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Stakeholder Vision of Future Direction and Strategies for Southeastern U.S. Nursery Pest Research and Extension Programming

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ABSTRACT. Extension and research professionals worked with a focus group of 10 nursery owners and managers across a five-state region (Georgia, Kentucky, North Carolina, South Carolina, Tennessee) in the southeastern United States to prioritize diverse nursery pests and production issues that are related to container and field production. A second focus group meeting, focused on technology, was followed by a survey that asked nursery growers to prioritize potential inputs and uses of information technology and the features they most valued, for example, that might be included within a nursery-specific mobile device application. The resulting prioritization highlights common challenges faced by growers across the southeastern United States in managing major plant diseases, arthropod pests, and weeds; as well as documenting emerging critical issues of nonpest related production issues, regulatory constraints, and technological needs. The focus group and survey format effectively identified grower needs that will help inform nursery producers and guide university Extension and research professionals, university administrators, industry associations, and state and federal government officials toward efficient resource allocation. These prioritizations explain the current state-of-need across a diverse agricultural industry segment and will help further refine future strategic action plans for nursery integrated pest management (IPM) and emerging critical nursery crop pest issues.

Key Words: application, integrated pest management, nursery crop, plant disease, technology

Nursery crop production and the maintenance of wholesale and retail nursery stock plants for ornamental landscape use is an important segment of U.S. agriculture, especially in the southeastern United States. Nursery production in the United States takes place on 365,631 acres, is responsible for $6.6 billion in annual sales, and employs tens of thousands of workers (USDA 2009). Within the United States, nursery production revenues as of 2009 exceeded that of key agronomic crops like tobacco and cotton. Despite efforts to protect the high value of nursery crops, the ornamental plant production and management (or "green") industry experiences extensive annual losses attributed to insect and plant disease pests. For example, losses to ornamental plant production systems in North Carolina alone were reported to exceed $91 million in 2004 (NCDA 2005). Losses attributed just to plant diseases in Georgia nurseries in 2007 were estimated to be $43.4 million (Martinez 2008). In both cases, losses from insect pests and plant diseases equates to roughly 10–15% of farm gate value.

Weeds also cause significant economic losses because of weed management expenses, as well as reduced plant growth resulting from competition with crops. Fretz (1972) reported that a single large crabgrass plant, *Digitaria sanguinalis* (L.) Scop., per container can reduce dry weight of Japanese holly, *Ilex crenata* 'Convexa' Thunb., by up to 60%. To manage weeds, nursery crop producers in the southern United States use three to six applications of preemergence herbicides each year, supplemented with hand weeding, which may have costly inputs for labor of between $2,389 and $5,506 per acre per year (Judge et al. 2004).

Pest management decisions are particularly challenging for nursery crop producers because of the tremendous diversity of plant species produced, potentially high initial product cost inputs, and intensive labor demands during the production cycle. For example, nursery liners (transplants) range in initial cost from 1 to $25 each, and after planting require significant management and manual labor (Jeffers et al. 2009, 2010). An individual commercial operation may grow just a few or in excess of several hundred plant taxa, with nearly 400 different genera (Yeager et al. 2007) and far greater numbers of individual plant species and hybrids produced industry-wide on an annual basis. These diverse taxa cannot be efficiently produced by applying uniform management for all cultural and pest control needs. As a consequence, skilled production managers who can group plants with similar management requirements are in great demand. The most efficient of these industry professionals often possess high levels of knowledge about sustainable crop production, complex multispecies system management, pest management, reentry interval restrictions, as well as quality expectations of the commercial market.

IPM techniques can assist nursery producers in reducing reliance on pesticides and can increase crop profitability in several ways. Proactive growers who scout and identify pest populations before outbreaks occur can limit crop losses and production costs by reducing the incidence of management actions and the proportion of crops requiring treatment. Scouting-based management also increases treatment efficacy by coordinating the timing of pesticide applications with treatment of susceptible pest life stages (Davidson et al. 1988, Stewart et al. 2002, South and Enebak 2006, Fulcher 2012). Despite these potential benefits, only a minority of growers practice IPM techniques frequently or consistently (LeBude et al. 2012). Green industry professionals who have not adopted IPM indicate misconceptions about the expense, difficulty, and time demands needed to implement efficient nursery IPM (Hoover et al. 2004, LeBude et al. 2012).

