Experiential Nursery Integrated Pest Management Workshop Series to Enhance Grower Practice Adoption

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SUMMARY. Three, 2-day hands-on experiential learning workshops were presented in three southeastern United States cities in June 2014, by the Southern Nursery Integrated Pest Management (SNIPM) working group. Attendees were provided 4 hours of instruction including hands-on demonstrations in horticultural management, arthropods, plant diseases, and weeds. Participants completed initial surveys for gains in knowledge, skills, and abilities as well as their intentions to adopt various integrated pest management (IPM) practices after the workshop. After 3 years, participants were again surveyed to determine practice adoption. Respondents changed their IPM practice behavior because of attending the workshops. Those returning the survey set aside more time to scout deliberately for pests, plant diseases, and weeds; used a standardized sampling plan when scouting; and adopted more sanitation practices to prevent plant disease. Fewer horticultural management practices were adopted than respondents originally intended. Future emphasis should be placed on using monitoring techniques to estimate pest emergence, for example, traps and pheromone lures, as well as plant phenology and record keeping. However, more work is needed to highlight both the immediate and long-term economic benefits of IPM practice adoption in southeastern U.S. nursery production.

The SNIPM working group was formed in 2009 to stimulate regional progress in improving IPM in nursery crop production. To gain a better understanding of how owners and supervisors working in southeastern U.S. production nurseries practice IPM, SNIPM developed and distributed a survey in 2009 to commercial growers of woody ornamental plants in Georgia, Kentucky, North Carolina, South Carolina, and Tennessee (LeBude et al., 2012). The goals of that survey were to assess the pest management practices currently used by ornamental nursery growers and identify critical instructional and outreach needs for education and research related to ornamental nursery IPM.

LeBude et al. (2012) divided IPM users into three practitioner groups, labeled G1, G2, and G3, based on a similar cluster analysis from Sellmer et al. (2004). Respondents in G1 used IPM practices more frequently than other groups at various levels of the IPM continuum.

Unfortunately, G1 respondents represented just 8% of all participants, and most growers surveyed in LeBude et al. (2012) fell into G2 (32%) or G3 (60%). Respondents in G2 used important components of IPM, for example, phenology of host plants, growing degree days, and keeping records of monitoring, but did so less consistently than G1. In addition, G2 was most receptive to extension training, which, combined with their relatively high appreciation for IPM, made them a group for which extension agents could affect the most change in behavior. Respondents in G3 generally used IPM tactics much less often and had a worse impression about the anticipated benefits from adopting IPM. Respondents in G3 used the services of extension more often than those in G1, which makes accessing G3 with educational opportunities easier.

Overall, groups G1, G2, and G3 were less likely to use traps or lures, sticky cards, double-sided tape, or plant phenology or any other proactive

approaches to determine when pests emerged (LeBude et al., 2012). Use of these methods helps to monitor the emergence of complex pests. As a result, SNIPM has been trying to improve grower resources for scouting, monitoring, and decision making concerning IPM by conducting research (Frank et al., 2013; LeBude and Adkins, 2014; Yeary et al., 2015), or publishing pest management strategic plans and crop profiles (Adkins, et al., 2010; Braman et al., 2015), books about IPM in major trees (Adkins et al., 2012) or shrubs (Braman et al., 2014), extension manuals (Cochran et al., 2014), popular press articles (Fulcher et al., 2013b), and developing mobile applications to aid growers (Fulcher et al., 2013a). With these abundant resources, SNIPM wanted to model these practices responsibly for a select group of growers and then evaluate change. Therefore, our objectives were to increase the knowledge, skills, and abilities of growers using IPM in the southeastern United States and track adoption of specific practices by growers after 3 years.

Materials and methods

Three, 2-d hands-on experiential workshops were presented in Quincy, FL [10–11 June 2014 ($n = 15$)], Decherd, TN [17–18 June 2014 ($n = 14$)], and Raleigh, NC [25–26 June 2014 ($n = 15$)], to 44 total growers or producers of woody ornamental crops. Space was limited at each workshop because of the hands-on nature of teaching. Four disciplines; entomology, plant pathology, weed science, and horticulture/technology, each had 4-h (1/2 d) blocks to present and train attendees, which consisted of illustrated lectures and plant and pest samples used for identification, calculation of soil physical properties, irrigation assessments, and scouting walks through both nurseries and landscapes. Every effort was made to make the content similar for each discipline at each venue; however, various faculty members within SNIPM near the venues were used to reduce travel costs. Therefore, teaching preferences and styles were different among venues, yet each discipline collaborated within themselves to provide uniform examples of concepts for the survey content to remain consistent.

