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Survey of the Monitoring and Control Practices for Arthropod Pests by the Nursery Industry in Pennsylvania[1]

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Abstract

The effort to encourage the nursery industry to adopt IPM practices has met with varied success. In 2000, a survey was conducted to assess the monitoring and control practices for arthropod pests by the nursery industry in Pennsylvania, a state that ranks fourth in the nation in the number of certified nursery and greenhouse producers. Most respondents were the owner or partner of the operation and were responsible for the monitoring and pest management decisions for the firm. Most respondents reported that they identify the specific insect or mite when monitoring, but their ability to do this increased with their level of formal education. Most respondents did not keep permanent records of pest problems, although record keeping increased as total sales increased. Commonly reported cultural control practices included isolation of plants with pest problems for treatment, planting and selling plants hardy to the area, and selling resistant cultivars, although the use of these practices increased with more formal education. Over half of the respondents indicated that they often use cultural practices and select pesticides that conserve beneficial insects, yet 62% never release beneficials. Respondents that earned less than $50,000 in 1998 were least likely to spray whether pests were present or not or to characterize their use of chemical pesticides as 'often.' However, a majority of respondents reported that they 'often' use chemical pesticides (61%) and 'rarely' or 'never' use less toxic alternatives such as horticultural oils, insecticidal soaps, or natural products, with some exceptions; 55% of landscape nurseries and 47% of garden centers reported often using oils and natural products, respectively. Although the nursery industry in Pennsylvania has adopted several cultural practices that are important components of IPM, results from the survey indicate that demonstrations of and education about the use, cost-benefits, and efficacy of less toxic alternatives to chemical pesticides and release of beneficials for the control of insects and mites are needed to convince the nursery industry to increase their adoption of these IPM tactics.

Index words: ornamentals, pest management, green industry, biological control.

Significance to the Nursery Industry

The green industry is the fastest growing agricultural enterprise in the United States. Integrated pest management (IPM) has multiple advantages for the industry, but the diffusion of IPM is not nearly complete. Inter-institutional collaboration and a well-developed education program should help improve adoption. We suggest that demonstrations of and education about the use, cost-benefits, and efficacy of less toxic alternatives to chemical pesticides and release of beneficials for the control of insects and mites are needed to convince the nursery industry to increase their adoption of these IPM tactics. Also, education programs for the nursery industry should focus on areas where increased use of IPM practices is most likely. For example, due to the high level of public preference for non-traditional chemical control products and the fact that most plant material will be sold locally, use of natural products might offer more immediate benefits with less risk to a garden center than a production nursery, thus making the garden center more likely to implement this practice.

Introduction

According to the most recent census conducted by the National Agricultural Statistics Service of the USDA, Pennsylvania ranked fourth in the nation in the number of nursery and greenhouse producers with 3,744 operators, behind Florida, California, and Oregon (18). In addition, between 1992 and 1997, the number of green industry operations increased by 78% in Pennsylvania, compared to the national average of 43% (20). In 2000, the Pennsylvania Department of Agriculture (PDA) listed 2,687 certified nurseries operating on over 39,480 acres of land with 22,062,195 sq ft under glass. The nursery industry consists of certified nursery growers and nursery stock dealers. Operations may include garden centers, greenhouse production, hobbyists, landscape contractors, landscape nurseries, mail order businesses, and production nurseries.

The philosophy of integrated pest management (IPM) is to manage pests to tolerable levels through a combination of cultural, biological, and chemical control tactics with an emphasis on using the least toxic alternatives whenever possible while still making a profit (7). Thus, periodic monitoring for pests to assess plant health is a critical component of the IPM approach. Nursery specific pest management surveys were conducted at national (3, 4) and local (15) levels to investigate the IPM practices and chemical pesticide usage in the 1980s and 90s. The most recent surveys regarding the level of adoption of IPM practices in greenhouse operations were conducted nationally in 1994 (3), in the Midwest in 1996 (19), and in New York in 2000 (6). These surveys showed that most growers employed at least some IPM practices and were interested in learning more about IPM. Although, the green industry has been slower to adopt IPM principles and practices than some other agricultural commodities (10), a 1994 national survey suggested that there was a decrease in chemical use for insect and disease control and an increase in non-chemical insecticide use in the greenhouse and nursery industry between 1988 and 1993 (3). In 2000,

