Original Article | Journal of Biosystems Engineering

J. of Biosystems Eng. 41(3):255-262. (2016. 9)
http://dx.doi.org/10.5307/JBE.2016.41.3.255

eISSN : 2234-1862
pISSN : 1738-1266

State of Knowledge of Apple Marssonina Blotch (AMB) Disease among Gunwi Farmers

Brianna B. Posadas[1], Won Suk Lee[1]*, Sebastian Galindo-Gonzalez[2], Youngki Hong[3], Sangcheol Kim[3]

[1]*Department of Agricultural and Biological Engineering, College of Engineering, University of Florida, Gainesville FL 32611, USA*

[2]*Department of Agricultural Education and Communication, Institute of Food and Agricultural Sciences, University of Florida, Gainesville FL 32611, USA*

[3]*Farming Automation Division, Department of Agricultural Engineering, National Academy of Agricultural Science, Jeonju, Korea*

Received: May 12th, 2016; Revised: May 26th, 2016; Accepted: June 4th, 2016

Abstract

Purpose: Fuji apples are one of the top selling exports for South Korea bringing in over $233.4 million in 2013. However, during the last few decades, about half of the Fuji apple orchards have been infected by Apple Marssonina Blotch disease (AMB), a fungal disease caused by Diplocarpon mali., which takes about 40 days to exhibit obvious visible symptoms. Infected leaves turn yellow and begin growing brown lesions. AMB promotes early defoliation and reduces the quality and quantity of apples an infected tree can produce. Currently, there is no prediction model for AMB on the market. **Methods:** The Precision Agriculture Laboratory (PAL) at the University of Florida (UF) has been working with the National Academy of Agricultural Science, Rural Development Administration, South Korea to investigate the use of hyperspectral data in creating an early detection method for AMB. The RDA has been researching hyperspectral techniques for disease detection at their Apple Research Station in Gunwi since 2012 and disseminates its findings to the local farmers. These farmers were surveyed to assess the state of knowledge of AMB in the area. Out of a population of about 750 growers, 111 surveys were completed (confidence interval of +/- 8.59%, confidence level of 95%, p-value of 0.05). **Results:** The survey revealed 32% of the farmers did not know what AMB was, but 45% of farmers have had their orchards infected by AMB. Twenty-five percent could not distinguish AMB from other symptoms. Overwhelmingly, 80% of farmers strongly believed an early detection method for AMB was necessary. **Conclusions:** The results of the survey will help to evaluate the outreach programs of the RDA so they can more effectively educate farmers on the identifying, treating, and mediating AMB.

Keywords: Fuji apples, Gunwi, Marssonina apple blotch disease, Rural Development Administration, South Korea

Introduction

Apple Marssonina blotch disease (AMB), also known as apple blotch, is caused by the fungus Diplocarpon mali (Harada et al., 1974). Favorable conditions for infections include 23.5°C and 20 mm of rain; for disease development a daily temperature of 25°C and 20 mm of rain are required (Park et al., 2013). Fuji and Golden Delicious apples are highly susceptible to AMB (Yin et al., 2013). About half of the Fuji apple orchards in South Korea have been infected by Apple Marssonina Blotch disease. Korea produces 715,982 metric tons of apples every year, and Fuji apples make up 77% of the total apple production, making AMB a major concern for the agricultural industry (Krissoff et al., 1997). AMB takes about 40 days to exhibit obvious visible symptoms. The disease symptoms begin on the leaves as small brown lesions followed by foliar chlorosis. Conidia can germinate and penetrate on both sides of apple leaves, and penetrate into the cuticle either by germ

***Corresponding author:** Won Suk Lee
Tel: +1-352-392-1864; **Fax:** +1-352-392-4092
E-mail: wslee@ufl.edu

tube or by the formation of aspersoria. There is no difference in the development of AMB on apple leaves of different ages (Zhao et al., 2013). AMB promotes early defoliation and reduces the quantity of apples an infected tree can produce (Lee et al., 2011), devastating profits for the farmer. The quality of the apple fruit is also affected by the decrease in starch content instigated by the decreased photosynthetic rates of the diseased leaves (Sagong et al., 2011). The weight of an apple from an infected tree also has a 22.6-30% decrease (Park et al., 2013). Even though the leaf has fallen from the tree, the fungus continues to sporulate on the surface of the leaf, and the spores can spread by the wind and infect healthy trees (Jacobi, 2013). Countries that have reported Apple Marssonina blotch disease as a serious problem include the Republic of Korea, India, and China.

