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Assessing the integrated pest management practices of southeastern US ornamental nursery operations

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Abstract

BACKGROUND: The Southern Nursery Integrated Pest Management (SNIPM) working group surveyed ornamental nursery crop growers in the southeastern United States to determine their pest management practices. Respondents answered questions about monitoring practices for insects, diseases and weeds, prevention techniques, intervention decisions, concerns about IPM and educational opportunities. Survey respondents were categorized into three groups based on IPM knowledge and pest management practices adopted.

RESULTS: The three groups differed in the use of standardized sampling plans for scouting pests, in monitoring techniques, e.g. sticky cards, phenology and growing degree days, in record-keeping, in the use of spot-spraying and in the number of samples sent to a diagnostic clinic for identification and management recommendation.

CONCLUSIONS: Stronger emphasis is needed on deliberate scouting techniques and tools to monitor pest populations to provide earlier pest detection and greater flexibility of management options. Most respondents thought that IPM was effective and beneficial for both the environment and employees, but had concerns about the ability of natural enemies to control insect pests, and about the availability and effectiveness of alternatives to chemical controls. Research and field demonstration is needed for selecting appropriate natural enemies for augmentative biological control. Two groups utilized cooperative extension almost exclusively, which would be an avenue for educating those respondents.

Keywords: cooperative extension; IPM; ornamental nursery crops; survey

1 INTRODUCTION

The US agriculture sector of ornamental nursery production utilizes over 369 000 acres, generates farm gate sales of $US 6.6 billion annually and employs tens of thousands of workers.[1] Within the southeastern United States, Georgia, Kentucky, North Carolina, South Carolina and Tennessee were responsible for producing 10% of the national value of ornamental nursery crops in 2007.[1] In these five southeastern states alone, nearly 400 different genera are grown industry wide,[2] and each type of plant has its own cultural and pest management needs, which require significant amounts of manual labor and production inputs. In light of these needs, plant damage by pests represents a key source of revenue loss for the nursery industry. In North Carolina, the green industry reported annual losses of $US 91 million due to insects and diseases.[3] Similarly, nursery stock losses due to plant disease in Georgia during 2007 were estimated at $US 43.4 million.[4] These revenue losses include resources spent on pest control, as well as lost sales attributed to either poor-quality stock or catastrophic crop failure.

Integrated pest management (IPM) is a decision-making process that coordinates the use of pest biology, environmental

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information and available technology in combination with biological, cultural, physical and chemical tools to minimize economic, health and environmental risks.[5] The National IPM Road Map emphasizes measuring adoption and implementation on a pilot scale or in a defined geographic area.[5] The National Agriculture Statistics Service (NASS) developed a national IPM adoption survey based on IPM protocols designed for specific commodities, including nursery and floriculture. Using this tool, Pest Management for Nursery and Floriculture data were broadly compiled within multistate regions that encompassed six of the highest-grossing revenue states in the United States.[6]

In brief, the NASS survey determined that scouting for pests was mainly executed while employees were performing other routine tasks rather than scouting as a dedicated task. Less than 25% of growers kept scouting records, and even fewer reported using any other form of monitoring technique to aid in pest detection.[6] When intervention was necessary, almost 50% of growers stated that they used scouting data and acted upon research-based action thresholds to determine when to apply pesticides, while another 30% relied on a preventive treatment schedule. Less than 20% used traps, biological pesticides or beneficial organisms for pest control.[6] The entire East Coast was represented by Florida and Pennsylvania in the NASS survey. At present there are no data that can relate these representative states to a contemporary assessment of nursery IPM adoption within the southeastern United States.

Sellmer *et al.*[7] surveyed the integrated pest management practices of all growers of nursery stock as licensed by the Pennsylvania Department of Agriculture. About 25% of respondents kept permanent records, consistent with the findings of NASS.[6] All respondents were placed into three distinct groups, based on the descending use of IPM, termed 'IPM savvy', 'IPM part-timer' and 'IPM reluctant'. Respondents in the IPM savvy group were more likely to select pesticides and cultural practices that preserved beneficial insects. Scouting was used often in this group, and respondents rarely sprayed on a calendar basis for insects, mites or diseases. Specific methods of monitoring insects, e.g. trapping systems, were not mentioned in the survey, and neither was the use of beneficial or predatory insects. All groups thought IPM was limited by the availability of damage thresholds used for making pest management decisions.

IPM has been used in other horticultural crops over a longer time period, and assessments of pest management practices have been reported. Fenemore and Norton[8] noted that apple growers in the United Kingdom have adopted one of three pest management strategies: calendar spraying, supervised spraying (SS) and integrated pest control (IPC). Calendar spraying requires a scheduled spray program and data on chemical efficacy against pests, phytotoxicity and pesticide costs. Supervised spraying takes into account chemical efficacy, phytotoxicity and cost; however, SS is applied according to need by establishing economic or action thresholds and may use suitable pest monitoring techniques, forecasting techniques or both. An IPC pest management strategy utilizes the techniques of SS and also includes monitoring techniques for natural enemies as well as the possible introduction of natural enemies, the use of selective chemicals (or selective application methods) and cultural practices to influence or selectively target pests, or enhance populations of beneficial insects and natural enemies.

Supervised 'spray and pray' (SSP), similar to SS above, was found to be the dominant method of pest management in production of one woody and two herbaceous crops in Australia.[9] The authors argued two points about the use of SSP. Firstly, SSP would remain the dominant form of pest management used by growers until pesticide resistance developed, and then growers might adopt IPM strategies to overcome resistance. If, on the other hand, scouting for pests and monitoring of insect populations became no longer feasible economically, growers would shift instead from SSP to calendar spraying. Secondly, strategic IPM utilizing beneficial insects and natural predators would not be feasible until the potential of natural enemies was fully documented and proven to be effective on small farms.