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we conducted a survey of the Pennsylvania nursery industry to assess their level of awareness and adoption of IPM practices; our goal was to identify specific areas for which research and extension program development are needed to further convince growers of the use and benefit of IPM practices (12, 13, 14). In this publication, we report the monitoring and control practices for insects and mites used by the nursery industry in Pennsylvania and discuss areas for which further education appears warranted.

Materials and Methods

A survey was developed in 1999 and mailed to 1,800 nurseries randomly selected from the 2000 certified nurseries mailing list compiled by the Pennsylvania Department of Agriculture (PDA), Bureau of Plant Industry. The survey, adapted from the Dillman method (2), was first mailed in February 2000. In April 2000, the same survey recipients received another copy of the survey, followed by a reminder postcard several weeks later. The 14-page survey consisted of 41 questions designed to assess awareness and implementation of IPM principles and practices, including scouting and record keeping practices; control and plant health care practices; perceptions of what limits the use of IPM practices; needs of the industry for information and education on IPM practices, and the resources used by the industry for pest management decision-making. Significant differences in monitoring and control practices among respondents as a function of education level, gross sales of the business in 1998, and type of business were examined using Chi-square analysis (21) unless otherwise noted.

Results and Discussion

Characteristics of the businesses responding to the survey. Of the 1,800 nurseries receiving surveys, 360 completed them resulting in a response rate of 20%, exceeding the benchmark response rate of 11% for direct mail surveys (9). Note that most respondents left some questions unanswered. The majority of respondents, regardless of their level of education, identified their business as production nurseries (18.4%), Christmas tree growers (14.6%), garden centers (11.7%), landscape nurseries (7.6%), and a category described as 'other' (47.7%) followed by a line to fill in the blank. 'Other' consisted of greenhouse operations (6%) cut flowers (<1%), or a combination of businesses, the majority of which were a combination of production nursery and landscaper (41%). Respondents with at least some college education were more likely to be from production nurseries, whereas those with a high school degree or less were more likely to be Christmas tree growers or operate a garden center ($\chi^2 = 53.2$, df = 24, $P = 0.0006$).

The majority of the firms had gross sales of less than $50,000 in 1998 (Table 1). The highest proportion of businesses grossing over $500,000 consisted of either greenhouse operations or combination businesses (especially nursery production and landscaper). Of those respondents that had the highest gross sales, the majority had at least some college education, with the largest group holding a Bachelor's degree (data not shown). The majority of respondents with less than a high school degree had the lowest sales.

On average, the firms that responded to our survey had been in business a mean of 18.2 ± 1.4 (SEM) years. In general, the higher the gross sales of the company in 1998, the longer the company had been in business. Landscape nurseries had been in business the longest (22.3 ± 5.4 years) and garden centers the shortest (14.9 ± 2.8 years).

Size of the firms that responded to the survey was assessed by total acreage occupied by the business and the number of employees working for the business. Nurseries that had higher gross sales tended to occupy more total acreage (14.0 ± 7.6 acres), although physical size of the firm's operation leveled off at sales over $100,000 (12.5 ± 2.8 acres). After that, having more space didn't necessarily translate into additional income. The number of employees working for these firms averaged 1.5 ± 0.03, but varied markedly, from 0 (one-person operations) to 300 (Table 2). Overall, there were more seasonal than full- or part-time workers. Combination businesses, production nurseries, and greenhouse operations had more seasonal employees than other firms. Not surprisingly, the greater the gross sales of the company, the more employees that worked for the company.