The recognition that ornamental plants nearing date of sale are subjected to a near zero consumer-tolerance threshold for pest damage, as well as any other factors that reduce visual plant quality material in wholesale or retail settings, has made it challenging for growers to understand how to best adapt IPM to their nursery production systems. Retail consumers strongly prefer healthy-looking plants and may be intolerant of even minimal damage (Sadof et al. 1987, Townsley-Brascamp and Marr 1995, Glasgow 1999). At point of purchase, more than half of consumers refused to accept azaleas that displayed azalea lace bug feeding injury to >10% of the shrub canopy, which corresponds to a little >1% actual leaf injury (Klingeman et al. 2000). Yet consumers also prefer reduced pesticide use during production and want to use low-maintenance plants in their landscapes (Gardner et al. 2003; Klingeman et al. 2004, 2006, 2009; Klingeman and Hall 2006). Growers may be able to increase their profit margins and production efficiencies if they can take advantage of these seemingly divergent points of view. For example, growers could apply graduated levels of pest management inputs across the multiseasonal and even multiyear crop production cycles as plants near prospective date of sale. Based on results from landscape IPM studies (Stewart et al. 2002), successful balance in production inputs with better knowledge about consumer willingness to accept different types or levels of esthetic pest injury, particularly among perennial crops, are expected to lead to substantial economic savings for growers.

Advances in technology transfer by using mobile applications and smart phone technology could simplify nursery and landscape IPM as well as management activities. Depending upon commercial grower and professional landscape manager desire and demand, tools could be developed that might integrate cultural task scheduling, pest monitoring and regional pest alerts, pesticide application and record keeping, even including treatment and efficacy history, arthropod pest, plant disease and weed diagnostics, and linkages to Extension-based fact sheets. Indeed, this concept has already been applied to pest management in turf systems via a Web app called "Turfgrass Management" and "Turf Management Lite" by research and Extension professionals in Georgia. Within 9 mo of launching the app, the subscription version and the free Lite version had 610 and 2,500 total downloads, respectively, with accessions in all 50 United States and 30 international countries (McCullough et al. 2011).

A regional group of Extension and research professionals from five important southeastern nursery-producing states was formed after personal contacts were initiated by A. Fulcher in October 2008. Original conversations were focused on changes in availability of formula IPM funding, which became the impetus for academics to pursue regional collaborative efforts to enhance funding and delivery of nursery crop programming. The group, which submitted and received a Southern Region IPM (SRIPM) Center grant to hold a nursery crop pest management strategic planning workshop, since has expanded and become formalized as the Southern Nursery IPM working group (SNIPM) and includes participants from seven southeastern states: Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, and Virginia. The SNIPM working group's interactions with growers have led to discussions and subsequent surveys intended to achieve key objectives including 1) documenting current trends in nursery IPM use by stakeholders, including perceptions about practices that have hindered grower adoption; 2) establishing baseline data for perceived pest control needs and pesticide use in nurseries; 3) assessing grower experiences with utility of individual IPM techniques in nursery crop production; and 4) using grower input to prioritize among projects and technologies that are expected to stimulate demand for nursery IPM tools and techniques. This report synthesizes data generated from the SNIPM working group's five-state nursery crop pest management strategic plan (Adkins et al. 2010a) and crop profile (Adkins et al. 2010b) and prioritizes SNIPM member's future time and resource investments. Focus group and survey efforts also yielded new insights on growers' most valued recommendations about ways that electronic information transfer can be integrated using contemporary technological applications and tools.

Process

A 2-day focus group session that was moderated by a facilitator, unaffiliated with developing the project outcome documents, took place on 30–31 July 2009 in Mills River, NC. Two growers from each participating state were invited to be part of the focus group and were selected to include container and field nursery growers of liners and finished shrubs and trees, and to broadly represent the respective state's nursery industry. Before the meeting, growers were asked to list and rank their top 10 pest arthropods, weeds, and plant diseases for container and field production systems and to identify other major issues affecting their commercial industry. At the meeting, the SNIPM team of coauthors described major production characteristics and current status for their state's nursery industry. Growers provided an overview of their individual nurseries. A general discussion on common pest problems and challenges to managing those problems followed. Growers identified specific concerns about emerging weed species, issues influencing arthropod, plant disease and weed management, and also discussed concerns about water rights and availability, contaminated irrigation water, and other nonpest issues. Grower-defined, premeeting pest rankings then were reviewed briefly, after which the facilitator assisted with time- and subject-moderated focus group discussions. Specifically, an initial open forum explored regional occurrences and challenges posed by the grower predefined top 10 lists of arthropod pests, plant diseases, and weeds. After participating in the conversation, growers next were asked to rerank individual arthropod pests by using a ballot system modified after Bens (2005). In this process, each focus group member was issued 10 votes and attributed relative pest status based on personal experiences with difficulty of control and pest prevalence. Within each pest type, all votes could be used on one pest or spread among several pest organisms. Not all votes had to be used (Bens 2005). Plant pathogens and weeds of field and container production were discussed and ranked separately. Finally, growers were led through time-moderated discussions to identify Extension, research, and regulatory priorities for insect, plant disease, and weed pest categories. Data were compiled, organized, and reformatted by the participating SNIPM team members to develop a five-state pest management strategic plan and crop profile for container and field nursery production (Adkins et al. 2010a,b).

