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IN THIS ISSUE

ESTABLISHING A RELATIONSHIP BETWEEN SAN JOSE SCALE GROWTH STAGE AND SPUR INFESTATION IN ALMOND

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Introduction

San Jose scale (SJS), *Quadraspidiotus perniciosus* (Comstock), was first identified in San Jose, California in 1870 on deciduous fruit trees imported from China. Since then, it has spread throughout the United States and Canada where it infests a variety of trees and shrubs. It is considered a key pest of apple, pear, plum, peach, and nectarine, where fruit infestation may render the fruit unmarketable. San Jose scale also infests almond but does not damage the fruit. In almond, infestation of fruiting spurs and scaffolds can result in wood death, which impacts yield. Both fruit and nut farmers have relied on annual dormant insecticide treatments to reduce fruit infestation and wood death. More recently, many almond farmers, particularly in northern California, have gradually moved away from annual treatments of SJS and they have not developed economic infestations. These untreated orchards have been monitored for SJS using pheromone baited sticky traps (Trécé®) and by examining fruiting wood, with only minor levels of infestation being detected (Bentley et al., 2001). Currently, there are no sampling guidelines to help farmers and pest control advisers decide if insecticide application is necessary. This study presents information developed in 2001 to aid in establishing such guidelines.

Methods and Materials

Five infested almond orchards in Kern County were selected for monitoring in 2001. These orchards ranged in size from 37 to 66 acres. The cultivar "Nonpareil" was the predominant variety in four of the orchards (50% of the planting). Two orchards used "Price" and "Carmel" as pollenizers. One of the orchards used "Fritz" and "Sonora" as pollenizers, and one orchard used "Carmel" and "Sonora" as pollenizers. The fifth orchard was comprised of "Mission" (25%), "Butte" (50%) and "Ruby" (25%) varieties. The varieties in the fifth orchard are commonly termed "hard shell."

Male SJS were monitored in each orchard using standard pheromone caps and sticky traps manufactured by Trécé®. Traps were placed in orchards on 19 February 2001 and monitoring continued through November. Traps were changed weekly and pheromone caps were changed monthly. Three of the orchards were monitored with four SJS traps, evenly distributed throughout. These three orchards were all at least 50 acres in size. The remaining orchards were smaller, less than 40 acres. Only three SJS traps were placed in these orchards.

A single tree at each of the four compass points around the tree that held the pheromone trap was selected to monitor SJS crawlers. A single, double-sided sticky tape (Scotch® Brand) was placed around one of the scaffolds on each of the four trees. The scaffolds chosen ranged from 3 to 8 inches in circumference. Tapes were installed prior to crawler emergence in the spring (April 1) and were changed after each crawler generation (a total of five changes made at approximately 6-week intervals). San Jose scale crawlers captured on the tapes were counted and totaled for the season.

The tree with the pheromone trap and each of the four trees around it (used to monitor the crawlers) was considered as a trapping site. At each site, the number of crawlers was totaled and an average per tape calculated for the growing season. The number of male SJS collected in the pheromone traps at each site was also totaled for the season. This method gave an average number of male SJS per trap per season and an average number of crawlers per tape per season at each trapping site. In the five orchards there were a total of 18 trapping sites.

During December, 25 live fruiting spurs were collected from each of the trees where sticky tapes were placed, for a total of 100 spurs per trapping site. The basal 3 inches of each spur was examined for SJS and the number of infested spurs were counted. A simple regression analysis was performed (StatView 5.1, no intercept model) using the number of crawlers per tape per season as the independent variable and the number of infested spurs as the dependent variable. The number of male scale per trap was also used as the independent variable and regressed against the number of infested spurs collected at each trapping site. Simple regression analysis was done utilizing each trapping site as a point. A total of 18 trappings site were pooled across the five orchards. The regression line was forced through zero because there cannot be less than zero spurs infested with SJS. A second simple regression was performed utilizing the average male scale per trap per orchard and the number of crawlers per tape per orchard as independent variables, and the number of infested spurs per orchard as the dependent variable. This was done because we were unsure of the distribution of SJS within each orchard when the study was started. Pooling the trapping sites would provide a better estimate of the regression relationship if scale populations were not uniformly distributed within each orchard. If SJS populations were uniformly distributed, both the averaging of trapping information per orchard (giving 5 data points) and the pooling of trapping sites across orchards (18 data points) should give equally good measurements of the regression relationship.