Demographics and responsibilities of the respondents. Of the respondents, the great majority (86%, 283), were the owner or partner of the operation. Only 10% (34) were the manager or supervisor of the business, while 2.8% (9) classified their role as operator, technical staff, or employee. Six surveys were returned with this question unanswered. Years of experience in the green industry ranged from 1–56, averaging 14.1 ± 0.8. In general, respondents without a high school degree or with a graduate degree had the fewest years of experience in the business at 7.1 ± 2.0 and 10.8 ± 1.7 years, respectively. The remaining respondents with a high school degree or at least some college education were more experienced, having worked in the green industry for 13–16 years. The vast majority of the respondents stated they make the IPM implementation decisions (91%) and the pest management decisions (93.8%) for their nursery regardless of size

Table 1. Gross sales of nurseries for 1998 by type of business.

Business type	Less than $50,000	$50,001–$100,000	$100,001–$250,000	$250,001–$500,000	Over $500,000
Production nursery	55.4% (31)	12.6% (7)	17.9% (10)	1.8% (1)	12.5% (7)
Landscape nursery	52.4% (11)	4.8% (1)	28.6% (6)	9.5% (2)	4.8% (1)
Garden center	58.3% (21)	13.9% (5)	13.9% (5)	5.6% (2)	8.3% (3)
Christmas trees	74.4% (32)	11.6% (5)	7.0% (3)	7.0% (3)	0.0%
Greenhouse	42.1% (8)	21.1% (4)	10.5% (2)	0.0%	26.3% (5)
Combination businesses[z]	40.8% (51)	12.0% (15)	16.0% (20)	12.0% (15)	19.2% (24)
Overall ($P < 0.0001$)	51.8% (159)	12.1% (38)	15.1% (46)	7.9% (24)	13.1% (40)

[z]Includes a combination of any two or more business types listed above.

Table 2. Mean number ((SEM), min/max) of employees who worked for the firm in 1998 as a function type of business.

Business type	Full-time	Part-time	Seasonal
Production nursery	9.9 (4.9), 0–200	5.6 (3.3), 0–90	9.8 (3.4), 0–70
Landscape nursery	2.8 (0.6), 0–8	1.6 (0.3), 0–3	1.4 (0.3), 0–3
Garden center	2.4 (0.6), 0–15	1.4 (0.4), 0–7	2.4 (0.5), 0–8
Christmas tree grower	1.0 (0.2), 0–5	1.5 (0.3), 0–6	6.2 (1.4), 0–30
Greenhouse	11.8 (4.4), 0–45	3.2 (1.1), 0–10	9.2 (2.6), 0–25
Combination businesses[z]	8.3 (3.0), 0–300	5.5 (1.8), 0–150	13.1 (3.9), 0–300
Overall	6.5 (1.5), 0–300	3.9 (0.9), 0–150	8.9 (1.7), 0–300

[z]Includes a combination of any two or more business types listed above.

Table 3. Who in the firm monitors for pests as a function of gross sales.

Gross sales	No one	Pest control consultant	Employee	Partner or family member	I do	PCC & I do
< $50,000[z]	7% (11)	2% (3)	0%	6% (9)	63% (100)	22% (35)
$50,001–$100,000	6% (2)	0%	0%	15% (6)	57% (23)	22% (9)
$101,000–$250,000	18% (8)	2% (1)	4% (2)	3% (3)	57% (26)	16% (7)
$250,001–$500,000	23% (6)	0%	4% (1)	10% (3)	43% (10)	20% (5)
> $500,000	12% (4)	2% (1)	30% (11)	0%	40% (14)	15% (5)
Overall (χ^2 = 76, df = 24, P < 0.001, N = 302)	8.6% (26)	2.6% (8)	3.6% (11)	5.6% (17)	52.3% (158)	27.2% (82)

[z]By gross sales (χ^2 = 87, df = 24, P < 0.001). Responses shown as % (number).

Table 4. Characterization by respondents as to how often they monitor for insects and mites.