In addition to technological initiatives identified during the 2-day Mills River session, a separate focus group discussion was conducted 26–27 July 2011 by the SNIPM working group at Clemson, SC. This second assessment was focused on technologies that could be used to assist growers and landscape management professionals with pest scouting and management, as well as scheduling common nursery management tasks. During the Clemson workshop, five participating nursery growers and landscape managers were shown features of a prototype version of a pest management decision-making application (e.g., supporting Blackberry, iPad, iPhone, and Android platforms) commonly referred to as an "app." A time-moderated and topic-facilitated conversation followed. Growers provided input about the displayed technology and offered their perceptions to SNIPM working group members about the characteristics they most desired related to future information delivery.

To better focus and prioritize SNIPM working group efforts in developing these new technological outreach applications, a short questionnaire was developed and sent to nursery producer listserves and emailed to members of professional associations in all five of the participating SNIPM states. Questionnaires also were provided to grower participants at the 61st Annual Meeting of the International Plant Propagators' Society Eastern Region, held 19–22 October 2011 in Louisville, KY; the 36th Annual Meeting of the International Plant Propagators' Society Southern Region, held 23–26 October 2011 in Valdosta, GA; and during a UT Eastern Region Nursery, Landscaping and Greenhouse program on 20 October 2011. Technology ranking and prioritization questionnaires were returned by 113 respondents and yielded 100 useable assessments. Tallies were made of number of times each option was indicated and responses that provided a numeric rank were used to prioritize the perceived importance of each option by yielding an average weighted rank value.

Results and Discussion

Based on the focus group discussions, several Extension and research initiatives were identified for research needs and Extension programming that would address key arthropod, plant disease and weed pests, as well as associated regulatory issues. Different priority rankings were developed for arthropods, plant diseases and weeds that negatively affect production efficiency in both container and field operations (Table 1). Priorities and initiatives spanned a broader than expected range of concepts, sometimes falling outside of traditional pest management concerns (Tables 2 and 3).

Prevalent Pests that Challenge Southern U.S. Ornamental Plant Producers. For arthropods, both difficulty to control and prevalence within production systems were assessed. Taken collectively, wood boring insects, which were broadly defined by growers to include flatheaded beetles (*Chrysobothris* sp.), granulate ambrosia beetles (*Xylosandrus crassiusculus* [Motschulsky]), and clearwing moths (Lepidoptera: Sesiidae), and mite and scale insects received 91 and 73%, respectively, of the total votes about difficulty to control and prevalence (Table 1). Scale insects, comprising species in various families, were ranked as the most prevalent arthropod pest and most difficult arthropod to control, followed by flatheaded and clearwing borers, granulate ambrosia beetle, and mites with emphasis on the spider mite group (Acari: Tetranychidae). Plant diseases identified by participants ranged from leaf spots and mildew, bacterial and fungal blights, root rots, and canker diseases (Table 1). Root rot pathogens (including *Phytophthora* spp., *Pythium* spp., and others) were the most highly ranked plant disease problem, followed by fungal leaf spots, powdery mildew, and downy mildew. Seven weed species were identified as most prevalent (Table 1). Spurge, woodsorrel, and bittercress were identified as the three most common weed problems of container nurseries. Yellow nutsedge was ranked as the most prevalent weed of field production; horseweed and crabgrass were ranked equally as the second and third most prevalent weeds. These weed rankings are consistent with results from the USDA IR-4 industry pest survey (Anonymous 2011).

Prioritizing Academic Research and Extension Investments. Research and Extension priorities identified by growers were very diverse and often discipline-specific (Table 2). When examined collectively, four common applied research priority themes emerged that could be described as stakeholder charges to university academics working with the commercial nursery industry and ornamental plant IPM. Because these initiatives are likely to vary across political boundaries, within diverse faculty appointment types, as well as in response to periodic shifts in emphases on regional management pressures, we chose not to assign stepwise priority to initiatives identified within each broad theme.

