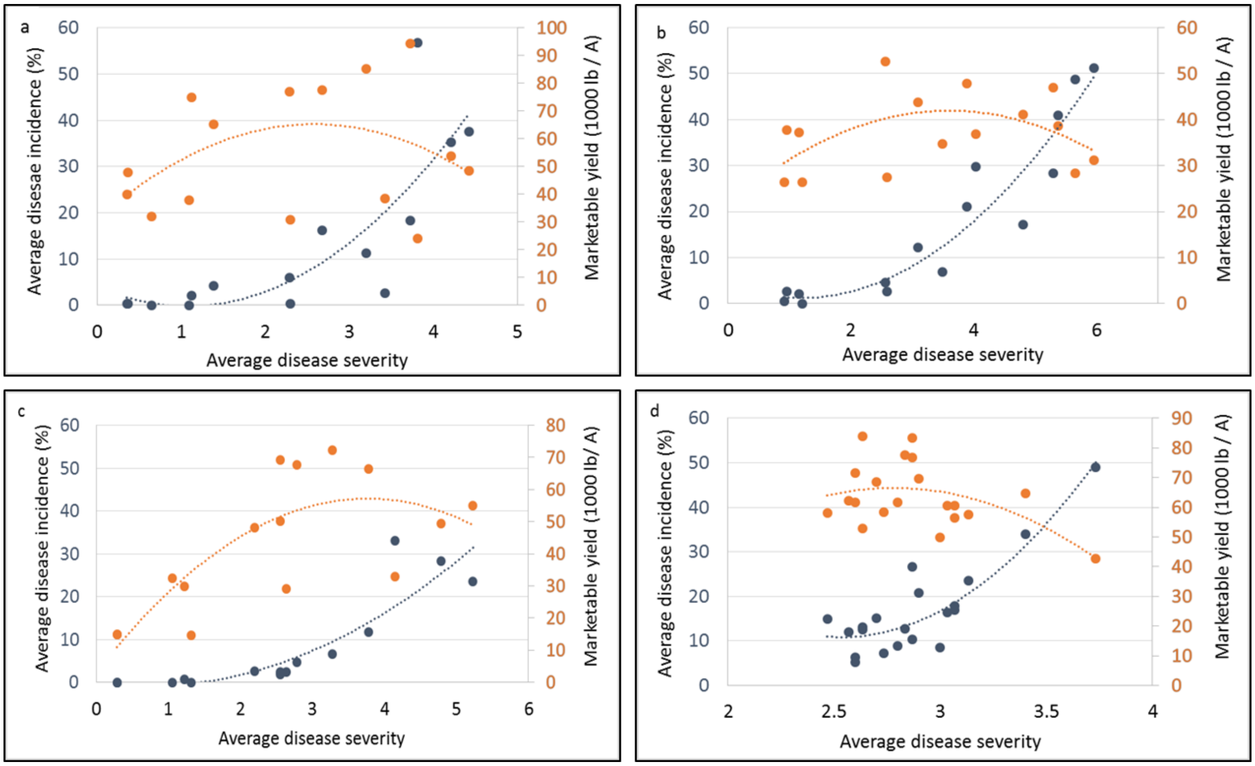


Figure 1. Visual rating scale: 0 = no lesion, asymptomatic; 1 = Local lesion (< 2.5 cm x 2.5 cm); 2 = Expanded lesion but less than ¼ leaf; 3 = ½ of leaf chlorotic or bleached; 4 = Entire leaf is bleached and wilting; 5 = One entire leaf and a portion of another leaf are bleached and wilted; 6 = Multiple fully symptomatic leaves; and 7 = ≥50% of leaves bleached and collapsed.

METHODS

To evaluate the effects of inoculum pressure and onion maturity on harvest and post-harvest losses due to bacterial disease, a split-split plot replicated field trials was established on 24 April at the Plant Pathology Farm at Russell E. Larson Research and Education Center at Rock Springs in Centre Co. The trial was planted on standard black plastic with a double row of drip irrigation. Each plot consisted of a 38 ft section of bed, 4 rows wide with 6-in. plant spacing within plants and between rows. Each plot was split into inoculated and uninoculated subplots (19 ft each). Plots were arranged in a randomized complete block design with five replications. On 17 Jun, the fourth leaves from the outside of each plant in two rows (one outer, one inner) of the inoculated plots were toothpick inoculated with a bacterial suspension containing a mix of *Pantoea agglomerans* and *P. ananatis*, isolated from symptomatic onions collected in PA, approx. 6-in. from the base of the neck. Crop fertility, insects and weeds were managed using standard commercial production practices.



Figures 2a-d. Bacterial disease incidence (blue curves) and marketable yield (orange curves) at harvest by average bacterial disease severity immediately preharvest. Datasets from (a) Rock Springs (RS13) and (b) Landisville (LNDS13) research farms, in 2013, and (c) Rock Springs (RS14) and (d) four grower-collaborator farms in Lancaster County (GCF14), in 2014, were plotted in Microsoft Excel. Foliar disease severity was a fairly good predictor of disease incidence, with R^2 = 0.68 (a), 0.90 (b), 0.81 (c), and 0.79 (d). Data fit lines more closely as R^2 approaches 1. This means that the line accurately describes the actual data points.