Frequency of monitoring activities[z]	Count	%	*P*-value
Annually	24	7.2	< 0.001
Occasionally	33	9.9	< 0.001
Daily during season of known pest activity	132	39.9	< 0.001
Monthly during the season	41	12.4	< 0.001
Once a week during the season	148	44.7	0.054
Upon notification of a pest problem by PDA inspectors	66	20.0	< 0.001
Upon notification of a pest problem in your area by PSU extension publications	49	14.8	< 0.001
Upon hearing of a pest problem in your area from a friend or colleague	50	15.1	< 0.001
Based upon accumulation of growing degree days	25	7.6	< 0.001
Do not monitor	5	1.5	< 0.001

[z]More than one answer was permitted for this question.

of business, type of business, or level of education. Only 3% of respondents stated that these decisions are made in consultation with a pest control consultant (PCC) or employee.

Monitoring practices. The majority of respondents either do the pest monitoring themselves or in concert with a PCC (52.3 and 27.2%, respectively; Table 3). The majority of greenhouse operators in New York also reported that they do the scouting for the business (6). Only 2.6% of the respondents relied entirely on a consultant to monitor for pests. Approximately 8% of respondents reported that no one in the firm monitors for pests, suggesting that the abundance of literature on the importance and practice of monitoring pests in the nursery and the landscape may be reaching the target audience (1, 8, 10, 16, 20). The response to this question differed significantly as a function of gross sales (Table 3). Businesses that had an employee monitor for pests generally earned the most money in 1998.

With respect to frequency of monitoring, a significant majority (80%) of respondents reported that they monitor 'often' for pests. In addition, 35% are planning to monitor more in the future, while 65% will continue to monitor at the same rate. Although not statistically significant, a greater emphasis on monitoring occurred among respondents with a high school education or higher, from 70% without a high school diploma to about 90% with education equivalent to a high school degree and beyond. Regardless of business type, greater than 85% of the respondents monitor for pests; for example, landscape nurseries all responded that they monitor for insects and mites.

With respect to the motivation for monitoring for insects and mites, a significant number of respondents indicated that they monitor based on a schedule or through notification of a pest problem in their area (98%; Table 4). During the growing season, 45% of the respondents reported monitoring weekly for insects and mites while 40% monitor daily during the season of pest activity (Table 4), a result that is consistent with the frequency of monitoring in greenhouse operations in New York (6). Between 20 and 15% of the respondents reported that notification by the Pennsylvania Department of Agriculture, Penn State University Extension, or a colleague prompted them to monitor for insects and mites. Few reported monitoring based on growing-degree-days (GDD) (7.6%). Given the effort since the mid-1990s by the Penn-Del IPM Research group to collect and report GDD data for pests of woody ornamental plants (5) this is a disap-

Table 5. Techniques used by respondents to monitor for insects or mites as a function of gross sales in 1998.

Technique	Frequency
Visual only	117
Visual and traps (pheromones, sticky cards, blacklight traps)	61
Visual and foliage samples	58
Visual, foliage samples and indicator or highly susceptible plants	35
Visual and indicator or highly susceptible plants	28
Visual, traps, foliage samples and indicator or highly susceptible plants	28
Visual, traps and foliage samples	21
Visual, traps & indicator or highly susceptible plants	8
Foliage samples only	1
Indicator or highly susceptible plants only	1
Traps only	0

pointing result; perhaps increased adoption of GDD collection and reporting by nursery operators coupled with increased extension programming on interpreting GDD data would encourage more businesses to use this information to initiate monitoring practices.

The most frequent single monitoring technique reported was visual inspection (33%; Table 5), an approach often described as the most familiar and widely used by the green industry (1, 8). In addition, this method is considered very effective for detection of early feeding damage (1). Over 65% employed a combination of techniques including visual inspection, traps (sticky cards, pheromones or blacklight), foliage samples and indicator plants. Although no significant differences were found among education levels or business types, there were some trends in the use of different monitoring techniques depending upon the gross sales of the firm. As income increased the number of methods used to monitor increased (linear-by-linear association $P < 0.001$). For example, 44% of businesses with sales under $50,000 relied on visual inspection alone, whereas only15% of businesses grossing over $500,000 used this method only. The most common monitoring technique for firms grossing over $500,000 was a combination of visual inspection and traps (27%), suggesting that the use of traps may be considered more expensive to employ by some firms or that respondents are not aware of the diversity, efficacy, and cost benefit of traps as a tool. It appears that further demonstrations of the use, cost-benefits, and efficacy of traps would be in order to convince growers of their value. In addition, further education on the use of phenology as a useful monitoring technique for growers is indicated.