The first thematic area can be broadly described as a directive to demonstrate that nursery IPM functions best when applied in a whole-systems approach. Optimal approaches for designing a comprehensive nursery IPM program would require growers, researchers, and Extension personnel to consider not only the pests (insects, weeds, or pathogens) of concern, but also the physiological states of plants and environmental and cultural conditions within the cropping system (Table 2).

Growers already appear to place high value on education and training programs that are related to nursery scouting, pest identification, use of economically viable or potentially more environmentally sustainable pest management products (e.g., horticultural oils), nontarget effects, and phytotoxicity of pesticides. In discussions, growers wanted to learn more about ways to optimize pesticide application timing, enhance worker protection, alleviate plant stress, and tips on other best management practices. Growers stated that they would like pest management resources to be developed that integrate knowledge of how routine production activities, including cultural practices, can affect nursery crop susceptibility to pests. Guidelines also are needed that update knowledge about current container, pot-in-pot, and field production systems. Participants were hopeful that university, state, and federal programs would be continued that provide financial support for county Extension personnel (Tables 2 and 3).

Research initiatives that fit the whole-systems approach include studies that help explain how pesticides interact within the likely complex of arthropod pests in nurseries after treatments have been applied. Growers acknowledged that certain chemistries applied to

Table 1. Self-reported rankings of the key arthropod, plant pathogen, and weedy plant pests that are perceived to challenge management efficiency in container and field nursery production operations across the southeastern United States

Arthropod (taxon)	Difficulty to control[a]	Prevalence[b]	Ranked import	Plant pathogen (taxon)	Ranked import	Weed (taxon)	System[c]	Ranked import
Armored and soft scales (Coccidae and Diaspididae)	33	22	1	Root rots (*Phytophtora* and *Pythium* spp.)	1	Spurges (*Chamaesyce* spp.)	C	1
Wood boring insects (Buprestidae and Sesiidae)	22	19	2	Powdery mildew (various)	2	Bittercress (*Cardamine* spp.)	C	2
Granulate ambrosia beetle (*X. crassiusculus*)	18	18	3	Fungal leaf spots (various)	3	Woodsorrel (*Oxalis* spp.)	C	3
Mites (Acari)	19	13	4	Downy mildew (various)	4	Liverwort (*Marchantia* sp.)	C	4
Root grubs and weevils (Curculionidae)	6	3	5	Phomopsis (*Phomopsis* spp.)	5	Groundsel (*Senecio vulgaris*)	C	4
Caterpillars (Lepidoptera)	1	1	6	Black root rot (*Thielaviopsis* sp.)	6	Eclipta (*Eclipta prostrata*)	C	6
Leafhoppers (Cicadellidae)	1	8	7	Botryosphaeria (*Botryosphaeria* spp.)	7	Annual bluegrass (*Poa annua*)	C	7
Flea beetles (Chrysomelidae)	0	2	8	Cedar rusts (*Gymnosporangium* spp.)	8	Yellow nutsedge (*Cyperus esculentus*)	F	1
Japanese beetle (*P. japonica*)	0	6	9	Needle and foliar blights (various)	9	Horseweed (*Conzya canadensis*)	F	2
Aphids (Aphididae)	0	7	10	Fire blight (*Erwinia amylovora*)	10	Crabgrass (*Digitaria* spp.)	F	2

[a] Percentage of total votes cast ($n = 89$) indicating the difficulty of control as perceived by the focus group members.
[b] Percentage of total votes cast ($n = 79$) indicating how frequently focus group members encounter the pest.
[c] Ranking of the most prevalent weed species in container (C) and field (F) production systems, with '1' being most prevalent, important, or difficult to control. Weeds are ranked in each production system separately. Note: grower rankings for some species were equal.

Table 2. Research and Extension initiatives identified by stakeholders during 2009 and 2011 focus groups (adapted from Adkins et al. 2010)