Results

When the number of crawlers per tape per season was pooled and regressed with the number of infested spurs per 100, a highly significant relationship was found, $R^2=0.788$, ($P<0.0001$). The regression equation is $Y=0+0.029*X$ (Fig.1).

Similarly, the number of male scale per trap per season at each of the eighteen trapping sites was regressed against the number of infested spurs per 100 and found to be highly significant. The $R^2=0.719$, ($P<0.001$). The regression equation is $Y=0+0.01*X$ (Fig. 2).

When averaging the number of crawlers per tape per orchard for the season and regressing it to the total number of infested spurs collected from each orchard (resulting in only 5 points), a highly significant ($P<0.001$) regression also was found ($R^2=0.982$). The regression equation is $Y=3.317+0.131*X$ (Fig. 3). When the average number of male scale per trap per orchard was regressed against the number of infested spurs collected per orchard, there was a significant relationship ($P<0.02$), $R^2=0.772$. The regression equation is $Y=0=2.973*X$ (Fig. 4).

Discussion

The information presented here indicates a close relationship between the total SJS crawlers trapped per tape per season and the amount of fruiting wood infestation in almond. Also, the total male SJS per trap per season is associated with the amount of fruiting wood infestation, but less so than the abundance of crawlers. Trapping male SJS is less time consuming than using sticky tape to trap crawlers. In this study, presence of fewer than 500 males scale per trap per season was associated with less than 10% spur infestation. However, the amount of wood death must now be included in the analysis. If spur infestation, crawler abundance, or male scale abundance can be related to resultant fruiting wood death, a valid treatment threshold for SJS can be developed. Wood death is currently being determined in the orchards monitored in 2001.

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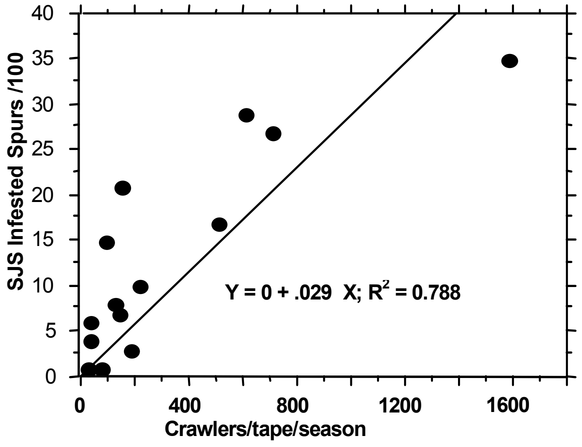

Figure 1. Relationship between San Jose Scale crawlers per tape per season and number of infested spurs per 100 sampled. Data pooled from 5 orchards.

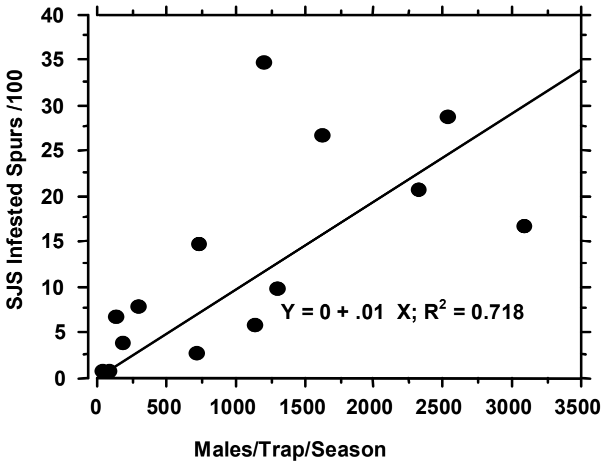

Figure 2. Relationship between total male San Jose scale per trap and number of infested spurs per 100 collected, data pooled from 5 orchards.