Attendees at each workshop were given a demographics survey

on day 1 ($n = 44$); however, not everyone completed a survey nor did everyone attend both days. All surveys were coded for each person to provide the ability to match their answers on all surveys with the subsequent 3-year follow-up survey. Directly after completing each discipline's 4-h training, attendees were surveyed about their level of knowledge about the disciplines of entomology, plant pathology, weed science, and horticulture. Because the survey was completed after each training, respondents estimated their level of knowledge before actually attending the workshop. They could indicate "very low," "low," "moderate," "high," or "very high" (Figs. 1 and 2). In addition, respondents participated in various hands-on, discipline-specific tasks, for example, "using sampling tools and tactics" for arthropods (e.g., using sticky cards, pheromone lures, and ethanol traps), and then were asked about their ability to conduct

these skill tasks on their own using the same Likert-type scale mentioned previously.

After each discipline's 4-h workshop was complete, attendees were surveyed also to determine if they intended to adopt specific practices at their place of business. These practices were covered in either illustrated lectures or modeled by the workshop lecturers, or both, and attendees had an opportunity to participate in the activity or ask questions about its methods. Attendees could respond "yes," "maybe," "no," or "already doing this" for each of the practices. In Figs. 3 and 4, the percentage is shown of all attendees who responded "yes" that they intended to adopt the practices. Those that responded otherwise were not shown because they indicated that their behavior might not be changed ("no" or "maybe"), but were still included to determine the percentage of respondents indicating "yes." Those indicating they were "already doing it" were excluded completely because they had already adopted the practice. The number of respondents completing a survey differed for each discipline

but ranged from 39 (horticulture) to 43 (arthropods), and those included in the percentages are included within parenthesis for each practice.

Twenty-four respondents [55% return rate ($n = 44$)] completed the follow-up survey sent 3 years (Dec. 2016) after the June 2014 workshops. Unfortunately, not every individual who completed the 3-year follow-up survey also completed the postworkshop surveys in 2014 for each discipline. Because the workshops were over 2 d and contained four different disciplines, some attendees arrived late or left early. In addition, some of the respondents on the follow-up survey were "already doing" some of the management practices. Fortunately, we kept track of individual responses for all surveys and were able to present the percent of individuals who intended to adopt each practice after the workshops, and, if they, in fact, adopted the practice during the subsequent 3 years. Where available, data in figures for intent to adopt are unfilled circles, whereas actual adoption after 3 years are filled circles (Figs. 5 and 6). Some questions from each of the

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Fig. 1. Attendees knowledge and building skills before (unfilled circles) and after (filled circles) they received instruction while in attendance at a workshop on arthropods. Attendees completed the survey after attending the arthropod portion of the workshop ($n = 43$).

Fig. 2. Attendee's knowledge and building skills before (unfilled circles) and after (filled circles) they received instruction while in attendance at a workshop on horticultural management. Attendees completed the survey after attending the horticulture portion of the workshop ($n = 41$). IPM = integrated pest management; EC = electrical conductivity.

Fig. 3. Percent of attendees who completed a 2-d workshop in June 2014, and marked "yes" that they intended to adopt an arthropod management practice in the coming 6 months (n specified for each practice). The remaining attendees chose either "no," "maybe," or "already doing this." Attendees that indicated they were "already doing this" practice were excluded from the n used to calculate percent intending to adopt a practice. Forty-three attendees completed the arthropod practice survey.

disciplines were removed from the follow-up survey to decrease the time to complete it and improve response rate. Additional questions were added that were included on the demographics survey and taken from LeBude et al. (2012). These questions did not have an original intent to adopt associated with them, so we used the demographics data and that from LeBude et al. (2012) as a proxy for

the baseline practice level before attending the workshops. These data are shown in Fig. 5 as either unfilled squares (G2 from LeBude et al., 2012) or filled squares (demographics survey data from current group of respondents only). The group labeled G2 is similar in their use of IPM as those who attended the June 2014 workshops. The percentages presented from LeBude et al. (2012)

can be used to place the workshop participants into a larger context of practitioners in the southeastern United States to gauge practice adoption.

Results and discussion

INFORMATION RESOURCES AND LEARNING OPPORTUNITY PREFERENCE. More than 75% of the attendants had experienced a live, illustrated lecture and preferred it over recorded presentations without live interaction. Close to 50% had previously attended a hands-on workshop (data not shown) and slightly more had met with extension agents or talked with a faculty member [Table 1 (column 2)] but underused those resources. In 2014, growers used the Worldwide Web weekly, Cooperative Extension documents, reference books in their office, and other growers seasonally for problem solving (Table 1). The advent of digital publications and informative, easy to navigate mobile websites, combined with ever increasing internet access through faster connections and smart phones allows growers to use the internet as an office or field reference tool. Nevertheless, after 3 years, growers increased their use of more interactive choices to gain information, for example, other growers nearby and in other states, and had more contact with extension agents and faculty [Table 1 (columns 2 and 3)]. They also used SNIPM publications more.