Once an orchard has been infected by D. mali, the only control measure is to remove the diseased tree. Preventative measure includes spraying with a fungicide, but D. mali has shown low sensitivity to copper fungicides and is becoming resistant to thiophanate-methyl ("European and Mediterranean Plant Protection Organization (EPPO)," n.d.). The best protectants against Apple Marssonina blotch disease were dithiocarbamates (mancozeb and metiram); maximum disease control when fungicides applied after 12 h of inoculation (97.92% disease control), followed by 24 h, 36 h, 48 h, and 72 h (Kumar and Sharma, 2014). Because of the farmers excessive use of fungicide to mitigate the disease, the fungus has developed a resistance to the most commonly used fungicides ("European and Mediterranean Plant Protection Organization (EPPO)," n.d.). Currently, there is no prediction model for AMB on the market. Not having this model has led to an over application of fungicide, which is harmful to the environment and costly to the farmer. The Rural Development Administration (RDA) in Korea provides extension services in the form of lectures, web resources, and handouts to inform local farmers about various diseases that affect the apple orchards and the best techniques for combating them, including the devastating effects of AMB and best fungicides. However, there has not been an efficient evaluation of these services or an investigation as to the extent of damage caused by AMB and how invested the farmers are in developing and adapting new, potentially more effective methods to combat it.

During the summer of 2015, as part of the National Science Foundation East Asia and Pacific Summer Institute Fellowship, a survey of Gunwi apple growers was distributed to determine the extent of knowledge of AMB in the region, the state of current methods to detect and treat AMB, and the need for an early detection method of AMB. Gunwi was chosen as the site location because of proximity to the RDA orchards. The objectives of this study were (1) to describe the population of growers who the RDA reaches with their outreach efforts, (2) to collect survey data of Korean farmers to determine impact of Apple Marssonina Blotch disease, (3) to determine current practices for combating AMB and (4) to detail farmers' commitment to investing in new AMB detection and prevention methods.

Materials and Methods

The primary instrument used to carry out this research was a paper survey questionnaire. The questionnaire was distributed to farmers who attended various lectures conducted by the RDA. The paper survey was written in Korean, and the farmers wrote their answers in Korean. We were most interested in collecting data from apple farmers in South Korea.

Sample selection and survey techniques

Since we were interested in not only evaluating the current state of knowledge of AMB, but also the effectiveness of RDA's outreach program, hard-copies of the paper questionnaire were distributed at the end of lectures given by the RDA in July 2015. Table 1 depicts the dates and number of surveys that were distributed

Table 1. Overview of data collection. There were six lecture dates and a total of 111 surveys were collected

Date	Number of surveys
July 02, 2015	19
July 03, 2015	14
July 07, 2015	19
July 17, 2015	14
July 26, 2015	35
July 29, 2015	10
Total	111

and returned.

Due to limited resources, it was not possible to conduct the traditional randomized method of survey distribution. With such a small population, to increase the number of surveys returned, every participant in the lecture was given a survey to complete.

Questionnaire topics

Hard copies of a 24 question survey were given to farmers at various lectures delivered by the RDA. The questions asked about their familiarity with AMB, current techniques they use in the field to mitigate AMB, and their comfort level with various technologies. The complete surveys in English and in Korean can be made available upon request.

Data analysis

The analysis of the responses followed guidelines discussed by Israel (2015). One hundred and eleven surveys were completed by farmers in July 2015. With a population of about 750, this means we had a confidence interval of +/- 8.59% with a confidence level of 95% and a p-value of 0.05. However, almost none of the farmers completely filled out the survey. Questions with a poor response rate will be noted in the results. Once the paper surveys were collected from the farmers, the surveys were scanned and saved in a digital format. The responses from the questionnaires were then translated into English, and descriptive statistics were conducted.

Results and Discussion

Because of the low response rate, and missing data from the surveys that were returned, the data analysis of this study was mostly restricted to descriptive statistics and analysis. In order to complete further analysis on the dataset, variables that were missing over 50% of the data were removed from the analysis and the remaining variables were imputed. However, from this early study, it is possible to begin understanding the grower population and their current needs as concerning AMB education and preventive techniques.