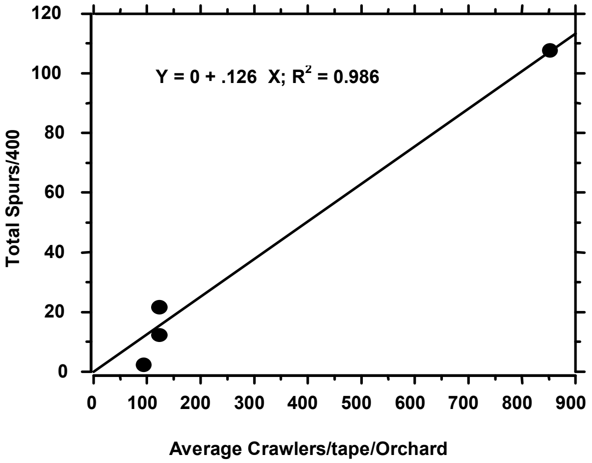

Figure 3. Relationship between total San Jose scale crawlers per tape per season and spur infestation per 400 collected, data averaged per orchard.

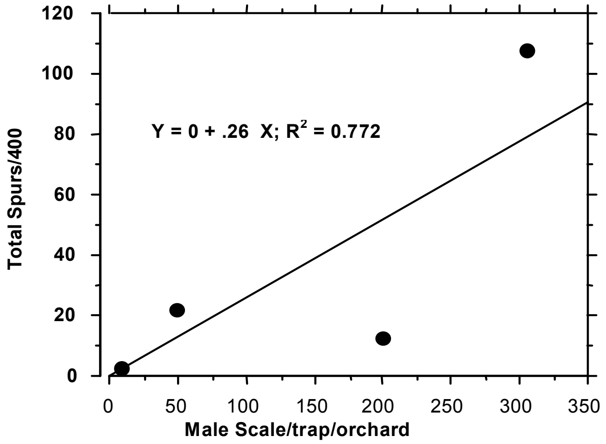

Figure 4. Relationship between total San Jose scale males per trap season and spur infestation per 400 spurs collected, data averaged per orchard.

BRINGING BIOLOGY AND ECOLOGY BACK TO WEED MANAGEMENT, *Anil Shrestha, IPM Weed Ecologist, UC Kearney Agricultural Center*

I am the new IPM Weed Ecologist at the Kearney Agricultural Center. I recently took over the vegetation management extension and research position vacated by Dr. Tim Prather.

I started working in agriculture after my B.Sc. (Ag.) degree in 1983. I served as an extension agronomist in the Department of Agriculture, Nepal, and as a Regional Supervisor for the FAO Fertilizer and Related Inputs Program. A quest for higher knowledge brought me to the United States in 1991 and I obtained a Masters degree in Crop and Soil Sciences from Cornell University, Ithaca, New York in 1993. My thesis work was on exploring alternative (herbicide-free) methods of alfalfa establishment, for which I studied the use of triticale and pea mixtures as companion crops. An enthusiasm to design resource-efficient cropping systems led me to Michigan State University where I completed a doctoral degree in Crop and Soil Sciences as a C. S. Mott Fellow of Sustainable Agriculture. My dissertation research involved the use of annual medics and berseem clover as emergency forages and green manures in winter canola rotations. I was a member of a collaborative project on exploring the potential of annual medics in North Central United States cropping systems.

The desire by producers to farm in an environmentally sound, ethical, economically viable and socially acceptable manner has driven cropping systems research beyond basic production agronomy. In this context, pesticide reduction in cropping systems is being mandated in several countries. The major pesticide use in agriculture today involves herbicides, because if there is anything more certain than death and taxes guaranteed in life to growers, it is weeds in their fields. What are weeds? Why are they weeds? Are herbicides the only option available to control them? Are there ways to 'manage' them rather than 'control' them? These thoughts led me to dedicate myself to studying weed management in agricultural cropping systems. After my doctoral degree, I spent five years training myself in weed science at the University of Guelph, Canada under Dr. Clarence Swanton. In this introductory article, I would like to share my philosophy on 'weed management' and why I think biology and ecology are important in this context.

With the advent of herbicides in the mid-20th century, more of the focus has been on 'weed control' than 'weed management'. The basic biology and ecology of weeds was greatly ignored as we started looking for the most effective herbicide 'management' strategy to 'control' weeds. Studies focused on new herbicide chemistry, most effective doses of herbicides, most effective time of application etc. These studies drifted many of us away from 'understanding weeds' to 'understanding herbicides'. However, successful IPM programs on insect and disease management have shown and proved the importance of understanding pest biology and ecology. Perhaps it is time to revisit the biology and ecology of weeds and learn to 'manage' them instead of controlling them.