Reports of pest management practices usually review one major crop, such as apples,[8] brassicas, citrus or cotton.[9] These commodities benefit from intense study of a single plant and its associated pest complex. The result of this concentrated research and extension effort includes established damage and action thresholds and other resources growers can rely upon to help implement effective IPM.[10] Nursery production systems involve hundreds of species that have an extensive potential for exposure to pest populations of both generalist and specialist pests, as well as pests that inflict differing amounts of feeding injury during their various pest developmental stages. Faced with a perception of such confounding management complexity, growers may simply opt to rely on pesticides with broad-spectrum control that they can use to treat many pests on many crops rather than use more selective pesticides that would require more knowledge of each pest problem and increase the labor needed to mix and spray multiple products. Although these practices may increase efficiency, they can have consequences for non-target organisms, secondary pest outbreaks and environmental health.[11]

Recognizing the need to assess this trade-off conundrum, Sellmer *et al.*[7] surveyed licensed growers in Pennsylvania. The results of Sellmer *et al.*[7] were pooled across all businesses with some form of nursery-stock-related operations, which included retail garden centers, Christmas tree producers and landscape operations. About 18% of their survey respondents indicated specific involvement in nursery production activities similar to the intended professional pool. Thus, it was not possible to examine responses by this professional segment independently. Because 10 years has passed since Sellmer *et al.*[7] conducted their survey in Pennsylvania, and a comparable survey has not been done in the southeastern United States, it is important to assess the current picture of grower practices and determine where future work should focus.

The Southern Nursery IPM working group (SNIPM) 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 US nursery production operations both perceive and utilize nursery 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. The principal objectives of the survey were to:

1. Assess the pest management practices currently used by ornamental nursery growers in the southeastern United States.
2. Identify critical areas of instructional and outreach needs for education and research related to ornamental nursery IPM.
3. Gain grower input relative to ornamental nursery growers' perceived best methods of receiving information about nursery IPM practices.

2 EXPERIMENTAL METHODS

2.1 Questionnaire development and delivery

A survey was developed, based on the survey utilized by Sellmer *et al.*,[7] and was modified to be suitable for southeastern US ornamental nursery growers. A draft of the survey was administered online to a test group of 20 nursery growers in Ohio, who commented on wording, clarity and length. The anonymous survey was available online from 1 June 2009 through NC State Web Survey Services. The target population was commercial wholesale woody ornamental producers from each of several southeastern states. A link to the survey was sent through e-mail listserves to all state nursery and landscape associations in Georgia, Kentucky, North Carolina, South Carolina, and Tennessee. Additional e-mails were sent 1 month later, and then on a bimonthly basis until the survey closed. Additionally, a postcard flyer advertising the survey was inserted into each trade association's newsletter, journal, registrations for trade shows and any other correspondence sent to growers who were nursery association members. The survey was advertised at various trade shows in summer 2009 and winter 2010 in all five states. The survey was closed to respondents on 1 March 2010.

The survey contained 230 questions divided into eight sections based on IPM implementation practices for insects, diseases and weeds: 'General Information', 'Prevention', 'Pest Monitoring', Decision-Making', 'Intervention', 'Limitations and Concerns about Using IPM in Nurseries', 'Information and Educational Needs' and 'Demographics'. These same headings will serve as the headings for the results and discussion section (Section 3) and may have subheadings to denote insects, diseases or weeds. The survey experiment was approved by the North Carolina State University Institutional Review Board for the Use of Human Subjects in Research.

2.2 Data analyses

Cluster analysis (SAS v.9.1; SAS Institute, Cary, NC) was used to determine whether respondents, based on their responses to questions, could be clustered into IPM practitioner segmentations, similar to the 'IPM savvy', 'IPM part-timer' and 'IPM reluctant' segmented clusters created by Sellmer *et al.*[7] To accomplish this, the present data were analyzed first using FASTCLUS to produce ten initial clusters, and those data were analyzed further using four cluster algorithms and their various criteria for determining the number of clusters.[12] A three-cluster analysis was chosen that best described the differences between groups. Thus, the survey's distinct segments are categorized as follows: 'G 1′ (= IPM savvy[9]), n = 10 respondents; 'G 2′ (= IPM part-timer), n = 40; 'G 3′ (IPM reluctant), n = 74 (Table 1). For the aforementioned questions, respondents could choose whether they performed the task 'always', 'often', 'rarely' or 'never'. For purposes of reporting and data analysis, respondents' answers were pooled into either 'yes' ('always' or 'often') or 'no' ('rarely' or 'never'), and analysis of variance (PROC GLM) was performed on the resulting pooled percentages. Means were separated among the three groups using Fisher's protected LSD at $P < 0.05$. On other questions, respondents were asked on a five-point Likert-type scale whether they strongly agree (1), (2), agree (3), (4) or strongly disagree (5) with a few statements concerning pest management and the use of IPM. Their responses were combined into one value termed 'agree' by averaging those responses from the categories strongly agree (1), (2) and agree (3). Respondents were asked about factors that might 'not be a limitation' or be a 'minor limitation', a 'moderate limitation' or a 'major limitation' for them, keeping them from implementing IPM in their nursery. Respondent's answers were pooled into a value termed 'limitation' ('moderate limitation' and 'major limitation'), and analysis of variance and means separation as described previously were performed on the percentage of respondents in each segment.

3 RESULTS AND DISCUSSION

3.1 Survey outcome, general scouting practices and demographics

A total of 178 surveys were completed and 124 surveys were analyzed. The surveys analyzed included only those of respondents with 40% or more wholesale container or field production of woody ornamentals. Among those excluded were landscape design and installation firms, floriculture producers, garden centers, Christmas tree growers and sod producers. The census population of nurseries in each state that meet these criteria are unknown, but survey invitations were sent to approximately 1600 nurseries in the five states that meet the initial criteria. Based on this, the response rate was approximately 8%. Responses were evenly distributed among states, with each state receiving 22–28 respondents. Among the respondents, 88% were either primarily or secondarily responsible for making pest management decisions for their nursery; 12% said another employee made the decisions.

Table 1. Demographics of the three practitioner segments identified using cluster analysis of survey response

	Practitioner segment[a]		
Respondent nursery demographics	G1	G2	G3
N (% of total)	10 (8)	40 (32)	74 (60)
Years for which company has been in business	40 ± 7 a	29 ± 3 ab	23 ± 2 b
Number of full-time employees (2008)	71 ± 25 a	26 ± 12 b	9 ± 1 b
Number of part-time employees (2008)	43 ± 32 a	3 ± 1 b	4 ± 1 b
Number of seasonal employees (2008)	49 ± 36 a	15 ± 9 b	4 ± 1 b
Average annual gross sales (2006–2008)			
$US 0–500 000	20 ± 13 a	30 ± 7 a	59 ± 6 b
$US 500 000–1 000 000	20 ± 13 a	20 ± 6 a	15 ± 4 a
$US 1 000 000 or more	60 ± 16 a	45 ± 8 a	20 ± 5 b

[a] Values with similar letters within rows are not significantly different at $P < 0.05$.