Approximately half of respondents 'always' identified the specific insect or mite prior to spraying for a pest problem while slightly less than half 'sometimes' did; only1% reported never accurately identifying insect and mite pests (Table 6); similar results were found for New York greenhouse operators (6). Although in our survey no significant differences were seen among business types or gross sales, the majority of the respondents who were only able to identify a specific insect or mite pest 'sometimes' tended to have less than a high school diploma. In general, the ability to 'always' identify the pest increased as education level increased. Over half (57%) of the respondents related insect or mite presence to the condition of the host plant. Less than 40% related pest presence to forecasted environmental conditions or identified the presence of beneficial predators (38 and 32%, respectively). Less than 20% determined the level of infestation by counting the numbers of specific insect or mites found. These results suggest that there continues to be a need for hands-on workshops to train green industry personnel how to identify key insect and mite pests as well as signs and symptoms in diagnosing pest problems. In addition, growers appear to need more evidence of the importance and benefits of determining infestation levels by random sampling or counting prior to investing in a treatment plan.

Table 6. When scouting, how often respondents accurately identified (in other words, determine the name of) the pest as a function of education ($P < 0.001$).

Education	Never	Sometimes	Always
Less than high school	0% (0)	75% (15)	25% (5)
High school or GED	1% (0)	51% (50)	45% (44)
AA degree or trade school	0% (0)	43% (32)	54% (40)
Bachelor's degree	1% (0)	39% (42)	59% (63)
Graduate degree	0% (0)	43% (16)	51% (19)
Overall	1% (2)	47% (154)	52% (172)

Despite the importance of record keeping as a component of IPM practices, significantly few respondents reported keeping permanent records of pest problems in Pennsylvania nursery operations (25%; $P < 0.001$) or New York greenhouse operations (32%) (6). In our study, a linear relationship is evident among business sizes with a gradual increase in record keeping being reported as gross sales increased in the business. Businesses grossing over $500,000 were the most likely to keep permanent records (45%); whereas, businesses grossing under $50,000 were least likely to do so (17%) ($\chi^2 = 14$, df = 4, $P = 0.007$). Smaller businesses may be under the impression that record keeping is too costly, or they may be unaware of the benefits. Despite the fact that record keeping has been documented to be a time and money saving IPM practice (8), the importance and economic benefits appear to require further reinforcement in extension programs.

Treatment decisions. A significant majority of the respondents consider incidence (80%, $P < 0.001$) and severity (86%, $P < 0.001$) when deciding to treat for insects or mites. Given that less than 20% of respondents determined the level of infestation, it would be interesting to determine how the respondents differentiate between incidence and severity. Additional education may be needed on these topics. Greater than half (56%, $P = 0.028$) considered the time of year, and fewer than half (41%, $P = 001$) considered using a preventative blanket spray when deciding to treat. However, we suggest that consideration of using blanket sprays by 41% of the respondents an unacceptably high figure. Furthermore, given that few respondents considered phenological indicators when deciding to treat (27%, $P < 0.001$), these findings suggest further education is needed on these topics across the industry. Decisions were not impacted by gross sales figures, education level, or business type.

Cultural control practices. Significantly more respondents stated that they 'often' use a variety of cultural control practices, such as isolating plants with pest problems for treatment, growing resistant varieties, and growing plants hardy to the area (Table 7). However, respondents appeared unsure about using a nursery layout based on key pests and plants to reduce pest access to susceptible plants. Although this practice has been reported to be quite effective (8), we suspect that most respondents were unaware of or had not consid-

Table 7. Use of cultural control practices currently in use or expected to be in use in the future.