My training at Guelph was on integrated weed management (IWM). IWM is a systems approach to weed management that advocates the use of several tactics to manage weeds. There are several components of IWM such as: tillage, critical period for weed control, alternative methods of weed control, enhancement of crop competitiveness, weed thresholds, crop rotation, seedbank dynamics, modeling crop-weed interference and herbicides. In the following sections, I will provide examples of my experience with these components.

Tillage: Tillage is an important component of IWM and it has an influence on weed population dynamics. At Guelph, we studied the influence of tillage systems and nitrogen on the composition of weed flora and found that the composition of weed flora in corn was influenced more by disturbance caused by tillage than by nitrogen rate (Swanton et al. 1999). We also found that the type of tillage had an effect on weed densities and there were associations of weed species with tillage type (Shrestha et al. 2002). Conventional tillage (moldboard plow) had a higher density of weeds than no-till and vice versa, depending on the crop type.

Critical period for weed control: Studies in several crops have shown that fields do not need to be kept weed-free throughout the entire growing-season in order to prevent yield losses. There is a certain 'window' during the growing season when it is necessary to keep the crop weed-free. This 'window' is the 'critical weed-free period' and a weed management program based on this principle can eliminate or reduce unnecessary applications of herbicides or long-term residual herbicides.

Alternative methods of weed control: Alternative methods (other than herbicides) for weed control are available. For example, cover crops have suppressed weeds in various cropping systems. In a study in Michigan, we found that annual medic species reduced the density of summer annuals in corn by as much as

80% (Fisk et al. 2001). However, the effect of cover crops on weed densities have not always been consistent. They are influenced by environmental and soil factors and interact with tillage systems (Swanton et al. 1999; Fisk et al. 2001; Shrestha et al. 2002). Further research is needed on the design of cover crop systems for weed management, especially in Mediterranean climates.

Enhancement of crop competitiveness: Manipulations in the cropping system can be made to enhance a crop's competitive ability with weeds. For example, in row crops, plant spacing can be altered to shade and suppress weeds. We found that planting corn in narrow rows (38 cm) helped in controlling later-emerging weed species compared to 76-cm rows (Shrestha et al. 2001). Corn yield was up to 8% greater in the narrow-rows than in the wide-rows in three out of the four years of the study. In the case of soybean, a combination of narrow (19 cm) row spacing and pre-plant herbicides provided better weed control than wide (76 cm) row spacing or pre-plant herbicides alone (Swanton et al. 1998).

Weed thresholds: Weed thresholds are an integral component of IWM but they should not be considered in isolation. For example, fields with high weed pressure may require some sort of weed control prior to crop emergence. Thresholds may be useful for 'weed escapes' after this initial control (Swanton et al. 1999). The concept of thresholds may be more difficult to develop and implement in weed management than for other pests because with weeds we may be dealing, in certain settings, with a multitude of species with different biology and management response as opposed to certain insects or pathogens.

Crop rotation: Crop rotation has been recognized as an important tool for weed management because some crops in the rotation suppress weeds by competing for resources and causing allelopathic effects. However, explaining the effect of crop rotation on weed communities may be a gross generalization because of interactions between crop rotation and management factors (Shrestha et al. 2002). The biology and ecology of the weed and crop-weed ecophysiology must be understood to interpret these complex dynamics.

Seedbank: A major goal of an effective weed management program is to deplete the soil weed seedbank. Although achievable, it may be difficult to completely eliminate the weed seedbank. Therefore, the objective may be to keep the seedbank below threshold levels. Seedbank dynamics are affected by several factors, which may interact. For example, we found that the vertical distribution of the weed seedbank was influenced by tillage type, depth of tillage and soil type (Swanton et al. 2000a). A knowledge of the seedbank can also help us predict weed populations and develop a management scheme.

Modeling crop-weed interference: Simulation models may help us develop an understanding of crop-weed interference and predict weed growth. However, biological parameters are required to develop useful models. Therefore, it is essential to understand the seed germination and emergence patterns and the phenological development of weed species. The temperature and moisture requirements for seed germination and seedling emergence have to be determined. Similarly, the effect of environmental factors on the development of weed growth also have to be determined to build these models. We have determined these parameters for several weed species and have defined their life cycle in accumulated thermal time (degree-days) (Shrestha et al. 1999; Huang et al. 2001).