A total of 96% of respondents deliberately inspected plants monthly for insects and mites (I), diseases (D) or weeds (W). When asked to describe their scouting practices for I and D, 65% of respondents said they made observations while performing another task (e.g. watering, loading or potting), and 35% said they set aside a specific time for scouting. For W, 80% reported scouting while working on other tasks, and 20% set aside specific time for scouting.

The most reliable information used by respondents to begin scouting for I (91%) or D (83%) was the presence of visible plant damage. Respondents also relied on information from other growers (82% I and 78% D), the appearance of the actual pest (78% I and 69% D) and notification by a cooperative extension employee (76% I and 63% D). Some growers acknowledged using records from previous years to begin scouting for I (60%) or D (49%), while others based their start on a calendar date (44% I and 27% D). Less than 50% used either phenology of host or indicator plants (44% I and 40% D), trap counts (30% I and 5% D) or growing degree days (28% I and 18% D) as a trigger to initiate scouting practices. About 80% of respondents began scouting for weeds when the pest appeared, and approximately 30% or fewer relied on any of the other techniques mentioned above. Although most respondents are scouting monthly, their routine consists primarily of observation while in the process of performing other tasks, rather than deliberate scouting during a specified timeframe. This is similar to the USDA NASS[6] survey results. Scouting of plants for I or D is initiated primarily when plants begin to show damage from the pests or when a pest is visibly present. Quite often, growers wait to initiate scouting for a particular pest after learning about it from another grower or extension agent.

Cluster analysis identified three distinct practitioner segments as: 'G1', $n = 10$ (8%) respondents; 'G2', $n = 40$ (32%); 'G3', $n = 74$ (60%). Based on response to the survey questions, G1 was defined as 'IPM savvy', G2 as 'IPM part-timer' and G3 as 'IPM reluctant' after Sellmer *et al*.[7] The distribution in each group was different from Sellmer *et al*.,[7] which reported $n = 176$ (49%), $n = 96$ (27%) and $n = 88$ (24%) in the three groups respectively. This suggests greater overall adoption of IPM by Pennsylvania respondents, although the PA survey included a greater variety of businesses than the present survey, including Christmas trees, sod producers and landscapers.[7] A limitation to the present study is the relatively small sample size ($n = 10$) of respondents that were classified as G1, which limits statistical power in separating G1 from G2 but results in a more conservative test.

Respondents categorized as G1 were employed at businesses that had been operating longer (40 years) than those in G3 (23 years), yet respondents of all groups had similar years of experience in the green industry (23 ± 1 year) (Table 1). All groups were employed at businesses with similar total acreages (150 ± 25 acres). Group 1 employed more full-time, part-time and seasonal employees than either G2 or G3 (Table 1). A large portion of nurseries in G1 (60%) had a gross revenue of over $US 1 million, whereas a similar percentage of nurseries in G3 (59%) had a gross revenue of $US 500 000 or less. Nurseries in G2 had a gross revenue spread from $US 500 000 to over $US 1 million. More than 75% of all respondents received a higher education degree (associate degree or higher) (76 ± 9%).

At the beginning of the survey, 90% of G1, 83% of G2 and 78% of G3 reported using IPM. At the end of the survey, the percentage of G1 had not changed, G2 increased to 90% and G3 decreased to 72%, which was lower than the other two groups. These findings are similar to those of Sellmer *et al*.[7] Respondents may have realized, relearned or recalled IPM practices during the survey and thus decided by the end that they were using IPM more or less than they reported previously.

3.2 Pest prevention techniques

The most common prevention techniques used by groups were to inspect incoming stock for pests (88 ± 3%), to grow pest- or disease-resistant plants (81 ± 4%), to decide no longer to grow a plant because it has consistent pest populations (68 ± 4%) and to employ preventive, scheduled fungicide applications across the entire growing area (55 ± 5%). More than half the respondents regularly spray their entire nursery with a fungicide as a preventive management action. Some preventive management treatments may be beneficial, particularly if growers specialize in producing *Phytophthora*-sensitive genera such as *Rhododendron, Pieris, Camellia* or *Viburnum*.

A majority of respondents (62 ± 4%) applied pre-emergence herbicides to reduce weed pressure around the perimeter of the growing area, but almost no one created a weed map (7 ± 2%) to plot persistent weed populations. Respondents in G1 and G2 were more likely to use preventive, scheduled pre-emergence herbicide applications throughout the entire growing area and used granular or liquid pre-emergence herbicides in containers more often than G3 respondents (Table 2). Pre-emergence herbicide use is a best-management recommendation that will limit hand-weeding costs and prevent infestation of new weeds transported with nursery stock or liners.

Quarantining or isolating incoming nursery stock was an infrequent practice used more by respondents in G1 (50%) and G2 (43%) than by respondents in G3 (13%). Similarly, G1 were more likely to sanitize clippers and pots (70%) than G3 (36%) (Table 2). Isolating incoming stock has been advocated to growers for decades and has demonstrated benefits for pest management. Further, quarantine recommendations have increased recently, with concerns related to ecologically dangerous pathogens, such as *Phytophthora ramorum*. This area may be a good target for future research and demonstration to increase adoption.

Two competing IPM strategies were detailed in the survey and involved either applying preventive, scheduled insecticide applications to the entire growing area or planting nurse crops such as ground covers, flowers or other non-crop plants to attract and conserve beneficial insects. Providing habitat for beneficial insect reproduction is an advanced component of IPM, while applying broad-spectrum insecticides uniformly across an area is not. Reliance on broad-spectrum pesticides may reduce IPM program effectiveness by indirectly increasing target pest populations.[11,13] Most respondents (60% of G1, 75% of G2 and 55% of G3) used either preventive or scheduled pesticide applications (Table 2). Only a small proportion of total respondents tried to attract and conserve beneficial insects (16 ± 3%). Nevertheless, more than twice as many respondents in G2 (48%) than in G3 (22%) stated that they checked to see whether natural enemies were present, with G1 (30%) intermediate between those two groups (Table 2). Scouting for natural enemies is a critical first step before utilizing these predators for target pest control, and conserving their populations is necessary to achieve effective and efficient IPM.[8,9,14] Limited conservation and augmentation of beneficial insects may indicate perceived difficulty or unorthodoxy for use of these methods in nurseries. In fact, almost no research has investigated how to implement augmentation biological or conservation biological control in woody ornamental nurseries growing plants hardy in the southeastern United States. This is

Table 2. Description of three practitioner segments derived from cluster analysis based on participant responses (%)[a] to questions assessing IPM cultural practices by growers in five southeastern US states