Describing the population of growers

Thirty-nine percent of responders were between the ages of 48 and 67 with very few of the responders being over 68 (Figure 1). As seen in Figure 2, the responders were overwhelmingly male (80% of the total responders). About 60% of growers had less than five years' experience, with over 90% of the responders reporting less than 20

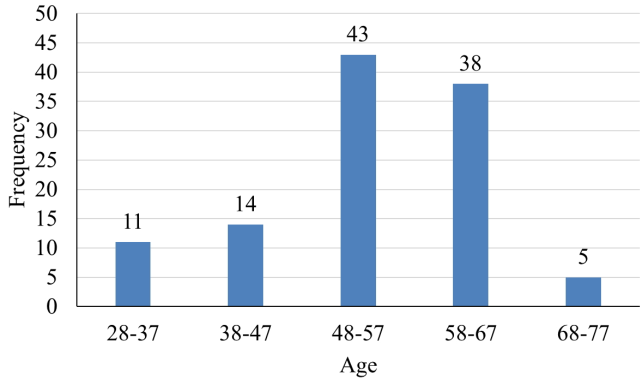

Figure 1. Demographic information of growers. The median age of growers is between 48 and 57.

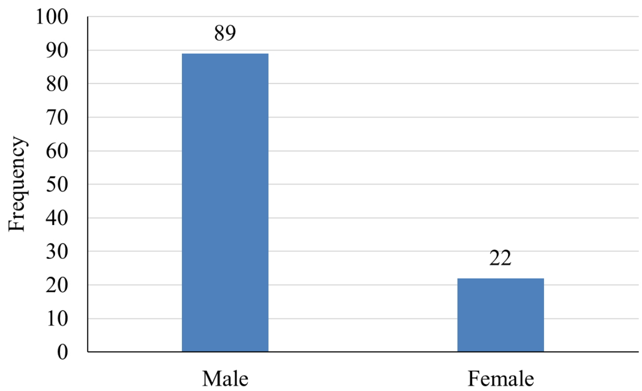

Figure 2. Demographic information of growers. Over 80% of the responders are male.

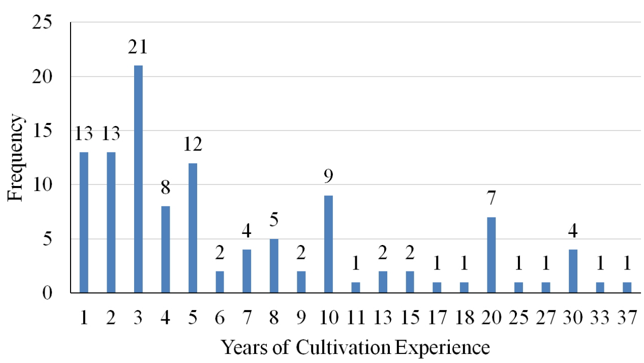

Figure 3. Demographic information of growers. The mode of years of experience as a grower is three years.

years of experience working as a grower (Figure 3). Almost 80% of the responders worked in orchards with only two workers, often a married couple, during the non-busy season (Figure 4). During the busy season, many of these growers hired additional help, reducing the 2-people orchards to 48% (Figure 5).

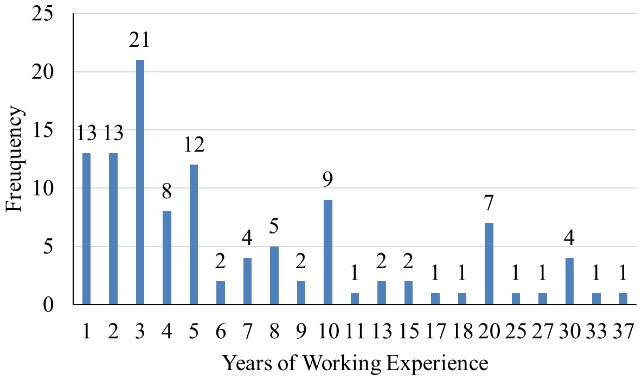

Figure 4. Demographic information of growers. Number of years worked in apple orchards.