Herbicides: In non-organic systems, herbicides are often an important component of IWM. However, IWM advocates the judicious use of herbicides. Unnecessary application of herbicides should be avoided and they should be used as a supplemental tool along with the other tools of IWM. The use of herbicides should be environmentally safe, socially acceptable and economically justifiable. In a study on Roundup Ready soybean, we found that timing of glyphosate application relative to weed emergence was critical for economic justification of the technology (Swanton et al. 2000b). Similarly, we found that crop rotations could help in reducing herbicide levels while maintaining economic returns (Swanton et al. 2002).

All of the above examples lead us to some important questions: how do weed species adapt to their environment? What makes them serious competitors to crops? Can we manipulate our cropping systems to manage these weeds? Is IWM merely a pipedream? The answers to these questions may be provided by a good knowledge of weed biology and ecology, because weed population and composition dynamics are driven by an interaction of several factors such as tillage, environment, soil type, crop rotation, crop type and timing and type of weed management practices. These are all components of cropping systems, and I believe that we may be able to design cropping systems for effective weed management if we bring biology and ecology back to weed science and think of 'managing' weeds rather than 'controlling' them.

I intend to continue extension and research in the several components of IWM discussed above. As the Regional IPM Advisor-Weed Ecologist at KAC, my primary responsibility is to develop and deliver information on vegetation management. My research will focus on IWM in forages, vegetables, row crops, and fruit and nut crops in California. I am particularly interested in aspects of weed biology, ecology and eco-physiology; crop-weed competition; cropping systems; agroecology; environmental aspects of vegetation management; and site-specific technology. I look forward to sharing my experience and to working together with people interested in issues related to vegetation management.

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NEW FACULTY FOCUSES ON ARTHROPOD IPM IN GRAPES, STONE FRUIT & NUT CROPS

Marshall W. Johnson, Assoc. Specialist & Assoc. Entomologist, Dept. of Entomology, UC Riverside / UC Kearney Agricultural Center

I am excited to join the distinguished group of scientists working at the Kearney Agricultural Center. My work will involve extension and research activities related to insect and mite problems on grapes, stone fruit, almonds and walnuts. I hold a faculty position at the Department of Entomology, University of California, Riverside, with the Kearney Agricultural Center being my home base.

I have been interested in insects since I was about 12 years old. I have B.S. and M.S. degrees in entomology from North Carolina State University, Raleigh, North Carolina. My master's thesis research examined the role of host plant phenology in attracting and stimulating adult corn earworms (*Helicoverpa zea*) to lay their eggs on plants. In short, corn earworm female moths become increasingly attracted to their host plants (e.g., field corn, soybeans, tobacco, cotton) as the plants begin flowering and this attraction decreases as the flowers wither and die (Johnson *et al.* 1975). In the eastern half of North Carolina, spring-planted corn serves as the initial plant host for the corn earworm. The first two generations build up on field corn. Later generations disperse to cotton, soybeans and tobacco because old corn plantings are no longer attractive. The corn acts as a "spring board" to increase the corn earworm numbers before they invade surrounding crops. Management of corn earworm populations in field corn can dramatically reduce corn earworm numbers in neighboring crop systems.

I received my Ph.D. in entomology in 1979 from the University of California, Riverside. My dissertation work examined the destructive role of broad-spectrum insecticides in decimating the natural enemies that suppress *Liriomyza* leafminers (e.g., vegetable leafminer). I identified the parasitic wasps responsible for controlling the leafminers (Johnson *et al.* 1980a) and demonstrated their impact on the leafminers in the absence of pesticides (Johnson *et al.* 1980b). Reduction of the leafminer's natural enemies led to economically significant populations of this normally benign insect. I also developed simple sampling techniques for estimating leafminer numbers in tomato plantings, enabling growers and pest control advisors to more efficiently make control decisions (Johnson *et al.* 1980c). Under low to moderate leafminer densities, sample processing times were reduced from 30 minutes to less than 5 minutes.

Following graduation from UC Riverside, I joined the Department of Entomology, Kansas State University at Manhattan, but was stationed at the Garden City Experiment Station in western Kansas. I worked on management of spider mites on field corn from 1979 to 1980. In 1981, I returned to the University of California, Riverside, working as a post-doctoral researcher on various projects involving spider mites and other pests of fruit and vegetable crops. Some of the research examined the negative impacts of spider mite feeding on plant photosynthesis rates and how this, in turn, impacts crop yields (Sances *et al*. 1982). Additionally, I examined the direct effects of certain insecticides on plant photosynthesis and found that some pesticides, not labeled as herbicides, may impact plant photosynthesis and even crop yields when used in a preventative manner (Johnson *et al.* 1983a; Jones *et al.* 1986).