Variable	Practitioner segment[b]		
	G1	G2	G3
Affirmative response frequency for grower-perceived adoption of IPM strategies within their nursery operation			
'Yes' (beginning of survey)	90 ± 10 a	83 ± 6 a	78 ± 5 a
'Yes' (end of survey)	90 ± 10 a	90 ± 5 a	72 ± 5 b
Prevention			
Quarantine/isolate incoming plants	50 ± 17 a	43 ± 8 a	13 ± 4 b
Sanitize pots, clippers, etc.	70 ± 15 a	53 ± 8 ab	36 ± 6 b
Preventive, scheduled insecticide applications over the entire growing area	60 ± 16 ab	75 ± 7 a	55 ± 6 b
Use granular or liquid pre-emergence herbicides in containers	80 ± 13 a	80 ± 6 a	55 ± 6 b
Preventive, scheduled, pre-emergence herbicide applications over the entire growing area	90 ± 10 a	88 ± 5 a	69 ± 5 b

[a] Respondents were asked whether they performed the task 'always', 'often', 'rarely' or 'never', and responses for 'always' and 'often' were pooled into percentage of respondents performing the task.
[b] Values with similar letters within rows are not significantly different at $P < 0.05$.

reflected in the results of searching the Web for science databases with 'augmentation biological' or 'conservation biological' and 'horticulture' and 'nursery' or 'ornamental' as search terms, which returns no published papers; the closest publications investigate palms, olives or herbaceous crops grown in controlled environments. Preliminary work is needed to determine and demonstrate the efficacy of pest, host plant and beneficial insect complexes in different nursery production systems, and to show growers ways in which these practices can be transitioned into existing scouting and cultural activities.

3.3 Pest monitoring

IPM scouting principles suggest that growers follow a standardized sampling plan to scout large numbers of plants efficiently, with focus concentrated on key plants that are most susceptible to key pests.[15] Respondents in G1 (90%) were more likely to follow a standardized sampling plan than respondents in G2 (48%) or G3 (32%) (Table 3). It seems the most frequent scouting method is to survey large blocks of plants visually to identify individual plants with damage (94 ± 2%), with focus on key or highly susceptible (94 ± 2%) or valuable (73 ± 4%) plants. Because very few respondents had previously created a weed map, few utilized it for scouting (6 ± 2%).

When damage was evident on plants, G2 and G3 were more likely than G1 to confirm visually whether insects, mites or diseases were actually present (Table 3). All groups reported following up visually to confirm that problems did not reflect a cultural problem (93 ± 2%). When insects or mites were present, G2 (100%) were more likely than G1 (80%) to verify that the insect was the causal agent of damage, yet a majority of respondents reported verifying the name of the pests (86 ± 3%). When plant disease was present, G2 (98%) were more likely than G3 (80%) to verify that the disease was causing the symptoms, and all groups reported that they verified the identity of the disease (81 ± 4%).

In order to make appropriate management decisions, growers must properly identify the arthropod pests, weeds and plant diseases they encounter, particularly if growers intend to develop nursery- or pest-specific action thresholds. Accurate pest identification can be achieved by submitting specimens and plant samples to a plant disease and insect clinic for diagnosis and recommendation. G1 respondents submitted ten samples annually on average, while G2 submitted three samples and G3 submitted 0.6 samples for insect identification (Table 3). Group 1 respondents utilized diagnostic clinics more frequently for disease than insect identification (19 samples per year), but G2 and G3 still sent only four samples and one sample respectively.

Permanent records of pest monitoring allow growers to identify pests accurately, diagnose problems more efficiently, determine trends in pest populations and provide a good training tool for new employees. Group 1 (50%) and G2 (33%) reported counting the total number of insects more often than G3 (11%). Group 1 (70%) and G2 (48%) were more likely than G3 (19%) to keep permanent records of pest monitoring and take pictures of pests (G1 = 60%, G2 = 35% and G3 = 13%) (Table 3). Only 22–28% of respondents from other regions of the United States kept records.[6] Group 1 reported heavy reliance on a combination of record-keeping, pictures and professional identification of pests to support their scouting and monitoring efforts, whereas G2 utilized these techniques to a lesser extent, while G3 respondents did not utilize any of these IPM techniques. Even though G1 is performing these tasks frequently, all groups would benefit from increasing their record-keeping techniques, which indicates the need for training or tools such as computer or PDA applications to assist with this task.

3.3.1 *Monitoring techniques*

Monitoring pest populations can be an aid to scouting efforts by providing early detection of arthropod pests and plant diseases. Infrequent and inconsistent monitoring can leave growers with few choices beyond reacting to plant damage and outbreak levels of key nursery pests. Group 3 (97%) used visible symptoms on a plant as a monitoring technique more often than G1 (80%). Group 1 (60%) used sticky cards and tapes more often than G2 (25%) or G3 (15%) (Table 3). Almost no one used passive trapping techniques, including lures (e.g. pheromone) or baited traps (e.g. alcohol) (15 ± 3%). Sticky cards and traps are an easy way to determine low levels of key pest insects and to establish when flying adult insects have become active and entered the nursery.[16] For wood-boring insects and any soil-dwelling larvae, the plant damage inflicted may not be evident until a year after adults have been detected; therefore, trapping adults prior to egg-laying is a

Table 3. Percentage of respondents[a] within three practitioner segments using various techniques to begin monitoring for insects, diseases or weeds

Pest monitoring	Practitioner segment[b] G1	G2	G3
Follow a standardized sampling plan while scouting	90 ± 10 a	48 ± 8 b	32 ± 6 b
When damage was evident on plants, these were done			
Visually confirm whether or not insects or mites are present	80 ± 13 a	100 b	97 ± 2 b
Visually confirm whether or not disease is present	80 ± 17 a	98 ± 3 b	97 ± 2 b
When insects, mites or disease was present, these were done			
Verify that the insect/mite is the causal agent of damage	80 ± 13 a	100 b	93 ± 3 ab
Verify that the disease is causing the symptoms	80 ± 13 ab	98 ± 3 a	80 ± 5 b
Count the total number of insects/mites present	50 ± 17 a	33 ± 8 a	11 ± 4 b
Determine whether natural enemies are present	30 ± 15 ab	48 ± 8 a	22 ± 5 b
Keep permanent records of pest monitoring	70 ± 15 a	48 ± 8 a	19 ± 5 b
Take pictures of the pests	60 ± 16 a	35 ± 8 a	13 ± 4 b
On average, how many times a year have you sent a plant sample to a plant diagnostic clinic to determine the name of a disease	19 ± 2 a	4 ± 0.5 b	1 ± 0.1 c
On average, how many times a year have you sent a plant sample to a plant diagnostic clinic to determine the name of an insect or mite	10 ± 4 a	3 ± 0.4 b	0.6 ± 0.1 c
Monitoring techniques used			
When a visible symptom appears on a plant	80 ± 13 a	90 ± 5 ab	97 ± 2 b
Sticky cards or tapes	60 ± 16 a	25 ± 7 b	15 ± 4 b
Growing degree day accumulation	40 ± 16 a	40 ± 8 a	9 ± 3 b
Phenology of host or indicator plants	40 ± 16 ab	65 ± 8 a	27 ± 5 b
Highly susceptible bait, trap or indicator plants	20 ± 13 ab	35 ± 8 a	18 ± 4 b