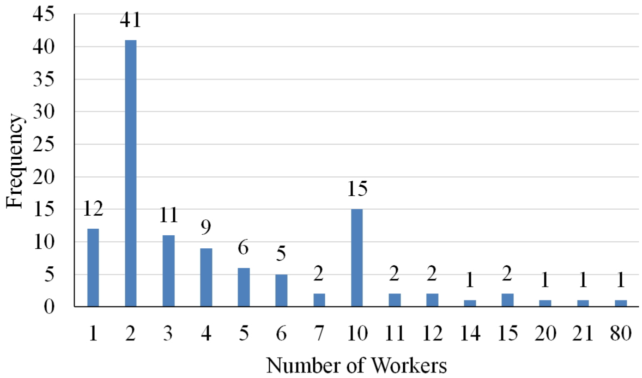

Figure 5. Demographic information of growers. Number of workers during the busy season.

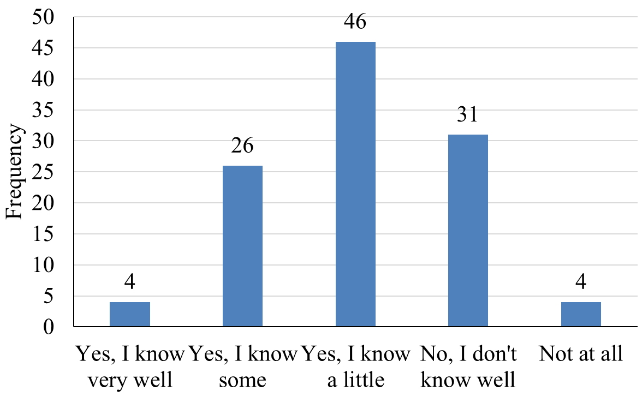

Figure 6. Results of the question “Do you know what AMB is?” Surprisingly almost half of growers were not familiar with the fungal disease.

Knowledge and impact of AMB

About 32% of responders did not know what AMB was with 41% of responders stating they only knew a little about AMB (Figure 6). A quarter of responders said they could not distinguish AMB from other symptoms at all with 38% of responders stating they were not confident in their ability to make these distinctions (Figure 7). Of those who did know what AMB is, the most popular source of information was print publications (Figure 8). For the growers who could detect AMB, the overwhelmingly frequent method of detection was a visual inspection every two weeks, eclipsing the other methods by 80%

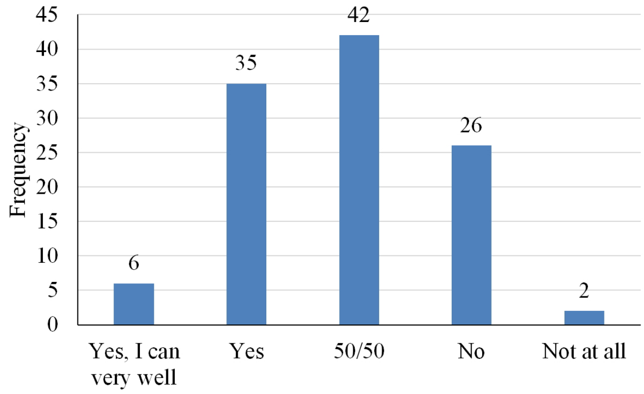

Figure 7. Results from the question “Can you distinguish AMB from another symptom?”.

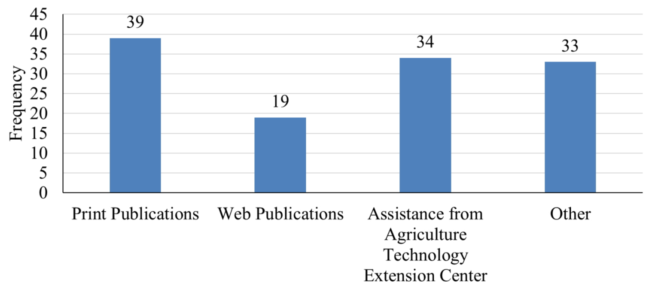

Figure 8. Results from the question “How do you learn about AMB?”.

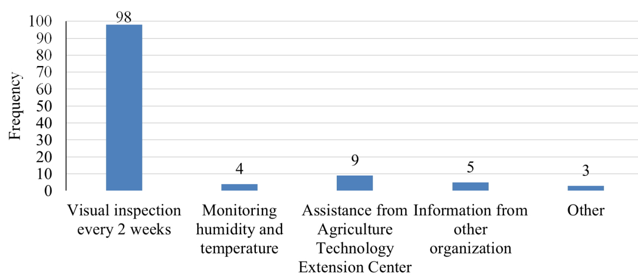

Figure 9. Results from the question “How do you detect AMB in your orchard?”.