	Research and Extension themes for nursery IPM			
	1. Apply nursery IPM within a whole-systems approach	2. Key pest biology: optimize pest monitoring and management tactics	3. Develop and adapt new technology and technology-transfer to practitioners	4. Assess economics and actual costs: validate benefits of adopting IPM
General operational initiatives[a]	Quantify differences in container- and field-grown plants and measure effects on pest susceptibility and pesticide efficacy (R)[b] Demonstrate relationships between production practices and pest pop dynamics (R, E) ● Pruning and fertilization timing and efficacy ● Water quality; conditioning, pH stabilization, pesticide solutions ● Cover crops, living mulches, and physical barriers to limit pests Optimize monitoring, scouting, and pesticide application timing to manage the pest complex (weeds arthropods, plant diseases) rather than individual pest species (R, E) ● Enhanced use of plant phenology indicators to predict seasonal activity ● Screen insecticides and formulations with reduced impacts on secondary pests, nontarget species, natural enemies, and pollinators ● Promote efficient pesticide applications, directed at susceptible pest life stages, to minimize risks and increase effectiveness	Develop training on pest scouting, early pest and disease detection and development, and use of action thresholds (R, E) Develop improved management guidelines, identification techniques and outreach literature, particularly for wood-boring insect pests and hard-to-control weed species (E)	Develop regional website to effectively distribute nursery IPM news and information (E) ● Develop a nursery scouting certification program, ideally delivered via distance education ● Develop pesticide efficacy tables that include mode of action, curative and preventative activity, re-entry interval, and label restrictions ● Increase use and access to digital diagnosis through county Extension ● Develop improved decision-aids and training to allow grower choice of the most appropriate, site-specific, integrated weed management option	Pesticide efficacy trials should include cost analyses and include generic products and formulations as alternatives (R)
Entomological, plant pathological, and weed science-based initiatives[a]	Survey current pest status of weeds in nurseries across the southeastern United States Investigate germination biology, seasonal development, and ecology of weeds in nurseries (R) Measure weed control with reduced preemergence (PRE) and postemergence (POST) herbicides (R) Assess long-term consequences, environmental persistence, and retreatment intervals for PRE and POST chemistries (R, E) Assess phytotoxicity of PRE and POST herbicides on diverse ornamental crop plants (R) Assess mechanisms of glyphosate damage, particularly related to tractor-mounted, shielded-sprayers in nursery crops (R)	Determine biology and host plant preferences of new and emerging nursery pests (R, E) ● Control of granulate ambrosia beetle (*X. crassiusculus*) after initial tree colonization ● Pest management options for soft vs. armored scales, determine life histories and assess application timing, efficacy on Japanese maple scale (*L. japonica*) and white peach scale (*P. pentagona*) ● Determine cause(s) and treatment options for *Cryptomeria* tip disorder, foliar nematodes, understand epidemiology and plant responses of *Thielaviopsis* sp. (black root rot disease)	Assess efficacy of novel and alternative pesticides and surfactants on key nursery pests (R, E) ● Assess surfactant relative efficacy and dose response ● Assess efficacy of bark-penetrant products against wood-boring pests ● Measure efficacy chemigation and other novel application techniques ● Develop systemic pesticides to control borer and scale insect pests ● Develop systemic pesticides to control borer and scale insect pests ● Develop new weed control technologies and herbicide formulations, including a controlled-release PRE herbicide ● Promote use of horticultural oils as inexpensive and environmentally safe alternatives	Develop more cost effective management strategies for fire ants (R) Develop and characterize economic thresholds for Japanese beetle (*P. japonica*) and compare costs to act on economic thresholds with management costs incurred to achieve regulatory compliance (R) IPM-based weed management recommendations should include more accurate cost accounting (including labor costs for hand-weeding) to make informed decisions on efficient resource utilization (R)

[a] Initiatives listed within each over-arching theme do not indicate a ranked order of importance.
[b] 'R', 'E', and 'R, E' indicate nursery IPM advancements would be made by either research- or extension-based projects or via a coordinated collaborative approach.

control a target pest species may enhance probability of secondary outbreaks for nontarget pests also present within the treated crop (Table 2). As an example, populations of some scale insects and mites can rapidly increase after pesticide treatments to trees intended to control granulate ambrosia beetles and potato leafhoppers, in response general cover sprays and municipal mosquito fogging programs (Roberts et al. 1973, Frank and Sadof 2011, Raupp et al. 2011, Szczepaniec et al. 2011). Other whole-systems research priorities included need to better understand how physiological differences in field-grown and containerized plants influence both susceptibility to pests and pesticide treatment efficacy (Table 2). Studies also were suggested that would determine effectiveness of alternative management options, such as cover crops, biological banker plants, living mulches, and physical barriers used to provide refuge for beneficial arthropods or prevent emergence of nursery weeds. Whole-systems research also was requested that would help determine how contemporary production practices (e.g., timing of fall fertilization and pruning) are likely to influence pest biology, host plant susceptibility to pests, and consequent pesticide efficacy (Table 2).