[a] Respondents were asked whether they performed the task 'always', 'often', 'rarely' or 'never', and responses for 'always' and 'often' were pooled into the percentage of respondents in each practitioner segment performing the task.
[b] Values with similar letters within rows are not significantly different at $P < 0.05$.

key step towards effective management of concealed pests. As an example, adult flat-headed apple tree borers (*Chrysobothris* sp.) emerge in spring and lay eggs, after which larvae tunnel under bark to overwinter. These life stages are difficult to detect and to control. When adults emerge the following spring, and as damage becomes evident, it is too late to provide crop-saving control. Simply waiting for damage to appear before beginning to scout is not going to limit tree injury. Indeed, borers were ranked as the top problematic pest at nurseries by growers in the southeastern United States.[16]

Growing degree day measurements can indicate when pests become active, and these data can stimulate scouting activity, especially when combined with sticky traps or other monitoring devices. Group 1 (40%) and G2 (40%) respondents reported using growing degree days more frequently than G3 (9%) respondents. Group 2 (65%) growers used phenology of host (or indicator) plants as often as G1 (40%), but more frequently than G3 (27%). Similar results were reported among groups when using highly susceptible bait or trap plants to monitor pests (G1 = 20%, G2 = 35% and G3 = 18%) (Table 3). These results are similar to those of producers in other parts of the United States.[6] In spite of availability of many websites, documents and publications devoted to these monitoring practices, they are not used by growers frequently. These techniques require extra steps for collecting and analyzing data, yet their effectiveness is invaluable. Directed efforts are needed to develop simple and efficient monitoring techniques, and extension workshops are needed to introduce and implement these strategies into nursery operations.

3.4 Pest management decision-making

3.4.1 Insect management

All groups reported that they evaluated how negatively plants were affected (severity) (94 ± 2%), and how often the pest was observed in the process of scouting (incidence) (85 ± 3%) when deciding to implement control tactics. Growers also determined whether the life stage of the pest that was present was one that caused harm to the plant (78 ± 4%), as well as whether or not the pest was expected to be a problem for the next plant owner (82 ± 4%). All groups relied less on the calendar (time of year) to determine whether they should actively intervene to manage pests (55 ± 4%).

Group 1 (70%) and G2 (58%) used anticipated date of sale more often than G3 (31%) to decide whether intervention was necessary (Table 4). This question was intended to represent a hypothetical scenario in which a leaf-feeding pest was present in summer, but deciduous plants would not be sold until winter. In such cases, neither the pest nor the leaves would be present when plants were sold, and no management action would be necessary. In a contrasting scenario, if similar pests were present in summer, and plants were anticipated to sell in fall, then action might be necessary to manage pests.

Group 1 (80%) and G2 (68%) used recommendations from plant diagnostic clinics to make pest management decisions more often than G3 (34%), which underscores the relative use of this tool by each group (Table 4). Group 2 (80%) was more likely to use either economic or damage thresholds than G3 (55%), while G1 (80%) was similar to both groups (Table 4). Economic or damage thresholds (the cost of treatment versus the amount of damage

Table 4. Percentage of respondents[a] in each practitioner segment using information to determine whether intervention will be needed to manage pests

	Practitioner segment[b]		
Decision-making	G1	G2	G3
Information used to determine whether intervention is necessary to manage insects/mites			
Recommendation from a plant diagnostic clinic	80 ± 13 a	68 ± 8 a	34 ± 6 b
Economic or damage threshold	80 ± 13 ab	80 ± 6 a	55 ± 6 b
Date of sale	70 ± 15 a	58 ± 8 a	31 ± 5 b
Phenology of host or indicator plants	60 ± 16 ab	65 ± 8 a	45 ± 6 b
Information used to determine whether intervention is necessary to manage plant diseases			
Recommendation from a plant diagnostic clinic	100 a	68 ± 8 b	36 ± 6 c
Economic or damage threshold	90 ± 10 a	73 ± 7 a	53 ± 6 b
Calendar day or time of year	90 ± 10 a	68 ± 8 a	49 ± 6 b
Date of sale	80 ± 13 a	58 ± 8 a	32 ± 5 b
Phenology of host or indicator plants	70 ± 15 ab	70 ± 7 a	39 ± 6 b
Information used to determine whether intervention is necessary to manage weeds			
If the weed is a persistent problem	100 ab	100 a	88 ± 4 b
Source of weeds (non-crop areas or property edge)	100 a	65 ± 8 b	57 ± 6 b
Species of weed found	90 ± 10 a	88 ± 5 a	70 ± 5 b
If the weed is in a stage that produces easily	90 ± 10 ab	95 ± 3 a	77 ± 5 b
If the weed is in a vulnerable part of its life cycle	80 ± 13 a	78 ± 7 a	47 ± 6 b
Calendar date or time of year	90 ± 10 a	90 ± 5 a	61 ± 5 b
Date of sale	90 ± 10 a	63 ± 8 a	32 ± 5 b

[a] Respondents were asked whether they performed the task 'always', 'often', 'rarely' or 'never', and responses for 'always' and 'often' were pooled into the percentage of respondents in each practitioner segment performing the task.
[b] Values with similar letters within rows are not significantly different at $P < 0.05$.

the plants can withstand and still be salable) require information about the type and number of insects present, the percentage of plants infested, the relative presence or absence of beneficial insects and the time of year, and a working knowledge of tolerable limits of damage to crops.