PEST PREVENTION AND MONITORING. Information within the demographics survey was used to try and place respondents within the three practitioner groups defined by LeBude et al. (2012) (Table 2). Based on these data, the attendees at the workshops might be placed within either G2 or G3, but most likely align with those in G2. There are two notable exceptions where this group uses more sticky cards than G2 (44.4% vs. 25%, respectively), and G2 uses more plant phenology than this group (65% vs. 24.4%, respectively) (Table 2). Attendees indicated that they submitted about five insect samples or 1.6 plant disease samples to a plant disease and insect clinic for diagnosis. In LeBude et al. (2012), G1, G2, and G3 submitted 19, 4, and 1 sample, respectively, to a plant disease clinic and 10, 3, and 0.6 samples, respectively to an insect clinic. About 82% of workshop attendees said that

Fig. 4. Percent of attendees who completed a 2-d workshop in June 2014, and marked “yes” that they intended to adopt a cultural management practice in the coming 6 months (*n* specified for each practice). The remaining attendees chose either “no,” “maybe,” or “already doing this.” Attendees that indicated they were “already doing this” practice were excluded from the *n* used to calculate percent intending to adopt a practice. Forty-one attendees completed the cultural practice survey. SNIPM = Southern Nursery Integrated Pest Management; EC = electrical conductivity.

IPM would save their nursery money and allow labor to be used more efficiently. This is further support for attendees being placed within G2 (data not shown).

Sixty percent of growers who attended the workshops in 2014 indicated they had changed their nursery production practices previously as a result of attending a workshop or lecture. SNIPM is confident that the growers attending the workshops were those who communicated regularly with Cooperative Extension and had a capacity to both learn and adopt strategies into nursery production practice. These workshops were designed to accommodate this group, their learning styles, and preference for educational opportunity.

INCREASE IN SPECIFIC DISCIPLINE KNOWLEDGE AND ABILITY TO CONDUCT TASKS WITHIN THOSE DISCIPLINES AFTER ATTENDING A 2-D WORKSHOP. Across all disciplines, both knowledge and building skills improved for the attendees (Figs. 1 and 2). The level of basic starting knowledge differed among disciplines (data not shown for weeds or plant pathology). For example, attendees appeared to know less about arthropods compared with plant diseases or weeds before attending the workshops. Despite this

difference, attendees of all disciplines moved about one category higher in knowledge. Because of the ordinal nature of the data, we do not truly know the amount of knowledge gained; only that the attendees were more knowledgeable about the subject matter after experiencing the workshops. Attendees in the horticulture discipline had more variability within their beginning knowledge about some items (Fig. 2), but this may be due to the first introduction for participants to outputs created by the SNIPM group, for example, electronic books about IPM for trees and shrubs. Moreover, knowledge and ability to measure substrate physical properties was “low” on arrival, then changed to “high” after a hands-on demonstration (Fig. 2).

INTENT TO ADOPT MANAGEMENT PRACTICES FOR EACH DISCIPLINE AFTER THE WORKSHOPS WERE COMPLETED. Eighty percent or more attendees at the arthropod workshop intended to rotate modes of action (MOAs) for pesticides to optimize control and decrease resistance, revise their current arthropod management plan to improve control of problematic pests, set aside a deliberate time to scout for pests, and train other employees about some of the concepts learned

at the workshop (Fig. 3). Fewer pledged to use traps and lures or send more samples to a pest diagnostic clinic. These attendees were not already practicing these tasks before attending the workshop, which indicates great intent in the population to address arthropod management from an IPM perspective. For those attending the weed management section, about 75% or more intended to either scout deliberately or while doing other tasks and rotate herbicide MOAs to optimize control and manage resistance (data not shown). Seventy percent or more of the growers in the plant disease portion of the workshop intended to adopt all of the practices presented (data not shown). This high level of intended adoption might indicate that plant disease management might be the most difficult aspect of horticulture production. With the exception of rotating fungicide modes of action, which had 100% of 24 possible people intending to adopt, there were many attendees who were not “already doing” the other practices (*n* ranged from 27 to 44 out of a possible 44). High intent to adopt fungicide rotation is encouraging considering fungicide resistance is an important challenge in preventing or curing infestations in nursery production.

The cultural (horticulture) practices section was presented to show attendees how other factors within the nursery production system can lead to pest and plant disease problems if not managed correctly. Measuring air-filled porosity (AFP) in substrates was a model hands-on practice. Virtually no one was doing this practice before the workshop, not to mention knowing much about it (Fig. 2), but almost everyone involved intended to do that practice afterward [90% (Fig. 4)]. Most growers in the southeastern United States use soilless substrates to pot plants into containers (personal observation), but the proper physical properties for best growth can vary annually and sometimes seasonally from the same substrate supplier (Kaderabek et al., 2017). It is important to measure these properties occasionally using a laboratory; however, measuring AFP is an easy onsite method to measure the percent of air contained in substrate pore spaces after the substrate is watered to container capacity