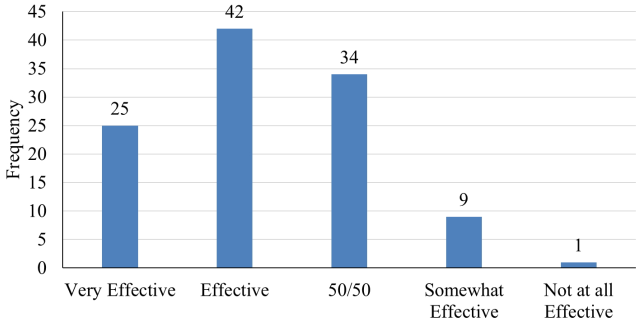

Figure 10. Evaluation of the effectiveness of visual inspection in detecting AMB.

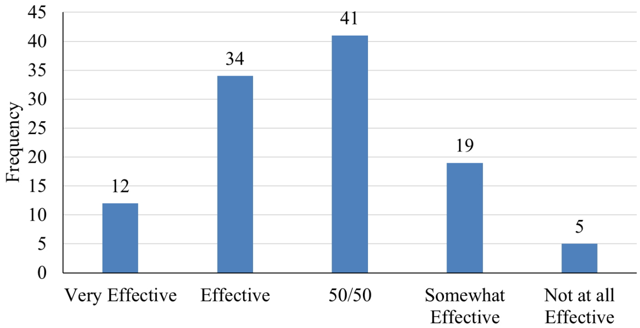

Figure 11. Evaluation of monitoring humidity and temperature in detecting AMB.

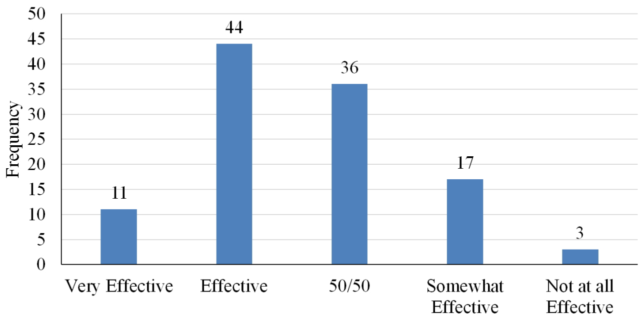

Figure 12. Evaluation of AMB forecast from the RDA in detecting AMB.

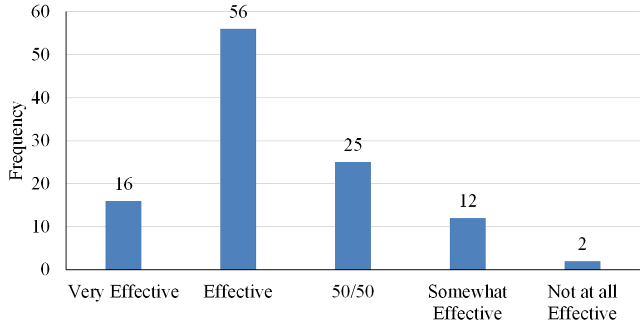

Figure 13. Evaluation of assistance from Agriculture Technology Extension Center in detecting AMB.

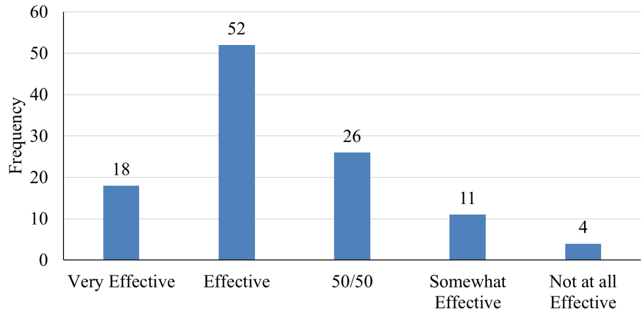

Figure 14. Evaluation of RDA agents conducting a visual inspection in detecting AMB.

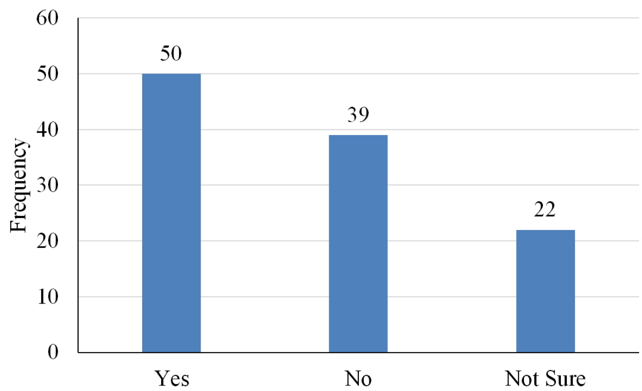

Figure 15. Results from the question, "Has your orchard been affected by AMB?".