Treatment plots were harvested at weekly intervals on 24 June, 1, 8, 15 and 22 July to reflect increasing stages of maturity. Prior to harvest, 20 plants per plot were rated for visual symptoms (Fig. 1) and for lodging (yes/no) before two 15 ft rows of the plot were pulled, topped and graded for size and marketability. The incidence of center and surface rots was recorded separately for inoculated, adjacent to inoculated, and uninoculated sub-sub plots to reflect varying levels of bacterial inoculum pressure. A sub-set of 30 marketable onions from each plot was dried for two weeks, then stored for 10 additional weeks in a cool, dark storage barn and graded for post-harvest bacterial disease incidence.

Five replicate plots (30 ft) were established 10 June in each of four grower-collaborator onion fields in Lancaster Co. Temperature sensors were placed in the center of each plot, and disease and pest management were left to the grower's discretion. After plot establishment and prior to harvest, 30 plants per plot were visually rated each week for bacterial disease severity using the scale in Fig. 1, as well as whether or not plants had lodged foliage. The inner 15 ft of each plot was pulled, topped, and graded for size and marketability as closely as possible to the grower's selected harvest date; for most growers, this was 10 July.

Data was analyzed by fitting two curves to each of the four datasets. Second-order best fit lines were fitted for each of set's marketable yield by disease severity (orange) and disease incidence by disease severity (blue). Each point in a, b, and c represents an average of five replicate plots, and each point in d represents a single plot in a commercial field (Figs. 2a-d). The derivative of the marketable yield best fit line was calculated to identify the yield optimum, then this value was solved for zero to identify the corresponding disease severity value. These values were collectively used to identify a threshold foliar disease severity value to be used as a tool to determine when to harvest onions.

Results and Discussion

With each successive harvest at Rock Springs from 24 June to 22 July, the proportion of marketable jumbo and colossal sized onions increased, with the most dramatic increase occurring between 8 July and 15 July, approximately 11 weeks post-transplant. Disease incidence increased significantly in the inoculated plots between 1 July and 8 July, approximately 10 weeks post-transplant and 3 weeks post-inoculation. Center rot disease incidence was 6.6%, 23.5%, and 11.8% for control (uninoculated), inoculated (high disease pressure), and adjacent-to-inoculated plots (moderate disease pressure), respectively, on the last harvest date.

Multiple components, such as fertility, water availability, and micro-climate effects, in addition to disease severity, contribute to marketable yields. Overall, while marketable yields were not well-described by foliar disease severity, disease incidence in harvested bulbs was well-described by these visual ratings (Figs 2a-d). By identifying the peak of the best-fit marketable yield curve, then relating that value to foliar disease severity, threshold values ranged between 2.6 and 3.8 (specifically 2.6, 3.6, 3.8, and 2.8 for RS13, LNDS13, RS14, and GCF14, respectively) (Figs. 2a-d). Plots on grower-collaborator farms were harvested according to the grower's selected date, resulting in very low variation between grower plots, with the exception of Farm 4, which was harvested last and had the highest disease pressure (Fig. 3). The remainder of the grower collaborator plots were fairly consistent, with disease severity ratings ranging between 2.5 and 3, disease incidence between 5 and 27%, and marketable yields between 42,672 and83,938 lb/A (Fig. 2d). In the two plots where disease incidence exceeded 33%, foliar disease severity averaged over 3.4 (Fig. 2d). One estimate of an economic break-even point for Simply Sweet® growers is 25,000 lb/A (J. Stoltzfus, pers. comm.), which all grower-collaborator study plots involved in this year exceeded.

Regular scouting for bacterial disease symptoms may be incorporated into an integrated pest management program to monitor levels of expected disease incidence in the onion crop. Average foliar disease severity ratings, based on the presented scale (Fig. 1), are representative overall of bacterial disease incidence at harvest, based on four separate datasets (Figs. 2a-d). From these datasets, an average foliar disease severity rating of 3 may be advisable to result in tolerable yield losses when scouting for bacterial disease in onion fields (Figs. 2a-d). This rating scale could also be successfully applied to research plots under natural inoculum pressure (Fig. 3).

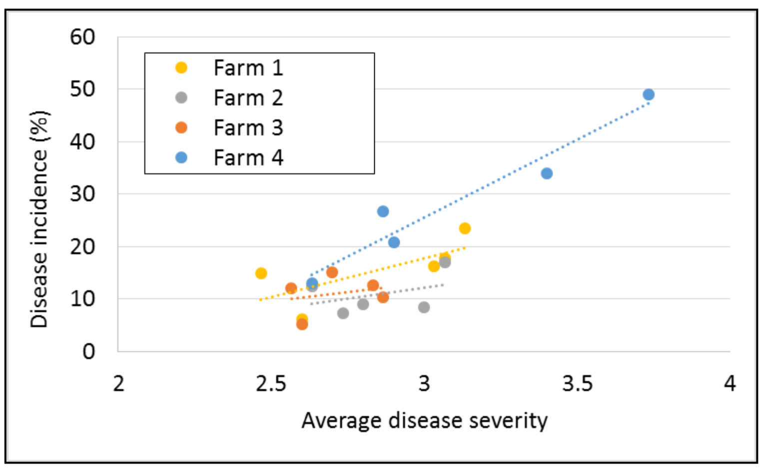


Figure 3. Bacterial disease incidence at harvest compared to average foliar disease severity (from 30 plants) recorded immediately prior to harvest on grower-collaborator farms in 2014.