Fig. 5. Intention to adopt arthropod management practices and actual adoption of them by nursery crop growers 3 years after attending a 2-d workshop in June 2014. Symbols represent the percent of attendees that completed both a post-workshop survey about their intention to adopt specific management practices and a post-season survey 3 years later indicating which management practices they actually adopted. Unfilled circles are the percent of eligible attendees who indicated that “yes” they intended to adopt the practice directly after the workshop. Eligible attendees were those that answered “yes,” “no,” or “maybe.” Attendees that answered “already doing this” were excluded since they had already adopted the practice. Filled circles are the percent of attendees who indicated they adopted the practice on the post-season survey at the end of the 3 years. The *n* is noted for each specific practice and it pertains to both prior intent (unfilled circles) and post-season adoption (filled circles). For some practices, there is no post-workshop data (unfilled circle) (we did not ask them specifically to adopt this practice), only 3-year adoption data (filled circle). For reference, we added filled squares to represent the percent of these respondents already conducting this practice before attending the workshop and unfilled squares that represent the percent of a corresponding group of growers (G2) (*n* = 32) using this practice indicated by LeBude et al. (2012). The squares can be used to see how these respondents improved personally over time and in comparison with a similar group of growers already conducting these practices in the southeastern United States.

(Bilderback, 2009). Everyone involved received his or her own porometer and dutifully filled it with substrate provided, saturated it, drained it, and calculated AFP. Afterward, attendees entered their values on a board in the classroom and quickly saw the need for both precision and replication because some values were wildly inaccurate. The class reached a consensus on which ones to be disregarded, then averaged the remaining values to compare with an industry standard. The substrate was very coarse, with a high percentage of air space between the pores; therefore, it would need to be watered more often which increases the volume of water used, the hours the foliage is wet (which leads to disease), and the potential for leaching of nutrients. In addition, growers

measured the volume of water applied to a mock growing area by running the irrigation for a set amount of time. By use of catch-cans placed throughout the irrigation zone, growers measured the uniformity of the application. They realized the zone was getting too much water at each irrigation event to compensate for poor distribution problems like worn nozzles, swaying irrigation risers, and wind in parts of the zone. Taken together, a coarse substrate that requires more frequent watering and a poorly performing irrigation system that applies water unevenly made the growers realize the meaning of determining cultural practices that contribute to poor plant health. This is indicated by their high intention of adopting all of these practices (Fig. 4).

POST-SEASON ADOPTION OF MANAGEMENT PRACTICES BY A SUBSET OF WORKSHOP ATTENDEES. Eighty percent or more of the respondents met or exceeded their intentions to set aside a time to scout deliberately and use a standardized sampling plan (Fig. 5). Attendees performed these tasks at a higher level than before attending the workshop or compared with G2 in LeBude et al. (2012) and they indicated they trained other employees about the practices. They also met goals to send more samples to plant and disease clinics and to use yellow sticky cards or double-sided tape for pest monitoring (Fig. 5).

Setting aside a time to scout deliberately using a standardized sampling plan, for example a rigid walk, random walk, or hot spot scouting method, are two vital components of IPM because they provide an efficient inventory of the incidence and severity of pests present in the nursery. Early detection of pests provides a cascade of options, for example, sending samples for diagnosis, choosing the least toxic alternative, timing the pesticide application for the life stages of the pests present, especially if there are life stages that do not occur on the plant or different life stages cause different types of damage, and evaluation of these intervention options. Combined with double-sided tape or traps and lures, scouting allows growers to monitor emergence of scale crawlers (*Lopholeucaspis japonica*) and borers (*Chrysobothris* sp.), which are both difficult to control and cause severe damage (Adkins et al., 2010). Although low, respondents met goals for double-sided tape, but fell short of their goals to use traps and lures; however, adoption of both practices was greater than or equal to their adoption before attending the workshops and more than G2 from LeBude et al. (2012) (Fig. 5). Respondents are making progress in pest management as a result of attending the workshops.

Respondents used plant phenology (40%) more than before attending the workshops (15%) but less than compared with their G2 counterparts (65%) in LeBude et al. (2012) (Fig. 5). This practice needs more refinement currently in the southeastern United States before widespread adoption occurs. For example, few reports have consistently created a reliable system

overlaying growing degree days, plant phenology and pest phenology in the southeast because of the varying bio-fix dates for pests, longer growing seasons, and warmer winter temperatures that prolongs insect growth over winter (Young, 2012). There are also no reliable data linking the growing degree days calculated at nearby weather stations to that of weather on nurseries, much less within the tree canopy where the insect pests are developing.

Eighty percent or more of the respondents routinely sanitized

clippers, pots, and hand pruners (Fig. 5) and determined points in the production system that might introduce pathogens (Fig. 6). Many respondents obtained pest and disease resistance information for plants being grown presently (75%), but that number was short of the respondents intending to adopt this practice (93%). Nevertheless, that is impressive for respondents who were not “already doing this task.” About 50% of eligible respondents intended to incorporate more pest and disease resistant plants into their operations

and they met their goal (Fig. 6). Growers are taking initiative to learn more about the plants they grow and are adding more pest and disease resistant cultivars into production deliberately.