(Figure 9).

In addition to asking farmers about how much they know about AMB, the survey listed several detection methods and asked the farmers to evaluate each method they used. These methods included visual inspection, monitoring humidity and temperature, the AMB forecast provided by the RDA, assistance from Agriculture Technology Extension Center, and visual inspection from the inspector. These results are in Figure 10-14. The least effective method was the humidity and temperature monitoring, with only 40% reporting it was effective while the most effective method being the assistance from Agriculture Technology Extension Center. Only 45% of responders reported having had AMB in their orchards, with 19% of responders not even sure if their orchards had been affected (Figure 15). Eight percent of responders agreed that a detection method was needed, with 36% believing that it was really necessary (Figure 16). These results strongly support the development of a prototype that would be readily tested in the field.

During the design of the survey, the hypothesis for this

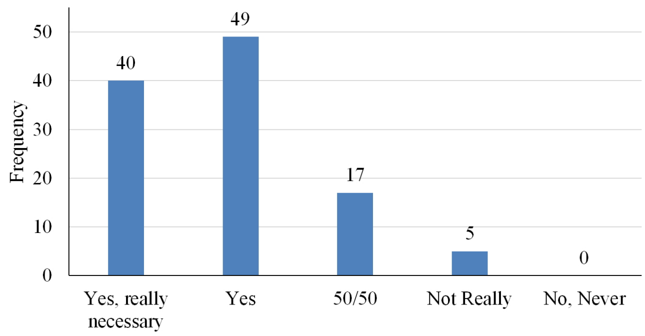

Figure 16. Results from the question, “Do you think that it is necessary to develop the early detection device for AMB?”.

question was that 90% of farmers would agree that they were familiar with AMB. These results disproved that idea and instead demonstrated that about 32% of the farmers responded that they didn’t know what AMB was. The majority of responses were from farmers who had heard of AMB but did not know much about it.

Important questions that had low response rates included how much a farmer was willing to invest (response rate 40%), what current method they were using to combat AMB (response rate 48%), what the yields were before and after AMB (response rate 32%), and in which year they experienced AMB (response rate 48%). Even with these low numbers, we could report the results, but among these responses were several “I don’t know” answers. Also, not every farmer experienced AMB, so of those that answered “yes”, 98% did give an answer for what year they were affected. Of the farmers who had been affected by AMB, most have seen the disease in their fields within the last five years.

Current practices for mitigating AMB

The following results were from questions that did not have many responses but can still give us some insight into how the apple farmers have been combating AMB.

Not many farmers told us the name of the fungicide they used; most left this question blank or just wrote “I don’t know”, which was a little surprising that they wouldn’t be familiar with what they spray in their fields. It might be because they didn’t remember the names of fungicides. In Table 2 is a summary of the few answers we did get. When this list is compared to the list the RDA provided of the fungicides they used, there were no matches. It is not clear if this is because the RDA used fungicides for other diseases, and those were included in the list, or if the farmers and the RDA followed different techniques for combating AMB. Even if the farmer did not tell the name of the fungicide, many responded to the question of how effective it was with about half saying it was effective and half not as confident, as seen in Figure 17.

As predicted, very few farmers answered questions regarding money. Only 11 farmers reported how much they spent on fungicide, with most farmers spending less than 1 million Won (842.72 USD) per season. Most of the

Table 2. Survey results of which fungicide is used in each orchard

Fungicide	Frequency
Iminoctadine triacetate	1
Apres	1
Ascorbic	4
BK - Limestone bordeaux mixture	2
Delan	4
Dithane	1
Flint	1
Fungicide from National Agricultural Cooperative Federation	1
Galvanic	1
Nativo	2
Peroxide	1
Preventative fungicide	1
Sallimggun (Metconazole)	1
Samjinwang (difenoconazole 3% & iminoctadine-triacetate 15%)	1
Strobe	1
Trifloxystrobin	1
Ved puran	4