I joined the faculty of the University of Hawaii at Manoa (in Honolulu) in 1983, where I established instructional and research programs on biological control and IPM of insects and mites on numerous crop systems. During the period from 1983 to 1996, I focused mainly on control of insect pests in vegetable crops. Since 1997, I expanded my work to include pest problems in pineapple, papaya and coffee. I remained at the University of Hawaii until March 2002.

My research experiences include over 30 years of work on various crop systems, including field crops, vegetables, and tropical crops and on many important pest species (*Liriomyza* leafminers, Mediterranean fruit fly, diamondback moth, corn earworm, *Dysmicoccus* mealybugs, greenhouse and silverleaf whiteflies, etc.) and their natural enemies. During the last few years, I have worked on pineapple pest problems where the interaction between feeding of pineapple mealybugs (*Dysmicoccus* spp.) and closteroviruses in pineapple plants produce the disease known as 'pineapple mealybug wilt.' Ants aggravate this situation because they protect the mealybugs from their introduced natural enemies (Gonzalez-Hernandez *et al*. 1999). Several factors (e.g., Food Quality Protection Act) threaten to reduce the chemical arsenal that farmers use to control the ants and mealybugs. My work in pineapple focused on three areas: development of natural enemy augmentation methods; understanding the role that weeds in the pineapple agroecosystem play as a source of mealybug infestation; and the development of simple, grower-usable sampling techniques for mealybugs. My efforts in Hawaii resulted in the development of techniques to mass-rear thousands of individuals of *Dysmicoccus brevipes* and its parasitoid *Anagyrus ananatis* from individual squash fruit; the discovery that *Dysmicoccus* mealybugs are only found on a few grassy species commonly found adjacent to pineapple plantings, thereby opening the door to disrupting mealybug population dynamics via weed management; and the development of a double-sticky tape sampling method for monitoring mealybug crawlers that can provide information useful for estimating the numbers of mealybugs per pineapple plant.

My research interests are primarily in developing alternative arthropod pest management strategies that minimize pesticide use, but provide growers with practical and feasible controls. My work spans the continuum from basic to applied research. Much of my prior work focused on the development of IPM programs in vegetable crops, using biological control as the core management tool. As part of this effort to conserve natural enemies, I have conducted studies in the areas of natural enemy biology and ecology (e.g., Johnson & Hara 1987; Johnson & Tabashnik 1999), sampling methodologies (e.g., Lynch & Johnson 1987; Johnson *et al.* 1991), arthropod impact on plant physiology (Sances *et al*. 1982; Johnson et al. 1983b) and yield (e.g., Welter *et al.* 1990; Johnson *et al.* 1992), and understanding pesticide resistance in conventional pesticides (e.g., Mason et al. 1987; Omer et al. 1993) as well as microbial-based biotic pesticides (e.g., Tabashnik *et al.* 1990, 1993). My fundamental research interests are in the ecology and behavior of parasitoids, especially mechanisms that they use to locate and parasitize their hosts over a wide array of host plant species, and the competitive interactions of parasitoid species within natural enemy guilds. Although my experience in vineyard, stone fruit and nut crops is limited, I bring knowledge and experiences to my new position that may provide management insights not apparent to individuals specifically trained in these crop systems.

I am also interested in why human efforts to manage pests occasionally fail although the necessary science and technology for success exist. This interest evolved from my experiences working with growers in crop systems where pesticides were no longer effective, but alternative controls were available but unused for some reason. I have proposed that human failures to 'learn, anticipate, and adapt' often contribute to pest management debacles (Johnson 2002). Additionally, these failures are not always the fault of growers, but may have their roots at the research or extension outreach levels. I intend to keep working on this topic because it could potentially provide insights to enhancing grower education on pest management and strengthening our research and extension programs.

Currently, I am developing my extension and research goals for the coming decade. Glassy-winged sharpshooter will most likely receive a significant amount of attention over the next few years, but I will not limit my focus to that insect. I look forward to meeting growers and pest control advisers throughout California and interacting with them to solve the numerous pest challenges continually faced in the state.

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