Even though 80% of respondents intended to measure AFP in substrates, fewer than 25% completed the task (Fig. 6). About 50% of respondents measured irrigation uniformity or conducted a pour-through to measure electrical conductivity (EC) or pH, which was about half of respondents intending to accomplish these goals; however, 80% revised irrigation management plans which exceeded goals set during the workshop (60%) (Fig. 6). These numbers are surprising because, as discussed previously, hands-on experiential learning stimulated intention of growers to adopt certain management practices. Horticulture personnel are uniquely suited to hands-on learning because the profession requires action to be successful. Everyone received a porometer, Cooperative Extension publication with directions, plenty of practice, and improved both knowledge and ability to complete the tasks (Fig. 2). The lack of adoption might be due more to the practice not being common in nursery production already. Alternatively, growers may be indirectly gauging the interdependence of the nutrient-substrate-irrigation system by monitoring EC and pH (Mack et al., 2017) than measuring irrigation uniformity or monitoring AFP (Fig. 6). Perhaps growers need different incentives for changing their behavior about adopting other practices surrounding substrates and irrigation, or more concrete examples of

Fig. 6. Intention to adopt horticultural management practices and actual adoption of them by nursery crop growers 3 years after attending a 2-d workshop in June 2014. Symbols represent the percent of attendees that completed both a post-workshop survey about their intention to adopt specific management practices and a post-season survey 3 years later indicating which management practices they actually adopted. Unfilled circles are the percent of eligible attendees who indicated that “yes” they intended to adopt the practice directly after the workshop. Eligible attendees were those that answered “yes,” “no,” or “maybe.” Attendees that answered “already doing this” were excluded since they had already adopted the practice. Filled circles are the percent of attendees who indicated they adopted the practice on the post-season survey at the end of the 3 years. The *n* is noted for each specific practice and it pertains to both prior intent (unfilled circles) and post-season adoption (filled circles). EC = electrical conductivity.

Table 1. Educational opportunities used by growers to learn about integrated pest management. Respondents completed a survey in 2014 (*n* = 44) before attending a 2-d workshop and then again in 2016 (*n* = 24).

Educational opportunity	Participants using this opportunity (%)		Use ^z
	2014	2016	
Worldwide web	97.3	87.0	Weekly
Extension publications	94.6	85.7	Seasonally
Reference books in office	84.2	81.0	Seasonally
Another grower nearby	77.0	87.0	Seasonally
Cooperative extension agent at nursery or on the phone	58.5	91.7	—
Conversation (telephone or in person) with university faculty member	56.1	83.3	—
Another grower in a nearby state	44.7	83.3	Seasonally
IPM for select deciduous shrubs in nursery production (Braman et al., 2014)	21.6	68.2	Seasonally
IPM for select deciduous trees in nursery production (Adkins et al., 2012)	19.4	65.2	Seasonally

^zChoices included daily, weekly, seasonally, and yearly.

Table 2. Pest prevention and monitoring techniques of June 2014 workshop participants ($n = 44$) and three other practitioner groups [G1 ($n = 10$), G2 ($n = 40$), G3 ($n = 74$)] in the southeastern United States.

	Workshop participants	Practitioner groups from LeBude et al. (2012) (<i>n</i> = 124)		
		G1	G2	G3
Management practice		Participants using this practice (%)		
Routinely sanitize clippers, pots, and hand tools	62	70	53	36
Follow a standardized sampling plan while scouting	51	90	48	32
Use sticky cards or double-sided tape	44	60	25	15
Plant phenology to predict pest emergence	24	40	65	27
Growing degree days to predict pest or disease emergence	22	40	40	9
Pheromone lures or ethanol traps	16	15	15	15
Quarantine or isolate plants	13	50	43	13

the economic benefits citing the amount and location where the savings take place (Chappell et al., 2012).

MODES OF ACTION. For a single problematic pest or plant disease, more than 50% rotated MOAs at least three times or more [Table 3 (added columns for 3–5 and 6+)]. For weeds, that number was 21% (Table 3). Generally, single problematic pests or plant diseases such as aphids (*Aphididae*) or powdery mildew (e.g., *Erysiphe* sp.) might linger for the entire growing season and require repeated applications every 10–14 d. Herbicides are applied fewer times over the year and have different effects on different genera that precludes using many MOAs within the nursery. When asked the reasons respondents might rotate a MOA, 25% said they do not change MOAs for herbicides (Table 4). They might switch products, for example, within the dinitroanilines, but not rotate out of that mode during the year. Almost 30% indicated they change MOAs when the seasons change, which could mean rotating off summer MOAs to control winter weeds, or that some MOAs are ineffective once temperatures begin to rise in spring.