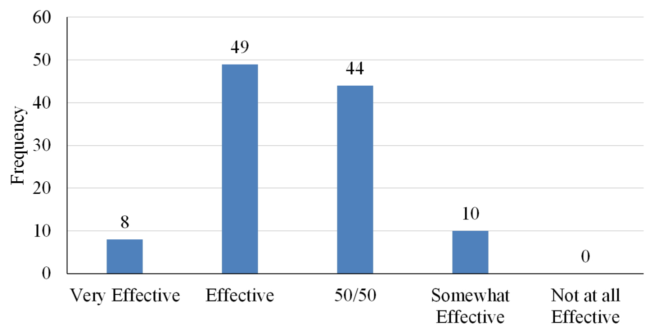

Figure 17. Results from the question, “How effective is this fungicide in preventing AMB?” Even though most growers did not report the name of the fungicide used in their orchards, most were able to indicate whether or not it was effective, with the utilized fungicide being effective about half the time.

farmers who answered this question applied fungicide less than 10 times in their fields during one season, with one outlier applying their fungicide over 20 times during a single season. This seemed aligned with the practices of the RDA.

Commitment to investing in AMB detection techniques

As with the previous section, not as many growers answered these questions about their current commitment to investment for a new AMB detection method. The chart in Figure 18 depicts the numerical responses to the "how much would you invest" question. A handful of farmers answered that they would be willing to spend as much as it costs to obtain this new effective method, and a handful also answered that they were not willing to invest at all. Of those that gave a numeric value, most of them were not willing to invest more than what they would spend on fungicide every year.

Perhaps this was a poorly written question, and the farmers were not clear if this was a yearly cost or a one-time investment for a new method. Maybe that is why the amount they want to invest was less than the yearly cost of the fungicide. This also may indicate that most of the farmers are satisfied with the current effectiveness of the fungicide and a new method would have to cost significantly less and be more effective to capture their attention.

From the demographic information obtained in this survey, the farmers in this region were newer to the profession, having less than five years experience. This may be why a higher percentage of them than predicted were not familiar with AMB or would be successful in identifying it in their fields. As far as they knew, their fields had mostly not been affected by AMB, and for the farms that have been affected, it was within the last few

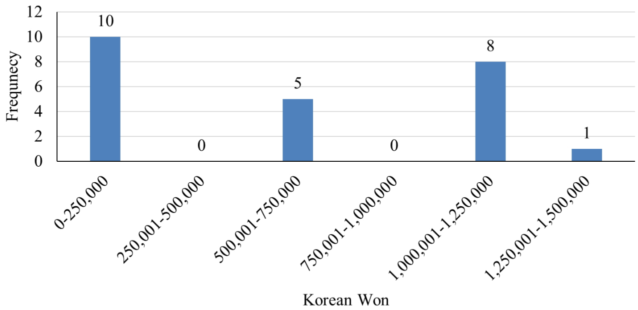

Figure 18. Results from "how much would you invest in a method that was significantly better than the fungicide at preventing AMB?".

years. Of the farmers who used a fungicide to protect their fields, many felt this was enough, and a new method did not need to be introduced. This summary does not depict a population of growers that were too concerned about the impact of AMB. From their own experiences, they have not been negatively impacted, and were mostly happy with the status quo. Considering the vast negative effects AMB can have, and how difficult it is to control once it has taken hold of an orchard, this lack of understanding is concerning and needs to be addressed by the RDA. The lack of knowledge about AMB can easily be addressed by the RDA's extension education services. The apple farmers of Gunwi need to be better educated in the different fungal disease that can impact apple orchards and how to identify them. The negative consequences of overusing fungicide to contain AMB also needs to be addressed. From this study, it appears fungicide application is the method of choice when protecting the apple orchards, but using too much can have long-term negative effects on the environment and future effectiveness of the fungicide.

Conclusions and future work

During the summer of 2015, the RDA collected survey responses from 111 farmers in the Gunwi area (confidence interval of +/- 8.59%, confidence level of 95%, p-value of 0.05) to determine the state of knowledge of AMB and evaluate current practices. It was found that 32% of growers were not educated about AMB and 45% of farmers had detected AMB in their orchards before. Several types of fungicides were used to mitigate AMB with a success rate of about 50%. It was unclear how much money farmers were willing to invest in a new method that could be more successful in mitigating AMB than current methods. However, 80% of farmers did agree that a new, effective early detection method for AMB was needed.