Unfortunately, no formal thresholds have been developed for plants under woody ornamental nursery production.[7] Nevertheless, customer tolerance of any damage is near zero,[17,18] so rough estimates of aesthetic thresholds, based on their own experience, are used more often by growers to determine when to intervene. Among apple growers, McDonald and Glynn[19] measured the adoption of IPM practices and found that 86% of growers self-reported using pest thresholds as part of their decision to intervene and manage insects, yet only 17% waited until the threshold was reached before applying pesticides. A more common occurrence (38%) was keeping the threshold in mind on the basis of experience.[19]

3.4.2 *Plant disease management*

All groups used severity (87 ± 3%) and incidence of plant disease (85 ± 3%) to determine whether intervention was warranted to manage plant diseases. If soilborne diseases are present, and symptoms are manageable in the nursery, plants can still be sold. Plant health, however, may not decline until plants have been established in the landscape and become stressed. All groups took this into consideration when intervening for disease control (84 ± 3%), and it appears that growers are very conscious about not knowingly selling diseased plants.

Plant disease management actions were directed by recommendations from plant diagnostic clinics more often for G1 (100%) than for G2 (68%) or G3 (36%). Group 1 (90%) and G2 (73%) both used economic or damage thresholds more often than G3 (53%) (Table 4). This was also true for calendar day or time of year. Group 2 (70%) used host plant phenology (or indicator plants) similarly to G1 (70%) and more often than G3 (39%). Few respondents used disease prediction software (e.g. Maryblyt) (7 ± 2%). As with insect pests, growers are more likely to rely on visual symptoms, phenology based on personal experience and professional identification than technology to guide management actions.

3.4.3 *Weed management*

All groups used weed incidence (95 ± 2%) and severity (91 ± 3%) to determine whether intervention was necessary to manage weeds. Respondents also considered whether the weed would be a problem for the next owner (71 ± 4%). Groups 1 (100%) and 2 (100%) considered whether the weed was a persistent problem more frequently than G3 (88%) (Table 4). Group 1 (100%) evaluated the source of weeds more often than G2 (65%) or G3 (57%). Both G1 (90%) and G2 (88%) identified the weed species and determined whether the weed was in a vulnerable life stage (G1 = 80% and G2 = 78%) more often than G3 (70% and 47%). Groups 2 (95%) and 1 (90%) determined whether the weed was close to reproduction, but G2 considered this more often than G3 (77%). Groups 1 and 2 used calendar date and time of year (90%) and considered date of sale (90% and 63% respectively) more often than G3 (61%, 32%) when determining how to manage weed infestations (Table 4).

A total of 80% of respondents wait until weeds appear before they initiate active scouting. This may be because weeds have a longer perceived window for control than other pests. However, weeds are harder to control post-emergence than pre-emergence.

Groups 1 and 2 utilized more preventive options than G3 to inhibit weed growth. Preventive measures reduce infestations and may also increase the flexibility of respondents to manage problems when they arise.

3.5 Management actions and direct intervention

When intervention was necessary to manage insects or mites, all of G2 (100%) and G1 (100%) chose insecticides, in contrast to G3 (86%), and all groups reported selecting the least toxic alternative (71 ± 4%) (Table 5). Group 2 (98%) alternated pesticide mode of action (MOA) to avoid resistance similarly to G1 (100%) and more often than G3 (84%). Group 1 (90%) was similar to G2 (68%) but more likely than G3 (55%) to spot-treat within a crop. A high percentage of all groups (88 ± 3%) applied a broadcast treatment to the entire affected crop, and fewer reported spraying the entire nursery (28 ± 4%).

A small percentage among groups adopted the use of natural products (11±3%), released beneficial insects (6±2%) or predatory mites (3 ± 2%) or applied entomopathogenic nematodes (2 ± 1%). Group 1 (70%) was more likely to discard plants compared with G2 (43%) and G3 (35%). Only 10 ± 3% of respondents stated that they did nothing and let the pest population self-correct.

When intervention was necessary to control plant diseases, 79 ± 4% of respondents applied a chemical pesticide. About 60 ± 4% chose a least toxic alternative, and 81 ± 4% alternated pesticide MOA to avoid resistance. Groups 1 (80%) and 2 (58%) used horticultural oils more often than G3 (38%) (Table 5). Although biological controls for plant pathogens were used infrequently by both G1 (30%) and G2 (13%), these groups reported greater use than G3 (4%). Only a small portion of respondents chose not to intervene (7 ± 2%) to control plant disease. Group 1 and 2 respondents utilize spot-spraying, which can be used when pests have been located and are limited to a portion of a crop.

When intervention was necessary to manage weeds, all groups hand-weeded (83 ± 3%). Groups 1 (90%) and 2 (73%) were more likely to apply a spray mix of broad spectrum and pre-emergence herbicides than G3 (54%) (Table 5). Group 1 (50%) was more likely than G2 (13%) or G3 (15%) to discard plants, and a small group of respondents chose not to intervene (2%).

Overall, ornamental nursery growers report using very few biological control agents in the southeast or elsewhere in the United States.[6,7] This might be explained by the lack of efficacy data in diverse nursery crops and production systems. In addition, biological control agents often require specific and different application procedures to those employed for pesticides. For example, the application of entomopathogenic nematodes requires continuous air agitation, rather than mechanical agitation, in cool (20 °C) (68 °F) water for efficacy.[20] Effective biological control also requires deliberate scouting to catch pest infestations early, which is time and labor intensive. As a consequence, growers may perceive that pesticides constitute the only cost-effective management option available.

3.6 Perceived limitations to nursery IPM

Respondents were asked about factors that might limit their use of IPM in their nursery. There were no differences among groups for any of the suggested factors, so a descriptive sketch is reported. It was established that 50% or more of respondents believe their implementation of IPM is constrained by the availability (53 ± 4%) and effectiveness of alternatives to chemical controls (61 ± 4%), by the availability of research comparisons between alternative and chemical controls (60 ± 4%) and by lack of information on the effective use of new, less toxic insecticides (60 ± 4%) and knowledge regarding specific scouting protocols needed to monitor diverse nursery pests (52 ± 5%), which is similar to the factors limiting IPM by respondents in Sellmer *et al*.[7]

From 2000, when Sellmer *et al*.[7] conducted their survey, to 2009, when the present survey was done, grower adoption of IPM remained constrained by the availability of alternatives to chemical controls. In spite of this perception, the availability of alternatives to broad-spectrum insecticides has increased in the last 10 years, but a need remains for research and demonstrations that compare the efficacy of alternative methods with traditional chemical controls. Moreover, a comprehensive information source is needed in both digital and print formats to inform nursery growers about effective pest management alternatives, less toxic chemical controls, specific scouting methods for pests and pest