Grower-identified objectives for the second thematic area can be collectively grouped within a need to better understand key pest biology (including arthropods, plant pathogens, and weeds) and to improve monitoring techniques to preemptively scout for these pests. Several difficult-to-control and nonnative arthropods, plant pathogens, and weeds are recognized as specific challenges that limit efficiency in field and container nursery systems and so are likely to be hindering

Table 3. Regulatory issues identified in 2009 and 2011 evoking concerns among nursery producers in the southeastern United States (adapted from Adkins et al. 2010)

	Regulatory issues related to nursery IPM
	Nursery research and Extension personnel should work with state and Federal regulatory officials to:
Water quality and availability concerns[a]	Address issues related to the legality for use of hydrogen peroxide to sanitize irrigation water
	Address issues related to chlorine availability, use, management and storage (e.g., concerns posed by Department of Homeland Security)
	Clarify future intent regarding irrigation water, particularly related to regulations that would affect water availability, quality, and requirements for monitoring and managing ground water, nursery runoff, etc.
Entomology and plant pathology concerns	Clarify any future regulatory actions planned to limit the spread of *P. ramorum* that would be expected to impact the commercial viability of ornamental oak production in nurseries
	Continue to address worker protection safety and economic issues leading to optimized quarantine treatment alternatives, specifically for fire ants (*Solenopsis* spp.) and Japanese beetles (*P. japonica*)
General commercial nursery industry concerns	Ensure that regulators identify ornamental production as an important agricultural industry and critical contributor to state and national economies

[a] Initiatives listed within each grower-identified concern category do not indicate a ranked order of importance.

grower adoption of nursery IPM. The armored scale insects, *Lopholeucaspis japonica* (Cockerell) and *Pseudaulacaspis pentagona* (Targioni-Tozzetti) were directly identified as warranting further research on their biology and management (Table 2). Such studies on arthropod biology should emphasize host plant feeding preferences as well as detection of overwintering sites. Improved wood boring insect identification tools and the development of a plant phenological indicator predictive model were also priorities identified for improving pest monitoring techniques. A survey of nursery system-specific weed species within a regional context, as well as studies related to weed biology (including development of predictive models for germination of key weeds), were suggested. The need to study pathogen biology and strategies for management of *Cryptomeria* tip disorder and black root rot also were identified specifically as top research priorities by growers (Table 2).

In the third theme identified, several projects were recommended by which academics should develop and adapt new technologies and improve technology-transfer to better share advances in nursery IPM, thus making pest scouting and monitoring techniques easier to adopt (Tables 2, 4, and 5). Growers want rapid access to information about the latest improvements to scouting and monitoring tools, as well as recent developments in pest identification and diagnostic aids and pest resistance management tools. Growers also wanted to know more about the duration of pesticide performance, the performance of alternative pesticide application technologies and techniques, and are concerned about finding ways to limit incidence of off-target mortality to beneficial insects resulting from pesticide use. In broad terms, growers would like the SNIPM working group to develop effective and economically viable management strategies that can reduce reliance on chemical pesticides.

Growers specifically identified the need for information about treatment efficacy and novel or alternative options for managing mites, potato leafhoppers (*Empoasca fabae* [Harris]); granulate ambrosia beetles; red and black imported fire ants (*Solenopsis* sp.); scale insects (in general, and also *L. japonica* and *P. pentagona*); foliar nematodes; *Cryptomeria* tip disorder; and black root rot (*Thielaviopsis* sp.) (Tables 1 and 2). Nursery growers were interested in possible ways to manage granulate ambrosia beetles once they have infested a nursery tree, despite generally being regarded as ineffective or impractical by the participating entomologists (Table 2). Several enhanced technologies and techniques also were proposed by growers as having potential for improving pesticide efficacy and delivery, including application of pesticides through chemigation systems, use of systemic insecticides for managing borer and scale insects, and use of surfactants and bark penetrants, particularly on large trees, to enhance insecticide efficacy. Insecticides that are effective against plant-damaging pests, yet have minimal impact on beneficial and pollinating insects, were identified as needing additional evaluation. Growers also desired research that would provide a better understanding about persistence of activity, formulation, application timing, application rate (particularly reduced rates that could be used closer to date-of-sale), and phytotoxicity of preemergence and postemergence herbicides (Table 2).

Grower participants identified county Extension agents and staff as critical support personnel for their businesses. Indeed, state and county Extension personnel continue to be viewed as the primary educators for agricultural industries, including commercial nurseries. In a companion survey, many growers from the five participating SNIPM states make frequent use of the diagnostic services provided by their respective state land-grant universities (LeBude et al. 2012). However, to facilitate timely sample processing and accurate pest identification to growers, focus group participants emphasized the need for easy access and use of digital diagnosis through the county Extension offices. Growers also requested that a regional website or clearing house of pest management information be created for information dissemination and communication (Table 2).