About 42% rotated MOAs for insect pests when targeting a new generation and 29% indicated they changed because of limited control with present MOA (Table 4). These reasons might be an extension of high adoption of scouting deliberately (Fig. 5), which allows growers to determine when the new generations occur and to evaluate whether interventions were successful. Respondents changing MOAs when controlling plant disease also indicated these reasons highly. For plant diseases,

Table 3. The percent of respondents ($n = 24$) indicating how many times they rotated modes of action for a single, problematic, pest, plant disease or weed. Respondents were asked to think of a particular pest at their nursery while answering, but not report which one.

Pesticide class	Rotations (no.)			
	0	1–2	3–5	6+
(%)				
Insecticide or miticide	4	30	49	17
Fungicide	9	35	39	17
Herbicide	17	62	17	4

respondents indicated that MOAs were changed most when suggested by a sales representative (29%) and to a lesser extent by another grower (17%). For arthropod pests, those numbers were 17% and 25%, respectively. Because growers generally seek information from other growers first before talking with Cooperative Extension (LeBude et al., 2012), this might indicate that growers may not be as confident or think other growers are not as competent with fungicides as they are with insecticides. Indeed the skills to identify the life cycle and biology of major plant diseases was ranked low by attendees before the workshops, but the ability to select the most effective fungicide was high (data not shown). Identification and diagnosis of plant symptoms and diseases is challenging and always needs professional development opportunities for growers. Once the plant disease is diagnosed, growers may be very adept at choosing the correct fungicide to manage it.

SYNTHESIZING INFORMATION AND APPLYING IT IN THE NURSERY. The workshop helped respondents to more efficiently control pests; already a problem at the nursery. For example, 75% or more of respondents identified a pest occurrence before it

became an outbreak so they could identify and time a pesticide application to the correct life stage of the pest (Table 5). This goes in concert with increased scouting as discussed previously. More opportunities are available to make decisions on when and how to intervene, as well as evaluate those choices afterward. Moreover, a large majority chose the least toxic alternative pesticide. This does not happen when neglected pests become so severe that only highly toxic pesticides can be used to solve the problem quickly before long-term crop value is lost. About 42% identified new pests in the nursery and fewer (33%) sent more than three plant samples to a pest or disease clinic for diagnosis (Table 5). Future instruction might focus more on professional development opportunities to identify pest arthropods and describing the life cycle and biology of major pests to allow growers to identify new pests and continue to choose the correct MOA.

ECONOMIC BENEFITS OF PROFESSIONAL DEVELOPMENT. About 67% of respondents adopted a new pest management practice as a result of attending the workshops in June 2014, whereas 33% said their adoption of practices was about the same as before

Table 4. Percent of respondents ($n = 24$) selecting what might have been a reason to rotate modes of action (MOAs) to control a single problematic pest, plant disease, or weed. Respondents were asked to think of a particular pest at their nursery while answering, but not report which one.

Reason to rotate modes of action	Insecticide or miticide	Fungicide	Herbicide
	Participants indicating this MOA change (%)		
Targeted a new generation of the pest in question	41.7	25.0	4.2
Limited control with present MOA	29.2	25.0	25.0
The season changed	25.0	16.7	29.2
Found a less expensive alternative in another MOA	25.0	25.0	8.3
MOA suggested by another grower	25.0	16.7	8.3
Pest resistance formed with previous MOA	20.8	8.3	8.3
MOA suggested by sales representative	16.7	29.2	16.7
New MOA controls a broader spectrum of pests	16.7	16.7	4.2
Reached maximum applications for one MOA	16.7	8.3	8.3
I did not rotate modes of action	12.5	8.3	25.0
Used up all current inventory of one chemical in a MOA	12.5	16.7	4.2
New MOA protects non-target, beneficial insects	12.5	0.0	0.0
I don't remember why we did it	8.3	12.5	4.2
Other reasons not stated here	8.3	8.3	8.3
Another pest arrived during intervention	4.2	0.0	0.0
Current MOA suddenly became unavailable	0.0	0.0	0.0

Table 5. In 2016, percent ($n = 24$) of respondents indicating they completed the tasks below since attending the June 2014 workshop.

Management practice task	Yes (%)
Identified an occurrence of a pest before it became an outbreak	91.7
Controlled an annual pest problem more efficiently than in the past	91.7
Timed a pesticide application more precisely	83.3
Determined the correct pest life cycle stage to apply pesticide application	75.0
Chose to use the least toxic alternative pesticide	62.5
Took photos of pests and their damage	62.5
Made a decision about fertilizer availability in containers by measuring the pH and electrical conductivity of leachates	50.0
Identified a new pest in production	41.7
Sent more than three pest or plant samples to be identified by a professional	33.3

attending the workshop. Similarly, about 62% said they applied fewer pesticide applications on average because attending the workshops, whereas 25% said about the same and 13% said they made more applications. Respondents (>80%) provided training about these practices learned at the workshop to other employees (Figs. 5 and 6). This has been the intention of Cooperative Extension since its inception over 100 years ago. To enable influential producers to complete tasks that impact businesses economically, and have them be an example of success in their business communities (Bohlen et al., 1960). The model has always been implied and reinforced by surveys of high rates of intended adoption by attendees of workshops and lectures, university field days, and webinars. These data indicate that adoption does occur for some

practices, and there is a multiplier effect of teaching growers who, in turn, educate other employees.