Table 5. Percentage of respondents[a] in each practitioner segment choosing among intervention practices perceived as necessary to manage pests

	Practitioner segment[b]		
Intervention	G1	G2	G3
When intervention is necessary to manage insects/mites, these practices are used			
Insecticidal products	100 ab	100 a	86 ± 4 b
Discard plants	70 ± 15 a	43 ± 8 b	35 ± 6 b
Spot-treat within a crop	90 ± 10 a	68 ± 8 ab	55 ± 6 b
Alternate pesticides to avoid resistance	100 ab	98 ± 3 a	84 ± 4 b
When intervention is necessary to manage diseases, these practices are used			
Horticultural oils	80 ± 13 a	58 ± 8 a	38 ± 6 b
Biological controls (Plantshield)	30 ± 15 a	13 ± 5 ab	4 ± 2 b
When intervention is necessary to manage weeds, these practices are used			
Tank-mix spray applications of a broad-spectrum herbicide and a pre-emergence herbicide	90 ± 10 a	73 ± 7 a	54 ± 6 b
Discard plants	50 ± 16 a	13 ± 5 b	15 ± 4 b

[a] Respondents were asked whether they performed the task 'always', 'often', 'rarely' or 'never', and responses for 'always' and 'often' were pooled into the percentage of respondents in each practitioner segment performing the task.
[b] Values with similar letters within columns are not significantly different at $P < 0.05$.

Table 6. Percentage of respondents from each practitioner segment that agreed[a] with the following statements concerning pest management and use of IPM

Statement	Practitioner segment[b]		
	G1	G2	G3
IPM practices would save my nursery money	100 a	83 ± 6 a	72 ± 5 b
IPM practices allow labor to be used more efficiently at my nursery	100 a	80 ± 6 ab	68 ± 6 b
There are alternatives to chemical pesticides that are as effective in controlling diseases	70 ± 15 a	35 ± 8 b	42 ± 6 b
Using natural enemies to control key pests is cost effective	50 ± 17 a	23 ± 7 b	39 ± 6 ab

[a] Growers were asked on a five-point Likert-type scale whether they strongly agree (1), agree (3) or strongly disagree (5) with a few statements concerning pest management and the use of IPM. Their responses were combined into one value termed 'agree' by averaging those responses from category 1 (strongly agree), 2 and 3 (agree).
[b] Values with similar letters within columns are not significantly different at $P < 0.05$.

predators and providing real-world testimonials about successful IPM applications in peer-grower operations.

3.7 Grower attitudes about current nursery IPM

Respondents were asked whether or not they agreed with statements about IPM costs and effectiveness, to determine how their perceptions of IPM may have affected their behaviors and implementation. A total of 35 ± 4% of all respondents believed that alternatives to chemical pesticides were equally as effective in controlling insect pests. When asked if there were alternatives to chemical pesticides that were as effective in controlling diseases, G1 (70%) agreed more often than G2 (35%) and G3 (42%) respondents (Table 6). Few respondents agreed that alternative controls to chemical herbicides were as effective for managing weeds (31 ± 4%). Half of G1 (50%) agreed that using natural enemies to control key pests was cost effective, in contrast to G2 (23%). Nevertheless, the perception of uncertainty associated with natural enemies as a control component in IPM has led many growers to apply insecticides.[9] Zalucki *et al.*[9] suggested that very little research had been conducted to show the feasibility or impact of using natural enemies in a given agricultural system, and that the research and extension community might be emphasizing their adoption too strongly as an ideal component of IPM. Moreover, other aspects of IPM need to be adopted first, including more deliberate scouting early in production, counting the number of insects present and determining the initial incidence and severity of diseases, scouting for and identifying natural enemies and improving cultural conditions to conserve beneficial insects prior to introducing beneficial insect populations as a pest control method.

In spite of reliance on chemical options to manage pests, a majority of respondents do not agree that monitoring pests and reducing pesticide use is too costly to implement (31 ± 4% agree). A high percentage agree that IPM practices benefit the environment (90 ± 3%), and that using fewer chemical pesticides would reduce risks to non-target organisms (birds, fish, etc.) (81 ± 4%), employees (80 ± 4%) and customers (70 ± 4%). Yet, only half agree that advertising the business as 'sustainable' or 'organic' could increase profits (50 ± 5%). Group 1 (100%) and group G2 (83%) agree more often than G3 (72%) that IPM could save their nursery money. Moreover, G1 (100%) has greater belief than G3 (68%) that IPM practices allow nursery labor to be used more efficiently. Such stated beliefs, however, are not reflected in the IPM behaviors reported by these groups. For example, not all growers use monitoring, scouting, identifying pests and choosing appropriate controls early in the pest infestation period, which reduce labor and input costs over the entire production cycle. The discrepancy underscores a need for economic assessments of IPM with demonstrated on-nursery components that quantify savings in labor and pesticide use, with reduced incidence of plant damage.[11]

3.8 Grower information sources and opportunities for professional development

When seeking knowledge about plant pests from reference materials, all groups used reference books in their office (87 ± 3%). Groups 1 (100%) and 2 (78%) supplemented that information using the World Wide Web more often than G3 (62%) (Table 7). Group 1 (90%) utilized state ornamental pest management guides more often than G2 (55%) or G3 (50%), and gained knowledge from a plant disease and insect clinic more often than the other two groups (G1 = 80%, G2 = 33% and G3 = 18%). G1 and G2 both utilized professional association publications (G1 = 80% and G2 = 55%) and trade journals, such as *Nursery Management* (G1 = 80% and G2 = 85%), more often than G3 (22% and 57% respectively). However, G1 (50%) was less likely than G2 (90%) or G3 (86%) to utilize timely reference materials, such as *Pest News*, from cooperative extension. Additional sources of information for all groups included plant disease and insect pocket guides (50 ± 5%), state Department of Agriculture inspectors and publications (49 ± 5%), state commodity association publications (42 ± 4%), control/pesticide guides from other states (36 ± 4%) and newsletters from outside their state (30 ± 4%).