A fourth research theme, to ensure that nursery research studies include actual cost–benefit analyses and give growers a solid economic rationale to adopt nursery IPM, reflects a general desire for a more comprehensive understanding of the economics of pest management, particularly in efforts to control insect and weed pests. The prominent stakeholder demand that university personnel 'make IPM profitable and viable to nursery crop production' does indicate a clear need for academics to more effectively link recommended practice with real and measurable economic benefits in educational outreach.

Management or action thresholds permit a population of pests to be present within a crop, as long as the pest population does not increase to a level that triggers a management action to prevent both economic losses and reductions in esthetic value (Pedigo et al. 1986; Raupp et al. 1989, 1992). For ornamental plant production, esthetic condition of a crop nearing its date of sale, particularly in retail markets, is an essential characteristic of plant quality. Participating growers gave top priority to development of economically-based action thresholds for key insect pests including potato leafhopper and Japanese beetles, *Popillia japonica* (Newman). This priority, while rated as highly important by stakeholders, will require substantial research efforts to clarify. Growers also indicated need for more cost analyses, including estimated costs of handweeding, in developing recommendations for weed management in nursery production systems. The economics of generic pesticides was also of interest (Table 2).

It is important to recognize that the four strategic themes identified above are not mutually exclusive. For example, development of a plant phenological indicator model would require researchers to take a whole-systems approach by studying the phenologies of both plants and pests, in conjunction with monitoring environmental conditions, to develop a practical pest monitoring tool. Attempts to more appropriately time pest management activities would require that the seasonal biology of pests and plant pathogens be better understood. Development of any economic threshold, whether for granulate ambrosia beetles or other key nursery crop pests (Tables 1 and 2), also will require thorough understanding of pest biology, as well as availability of practical management tools, consumer expectations, and awareness of the economic components influencing profitability within field and container nursery systems.

Although not recognized to be generally outside the scope of direct academic influence, six regulatory issues also were identified as priority concerns by growers, with water regulations and water quality issues dominating the discussion (Table 3). Discussion of strategic initiatives about regulatory issues highlighted the misperception among commercial nursery growers that university academics play a direct and active role in establishing state and federal guidelines related to industry regulations. Regardless, 'numerous water issues' were described ranging among availability and quality of water, regulations (potential and current) effecting water access and use, and concerns about the use of hydrogen peroxide and chlorine as water sanitation tools. Regulations involving invasive pest species, particularly *Phytophthora ramorum* Werres, de Cock & Man in't Veld, red and black imported fire ants, and Japanese beetles, were also of great concern to growers. Indeed, growers do not feel that the fine points of details related to many invasive species regulations have been clearly presented to them, resulting in overall grower confusion and frustration about the exclusionary process. Finally, growers continue to urge their state professional associations and university peers to gain legislative recognition that ornamental plant production remains a vital segment of the U.S. agricultural economy (Table 3).

Integrating Progressive Technologies to Facilitate Nursery IPM. Grower participants at the Mills River, NC and Clemson, SC workshops identified a list of 12 desirable features that should be included within future technological outreach applications under development. These features were further evaluated by >113 growers from within the SNIPM region who were participants in regional workshops during Fall 2011. Respondents returned 100 usable questionnaires designed to help prioritize SNIPM efforts related to these features (Tables 4 and 5). Among those surveyed, 58% of growers already own a smartphone or iPad and 34% indicated that they planned to buy a smartphone or iPad "within the next 6 mo" (data not shown). Growers ranked their top five most desirable options (Table 4). Of these, differences were apparent between tally counts noted for each option versus the ranked values volunteered about that option. For this reason, a weighted priority rank is given to help clarify the grower-perceived value of each listed option and its prioritization within the list. Both tally counts and weighted priority ranks are presented (Table 4).

Growers reported greatest interest in development of a real-time resource that would let them (electronically) submit the identities of pests, diseases, and weeds they are encountering into a community network of information that would be shared with other growers. Growers also valued efforts to develop a regional ornamental IPM calendar that could prompt growers to implement key pest monitoring, management, and nursery task actions. A resource that would help growers and Extension agents identify fungal and bacterial diseases in the field also was favored (Table 4). Growers were very interested in research and technology that could relate plant flowering phenology with information about key pest emergence and activity (Tables 2 and 4). The fifth most favored technological initiative was development of an email alert system for growers that would include key pest and disease photos and information about relevant management actions (Table 4).