The empirical effect of individual management practices on nursery production systems is not well understood economically and to a lesser extent its effect on grower adoption and implementation. Respondents were asked “Compared to your pest management practices before June 2014, how much more profit did your business make thanks to IPM practices you’ve tried in the 3 years since? That additional profit may have come from savings, increased product quality, better survival, or other improvements. If the practices you tried resulted in decreased profit, use a negative number.” Of the 10 responses, five were not sure after 3 years of the effects of the practices adopted. Three offered a positive response with an average of 7.3%, whereas one simply

put “negative.” Two comments stated that “the practices reduced the cost of production and provided better production of quality” and “there was more product to sell because of better quality and survival.” Clearly, we need to investigate and monetize how adoption of the various practices might stimulate benefits within the economic management system of the nursery. For example, Fulcher et al. (2013b) stated that within a 5-year-long mentored scouting program that a grower “saved \$20,000 in maple sales by detecting a new scale pest early and eradicating it from his nursery; and that three growers who trapped granulate ambrosia beetles saved a combined \$34,500 due to improved control; and that by the end of the fifth year of the scouting program, growers estimated they’d saved an average of \$9179 per nursery, a significant return on investment.”

A 2-d workshop is not going to bring similar returns as a 5-year focused program with interns and checks and balances, but the system can move toward that model by incorporating some of its aspects. For example, future workshops can schedule more interaction between extension agents and growers before, during, and after the workshops, elicit feedback over the season instead of after only 3 years, or create an online discussion group to determine where problems might be occurring or how others are making the process work to link together those involved.

Conclusions

Hands-on experiential learning is a proven method to model management practices and provide tactile learning environments for grower experimentation. Growers attending these workshops prefer them over teaching methods such as webinars and previously recorded presentations. However, the cost of multispeaker hands-on workshops is more extensive and time consuming than illustrated lectures or recorded podcasts. Combining the two methods might use the practicality of engaging in a hands-on task to improve comprehension with the widespread access and efficiency of a webinar. In addition, they need to be engaging, accessible to growers, and more informative on an employee level for training use. One example might be to include a hands-on assignment for viewers to complete and contribute data so all participants can gauge industry-wide adoption strategies and frequency of use.

Extension training materials need to be available for use by informal educators at their place of business. With the decline of Cooperative Extension budgets, and unrelated cross-commodity responsibilities of most agents, there are simply fewer agents to engage the community. Complete training and education kits with instructions, supply lists, either recorded or provided presentations, and embedded evaluation tools are needed that can send efficacy information through smartphones of participants.

The growers at the three, 2-d workshops changed their behavior and adopted management practices as a result of attending. Initially, this

group of growers was similar to another group called G2, defined as medium level practitioners of IPM by LeBude et al. (2012). For some practices, a higher percentage of growers in the present group adopted these tasks compared with those in G2. For other practices, adoption was similar or slightly less than growers in G2. Without exception, the growers attending the workshops are better practitioners of IPM, and prove that those within the larger context of G2 in the southeastern United States are equally capable of learning new practices and adopting them in higher percentages given instruction, skills, and demonstration of methods. In addition, efforts need to be made, both empirically and in practice, to determine how effective these practices are in nursery production systems in terms of economic impact and improving plant health.