When gaining knowledge or advice via person-to-person contact, all groups chose to communicate first with other growers (83 ± 3%). Group 1 (60%) spoke more often with crop consultants than did G2 (20%) or G3 (16%) (Table 7). Approximately half of all respondents contacted salespeople or representatives from chemical companies or distributors (56 ± 4%), or contacted an extension agent either by telephone (50 ± 5%) or e-mail (46 ± 4%). Group 2 (43%) was more likely than G3 (24%) to subscribe to a listserve, and almost one-third followed a pest management weblog (blog) (27 ± 4%). All groups attended professional development opportunities; however, the overall percentage was low. The most frequent opportunity for learning was on-site troubleshooting with a county agent, consultant or pest expert (44 ± 4%), followed by attending either 1 day meetings (38 ± 4%), multiday workshops sponsored by Cooperative Extension or state commodity group tradeshows (38 ± 4%), university field days (31 ± 4%), evening meetings (30 ± 4%) or pest education

Table 7. Percentage of practitioner segments[a] (percentage of operations) that gained knowledge about plant pests from various sources

	Practitioner segment[b]		
Information source	G1	G3	G2
Searching the World Wide Web	100 a	78 ± 7 ab	62 ± 6 b
Your state's ornamental pest management guides	90 ± 10 a	55 ± 8 b	50 ± 6 b
Trade journals (*Nursery Management & Production*, etc.)	80 ± 13 ab	85 ± 6 a	57 ± 6 b
A plant disease and insect clinic	80 ± 13 a	33 ± 8 b	18 ± 5 b
Other professional associations or publications	80 ± 13 a	55 ± 8 a	22 ± 5 b
Printed-paper materials such as newsletters, factsheets and pest management updates from cooperative extension	50 ± 17 a	90 ± 5 b	86 ± 5 b
Crop consultants	60 ± 16 a	20 ± 6 b	16 ± 4 b
Subscribing to an e-mail listserve	20 ± 13 ab	43 ± 8 a	24 ± 5 b

[a] Respondents were asked whether they performed the task 'always', 'often', 'rarely' or 'never', and responses for 'always' and 'often' were pooled into the percentage of respondents in each practitioner segment performing the task.
[b] Values with similar letters within rows are not significantly different at $P < 0.05$.

meetings held at other nurseries (27 ± 4%). The fact that G2, and G3 to a lesser extent, utilized cooperative extension almost exclusively validates ongoing efforts to reach these groups with new information, pest management materials and professional development opportunities to improve IPM adoption and retention. In other IPM programs, the ability to affect change was associated with the extent of interaction among stakeholders and those working to affect change.[21]

Low enrollment by growers at most educational outreach opportunities is an obstacle to educating growers about IPM. In addition, university field days highlighting research have become limited in southeastern US states, owing in part to lower operating budgets, faculty and support staff reductions and the increasing costs of conducting research operations. Will enrollment increase as webinars and other online synchronous or asynchronous content delivery become more available? Currently, a low percentage of growers use the Internet for most of their education, although this may change over time if the Internet becomes a primary delivery method.

4 CONCLUSIONS

4.1 Summary of group assessments

Respondents clustered in the present analysis into G1 used IPM practices more frequently than other groups at various levels of the IPM continuum. For example, they were more likely to employ preventive practices such as sanitizing of clippers and pots, quarantining of incoming plants and scheduled applications of pre-emergence herbicides over the nursery to reduce pest problems in the future. Likewise, they were more likely to scout pests using a standardized sampling plan and monitor pests using sticky cards and permanent records rather than wait for plant damage to appear before scouting. Moreover, this group submitted more samples to a diagnostic clinic to determine pest identification and used the recommendations of the diagnostic clinic in their decision-making process to intervene. When control was necessary, respondents in G1 were more likely than the other groups to select reduced-risk pesticides and employ them in a more judicious manner, such as spot-treating small areas. These practices reflect a greater understanding and appreciation of the potential benefits of IPM for the health of their business, workers and the environment.

Unfortunately, G1 respondents represented just 8% of all participants, and most growers surveyed fell into G2 (32%) or G3 (60%). In spite of differences in stated action and philosophy, many practices employed by G2 growers overlapped with those classified as G1. Respondents in G2 utilized important components of IPM, for example phenology of host plants, growing degree days, identifying natural enemies and keeping records of monitoring, but did so less consistently. Businesses employing respondents in G2 had similar gross sales as those in G1, but employed fewer workers. Even though fewer employees may mean less emphasis on IPM, G2 did believe that IPM practices allowed labor to be used more efficiently at their nursery. This is good news, because G2 was also most receptive to extension training, which, combined with their relatively high appreciation for IPM, makes them the group for which extension agents could affect the most change.

G3 respondents generally used IPM tactics much less often and had a worse impression about anticipated benefits from adopting IPM than those in G1. This contrast was most apparent in prevention, scouting and monitoring techniques and sources to retrieve information. Additionally, businesses employing respondents of G3 had been operating for less time, with fewer employees, and had lower gross revenues compared with G1 and G2. Those in G3, however, shared a similar affinity for information and opportunity for learning as those in G2. The present snapshot suggests that, by 2009, growers at many nurseries in the southeastern United States had not adopted several principles of IPM, and that G3 respondents were more likely to be found at businesses that had not been in business as long as nurseries employing G1 and G2 respondents. Therefore, an emphasis by cooperative extension over time may improve knowledge about and adoption of more IPM principles by G3.

4.2 Final thoughts and future directions

Among the present cumulative pool of survey participants it was possible to recognise that different adoption levels for IPM exist between practitioner segments, particularly with regard to scouting and monitoring behaviors. Many respondents stated that they scouted plants for pests, but results suggest that scouting methods need improvement. The actual time needed to scout may not change among groups. More deliberate scouting methods might need to be adopted, however, in order to obtain information in a timely manner, which, in turn, would provide a series of management options rather than simply waiting to apply chemical pesticides. Moreover, pest monitoring practices such as pheromone lures, traps and sticky cards remain underutilized. These invaluable and passive monitoring devices can serve almost as another employee for detecting insect pests. Conceptual monitoring techniques, such as growing degree days and phenology of host plants, are equally underutilized in the southeastern United States. Both of these monitoring techniques would aid respondents in first stimulating scouting behavior and then targeting that labor toward specific pests rather than waiting for damage to occur prior to taking corrective action.

Nursery-based IPM involves decision-making processes that coordinate knowledge of pest biology, environmental information and available technology in combination with biological, cultural, physical and chemical tools in optimized approaches to reduce economic, health and environmental risks.[5] The present survey validates the observation that virtually all growers use some nursery IPM components within their growing operation. Many growers, particularly those classified as G3, were unaware that many of the techniques they reported using did in fact constitute IPM practices. This highlights the necessity and ease of educating growers about IPM principles. Targeting G3 and G2 respondents with educational programming may provide a high-impact yield for IPM education programming.

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