Table 4. Prioritization for grower-identified technological initiatives identified in 2011 and intended to enhance nursery IPM in the southeastern United States

Focus group-identified technological initiative[a]	Tally[b] [Weighted sum, priority rank][c]
University Extension and Research teams should:	
Develop an online system for growers to notify other growers which arthropods, diseases and weeds they are seeing	53 [3.96, 1]
Develop a regional ornamental IPM calendar (e.g., that would incorporate action notes like, *"in middle of April, look for X pest or Y plant disease")*	72 [3.64, 2]
Provide growers and Extension agents with the ability to identify fungal and bacterial diseases in the field	40 [3.53, 3]
Integrate existing knowledge of plant flowering phenology with key pest emergence	37 [3.32, 4]
Develop e-mail alerts that include important action information and relevant pest or disease pictures	47 [3.15, 5]
Develop a regional nursery crop newsletter or newspaper article	24 [3.08, 6]
Develop a tool to log the history of key pest or disease activity within a larger geographic region	38 [3.00, 7]
Increase ease of using degree day information by integrating regionally available weather station data	23 [2.87, 8]
Integrate knowledge of pest developmental degree days with seasonal action tasks already on-going within the nursery	31 [2.81, 9]
Link information to update new technology and practices with the anticipated influence on pest and plant disease activity	38 [2.79, 10]
Help growers work with agents by showcasing information about what images are needed to help perform digital identification	27 [2.56, 11]
Create a one-stop resource to showcase nursery and landscape related information valid among several states	40 [2.55, 12]

[a] Technological initiatives were prioritized by asking the NC and SC focus group participants to identify their top 5 most desirable technological advances as identified in earlier focus group sessions.
[b] Tally counts represent the no. of times that grower respondents (n = 100) indicated that the listed initiative was included among their top 5 most desirable technological advances.
[c] Priority ranks, wherein "1" is perceived to have the greatest importance, were derived by summing self-stated grower importance rankings given for their top 5 most desirable technological advances and dividing that value by the respondent tally for each initiative.

Responding to a wish list of 12 technological initiatives and 11 functional characteristics that could be developed for a smart phone or tablet application, growers requested that the technology should include an index that would allow growers to search for information about key pests and pest management solutions. Growers most want the application to have a free trial offer period and want it to help them to create a nursery-specific pesticide treatment history record. The tool should provide users with an automated reminder to prompt initiation of specific activities for pest management. Growers also were interested in the capability of the program to interface with GPS technology for the purpose of monitoring plants and pest activity within multiple sectors of a nursery. Finally, the application should be able to quickly link to online Extension fact sheets and other documents relating to management strategies and information about the pests that growers are encountering (Table 5).

In summary, this focus group-based approach effectively combined prior experiential knowledge of nursery crop producers and

Table 5. Growers' perceived valuation in 2011 of functional characteristics considered for development of a smart phone and tablet application to assist with nursery-based IPM as identified by nursery producers in the southeastern United States

Focus group-identified technology function	Perceived value[a] [Priority rank][b]
Ability within the technology application to:	
Search for a key pest or tasks within the index	4.30 [1]
Have a free trial period	3.91 [2]
Build a nursery-specific pesticide record (or treatment history)	3.86 [3]
E-mail reminder (or treatment history) to oneself	3.80 [4]
Use GPS to "mark" plant or pest activity for future monitoring	3.79 [5]
Link to online Extension factsheets	3.79 [5]
Allow user to create their own photo album	3.49 [7]
Know identity and contact information of data contributors	3.39 [8]
Turn off an alert for a particular task	3.21 [9]
Track downloads by state, region, or individual	3.10 [10]
Include access to a chat room of app users	2.94 [11]

[a] Self-stated valuations were made by growers ($n = 100$) who were asked to characterize their respective interest or valuation of each functional option wherein, "1 equals would not buy or use, or not interested; 5 equals extremely interested, or would buy and use" the stated function.
[b] Priority rankings listed from 1 to 11 where "1" elicited the greatest interest.

facilitated discussion with Extension and research professionals to integrate one vision for identifying and prioritizing major pests of ornamental crops in both container and field nursery operations. The focus group also was able to assist in prioritizing, among diverse pest and production issues, those topics most critical for developing high-impact Extension programming and applied research initiatives across at least five southeastern U.S. states. Moreover, these grower-driven priorities will help refine future strategic action plans, including investment in and development of technological transfer tools. This multistate collaborative effort with stakeholders is expected to optimize resource allocation and enhance team building to achieve state and regional research and Extension objectives in nursery IPM.

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