Literature cited

- Adkins, C.R., G. Armel, M. Chappell, J.C. Chong, S. Frank, A. Fulcher, F. Hale, W. Klingeman, III., K. Ivors, A.V. LeBude, J. Neal, A. Senesac, S. White, J. Williams-Woodward, and A. Windham. 2010. Pest management strategic plan for container and field-produced nursery crops. Southern Reg. IPM Ctr., Raleigh, NC.
- Adkins, C.R., S.K. Braman, M.R. Chappell, J.-H. Chong, J.F. Derr, W.C. Dunwell, S. D. Frank, A.F. Fulcher, F.A. Hale, W.E. Klingeman, G.W. Knox, A.V. LeBude, M. L. Paret, J.C. Neal, J.R. Sidebottom, N.A. Ward, S.A. White, J.L. Williams-Woodward, and A.S. Windham. 2012. IPM for select deciduous trees in southeastern U.S. nursery production. In: A.F. Fulcher and S.A. White (eds.). Southern Nursery IPM Working Group, Knoxville, TN.
- Bilderback, T. 2009. A nursery friendly method for measuring air-filled porosity of container substrates. Proc. South. Nursery Assn. Res. Conf. 54:212-215.
- Bohlen, J., C.M. Coughenour, H.F. Lionberger, E.O. Moe, and E.M. Rogers. 1960. Adopters of new farm ideas: Characteristics and communication behavior. North Central Reg. Ext. Publ. No. 13. 3 May 2017. <<http://www.soc.iastate.edu/extension/pub/comm/NCR13.pdf>>.
- Braman, S.K., M.R. Chappell, J.-H. Chong, J.F. Derr, W.C. Dunwell, A. Fulcher, F.A. Hale, W.E. Klingeman, G.W. Knox, A.V. LeBude, M.L. Paret, J.C. Neal, N.W. Gauthier, S.A. White, J. Williams-Woodward, and A.S. Windham. 2014. IPM for shrubs in southeastern U.S. nursery production. In: S.A. White and W.E. Klingeman (eds.). Southern Nursery IPM Working Group, Clemson, SC.
- Braman, S.K., M.R. Chappell, J.-H. Chong, A. Fulcher, N.W. Gauthier, W.E. Klingeman, G. Knox, A. LeBude, J. Neal, S.A. White, C. Adkins, J. Derr, S. Frank, F. Hale, F.P. Hand, C. Marble, J. Williams-Woodward, and A. Windham. 2015. Pest management strategic plan for container and field-produced nursery crops: Revision 2015. In: A.V. LeBude and A. Fulcher (eds.). Southern Region IPM Center, Raleigh, NC. 3 May 2017. <www.go.ncsu.edu/NurseryCropsIPM2015.pdf>.
- Chappell, M.R., M. van Iersel, E. Lichtenberg, J. Majsztrik, P. Thomas, J. Ruter, and S. Wells. 2012. Benefits of precision irrigation of *Gardenia augusta* 'Heaven Scent'^{TM}: Reducing shrinkage, shortening the cropping cycle, and economic impact. Proc. South. Nursery Assn. Res. Conf. 57:321-323.
- Cochran, D.R., A. Fulcher, F. Hale, and A. Windham. 2014. An overview of systems-based pest management for nursery production. Univ. Tennessee PB1825. 3 May 2017. <<https://extension.tennessee.edu/publications/Documents/PB1825.pdf>>.
- Frank, S.D., W.E. Klingeman, S.A. White, and A. Fulcher. 2013. Biology, injury, and management of maple tree pests in nurseries and urban landscapes. J. Integrated Pest Mgt. 4:1-14.
- Fulcher, A., J.-H. Chong, S.A. White, J.C. Neal, J.L. Williams-Woodward, C.R. Adkins, S.K. Braman, M.R. Chappell, J.F. Derr, W.C. Dunwell, S.D. Frank, S.A. Gill, F.A. Hale, W.E. Klingeman, A.V. LeBude, K. Rane, and A.S. Windham. 2013a. Developing a mobile application as an extension education tool: A case study using IPM Pro. HortTechnology 23:402-406.
- Fulcher, A., A. LeBude, S.A. White, J.-H. Chong, C. Adkins, K. Braman, M. Chappell, J. Derr, W. Dunwell, S. Frank, S. Gill, F. Hale, W. Klingeman, G. Knox, J. Neal, M. Paret, K. Rane, N. Ward, J. Williams-Woodward, and A. Windham. 2013b. IPM in action. Nurs. Mgt. 29 (12):30-33.
- Kaderabek, L., B.E. Jackson, and B. Fonteno. 2017. How pine bark aging affects hydrologic properties. 16 Aug. 2017. <<https://www.amerinursery.com/pest-management/pine-bark-aging-affects-hydrological-properties/>>.
- LeBude, A.V. and C. Adkins. 2014. Incidence and severity of buprestid infestation in field-grown *Acer platanoides* related to cardinal orientation of understock bud union. J. Environ. Hort. 32:215-218.

- LeBude, A.V., S.A. White, A. Fulcher, S. Frank, J.-H. Chong, M.R. Chappell, W.E. Klingeman, A. Windham, K. Braman, F. Hale, W. Dunwell, J. Williams-Woodward, K. Ivors, C. Adkins, and J. Neal. 2012. Assessing the integrated pest management practices of southeastern U.S. ornamental nursery operations. *Pest Mgt. Sci.* 68:1278–1288.
- Mack, R., J.S. Owen, A.X. Niemiera, and J. Latimer. 2017. Virginia nursery and greenhouse grower survey of best management practices. *HortTechnology* 27:386–392.
- Sellmer, J.C., N. Ostiguy, K. Hoover, and K.M. Kelley. 2004. Assessing the integrated pest management practices of Pennsylvania nursery operations. *HortScience* 32:297–302.
- Yeary, W., A. Fulcher, W. Klingeman, J. Grant, and X. Sun. 2015. Responses of three natural enemy species to contact and systemic insecticide exposures in confined assays. *J. Entomol. Sci.* 50:35–46.
- Young, R. 2012. Alabama phenology garden project: Using degree-days and phenology to predict pest activity. M.S. Thesis, Auburn Univ., Auburn, AL.