This section discusses suggested changes to the survey protocol if the experiment should be repeated in the near future. For survey redesign, the questions themselves need to state more clearly what type of answers are needed. For example, the question, "How much would you invest in a method that was significantly better than the fungicide at preventing AMB?" needs to be rewritten to indicate that 1) we are seeking a numerical response and 2) we are interested in what one-time investment they are willing to make, not a yearly or continuous investment. Controlling the type of answers that are given will also be easier if the survey platform is changed. Distributing the survey over the internet, where the software can indicate to the responder whether or not their answer is acceptable, or through interviews where the research can easily give feedback about the quality of the answer, can help mitigate ambiguous responses to survey questions. Also, in order to have a robust dataset where more rigorous analysis can be conducted, at least 200 complete cases must be obtained. To ensure there are enough cases for analysis, the RDA should aim to complete 250 surveys. These cases should be obtained as randomly as possible to better ensure the responders represent the target population; i.e., it is not advisable to distribute the surveys at the end of RDA lectures because the sample population is then restricted to people who attend RDA lectures, which may have characteristics different than the farmer population as a whole. If more than one researcher will be involved in distributing the surveys, a script must be written and given to each researcher, so there is consistency in how the survey was conducted; each researcher should read the same instructions to the responder, and give the responders the same amount of time and provide the same level of assistance to ensure the quality of the survey.

Conflict of Interest

The authors have no conflicting financial or other interests.

Acknowledgement

Survey collection was completed with the help of the researchers at the Apple Research Center in Gunwi, Korea under the supervision of Dr. Yun Soo Do. This study was supported by the Rural Development Administration (RDA, PJ102032) of Korea, the U. S. National Science Foundation (Award Number 1514823) and the National Research Foundation (NRF) of Korea.

References

European and Mediterranean Plant Protection Organization (EPPO). (n.d.). Retrieved May 2, 2016, from https://www.eppo.int/QUARANTINE/Alert_List/fungi/Diplocarpon_mali.htm

Harada, Y., K. Sawamura and K. Konno. 1974. Diplocarpon mali sp. nov., the perfect state of apple blotch fungus Marssonina coronaria. Annals of the Phytopathological Society of Japan, 40(5):412-418.

Israel, G. Phases of data analysis. 2015. Retrieved August 01, 2015, from https://edis.ifas.ufl.edu/pd001

Jacobi, W. 2013. Aspen and poplar leaf spots. Retrieved October 20, 2014, from http://www.ext.colostate.edu/pubs/garden/02920.html

Krissoff, B., L. Calvin and D. Gray. 1997. Barriers to trade in global apple markets. Fruit and Tree Nuts Situation and Outlook/FTS-280/August 1997, Economic Research Service, USDA, pp. 42-51.

Kumar, A. and J. Sharma. 2014. Monitored control of Marssonina blotch of apple caused by Marssonina coronaria. Indian Phytopathology 67(1):70-76.

Lee, D.-H., C.-G. Back, N. K. K. Win, K.-H. Choi, K.-M. Kim, I.-K. Kang and H.-Y. Jung. 2011. Biological characterization of *Marssonina coronaria* associated with apple blotch disease. Mycobiology 39(3):200-205.

Park, M., D. Sagong, H. Kweon, Y. Do, Y. Song and D. Lee. 2013. Influence of seasonal incidence and defoliation degree of Marssonina blotch on fruit quality and shoot growth of 'Fuji'/M.9 apple tree. Korean Journal of Horticultural Science and Technology 31(5):523-530.

SaGong, D. H., H. J. Kweon, Y. Y. Song, M. Y. Park, J. C. Nam, S. B. Kang and S. G. Lee. 2011. Influence of defoliation by Marssonina blotch on vegetative growth and fruit quality in ‘Fuji’/M.9 apple tree. Korean Journal of Horticultural Science and Technology 29(6):531-538.

Yin, L., M. Li, X. Ke, C. Li, Y. Zou, D. Liang and F. Ma. 2013. Evaluation of Malus germplasm resistance to marssonina apple blotch. European Journal of Plant Pathology 136(3):597-602.

Zhao, H., Q. Han, J. Wang, X. Gao, C. L. Xiao, J. Liu and L. Huang. 2013. Cytology of infection of apple leaves by Diplocarpon mali. European Journal of Plant Pathology 136(1):41-49.