	Current				Future[z]			
	Often	Rarely	Never	*P*-value	More	Same	Less	*P*-value
Nursery layout based on key pests & plants to reduce pest access to susceptible plants	32.8% (108)	36.5% (120)	30.7% (101)	0.431	32.1% (97)	61.3% (185)	6.6% (20)	< 0.001
Isolate plants with pests problems for treatment	53.2% (173)	32.3% (105)	14.5% (47)	< 0.001	35.1% (106)	61.3% (185)	3.6% (11)	< 0.001
Grow and sell plants hardy to the area	92.4% (315)	5.6% (19)	2.0% (7)	< 0.001	45.2% (142)	54.5% (171)	0.3% (1)	< 0.001
Grow and sell resistant varieties	79.8% (264)	16.3% (54)	3.9% (13)	< 0.001	50.8% (155)	48.5% (148)	0.7% (2)	< 0.001

[z]Fewer respondents answered the question about future plans than did for current practices. Responses shown as % (number).

Table 8. Responses to the question, 'Do you isolate plants with pest problems for treatment' as a function of respondent's education level.[z]

Education level	Often	Rarely	Never
Less than high school	27.8% (5)	61.1% (11)	11.1% (2)
High school or GED	57.1% (52)	30.8% (28)	12.1% (11)
AA degree or trade school	62.9% (44)	27.1% (19)	10.0% (7)
Bachelor's degree	51.9% (56)	31.5% (34)	16.7% (18)
Graduate degree	38.2% (31)	34.2% (12)	26.5% (9)

[z]Responses shown as % (number). Pearson's $\chi^2 = 15.7$, df = 8, $P = 0.047$.

ered this approach because 32% indicated that they plan to use this approach 'more' in the future. In general, significantly more respondents intend to continue their current cultural control practices at the same level or, in some cases, increase their use of these cultural practices.

Isolation of plants with pest problems for treatment is considered an effective IPM strategy (10), and apparently the message has reached the Pennsylvania nursery industry. A majority of the respondents indicated that they use this practice 'often' and plan to continue their use of this practice to the 'same' level in the future, while 34% planned to use this practice 'more' in the future (Table 7). Respondents with less than a high school diploma were most likely to employ this practice 'rarely' (61%) and least likely to use this practice 'often' (28%; Table 8). For obvious reasons, Christmas tree growers were least likely to isolate plants with pest problems (data not shown). Also, respondents with less than a high school degree were least likely to grow and sell plants hardy to the area (Pearson's $\chi^2 = 18.6$, df = 8, $P = 0.017$; data not shown).

Over half of respondents indicated that they 'often' use cultural practices and select pesticides that conserve beneficial insects (54.6 and 57%, respectively; Table 9). Furthermore, 38–40% are planning to increase the use of these practices in the future and about 60% plan to continue using the same level of this practice. Although not statistically significant, there was a trend in the use of cultural practices and selection of pesticides that conserve beneficials as a function of education level. The frequency of use of these practices was described as 'often' among respondents without a high school diploma and increased incrementally among those with a graduate degree. Also, respondents with less than a high school diploma were least likely to select pesticides that conserve beneficials (35%), while 50% of the remaining respondents stated that they 'often' use this practice. Nearly half of the landscape nurseries and greenhouses are planning an increased effort toward selecting beneficial friendly pesticides, while 24–34% of other businesses indicated their intention to increase this practice.

Biological and chemical control practices. A majority of respondents (62%) 'never' release beneficial insects to control pests and 68% do not plan to increase their use of beneficials (Table 9), a result similar to reports by Wawrzynski et al. (19) and Lamboy (6) for Midwest and New York greenhouse operations, respectively. Only 10% reported releasing beneficials 'often' and 25% indicated they plan to increase this practice in the future. Because many of the operations involved in our survey grow plants outdoors, one might speculate that beneficials may already be present in the landscape and, thus, do not need to be released. In this case, conservation of beneficials may be sufficient to support naturally occurring natural enemies. However, no significant differences were seen in the response to this question among types of businesses (e.g., Christmas tree grower vs. garden center or greenhouse operation), suggesting that this may not be the case. Instead, growers may not be convinced that biological control agents are effective. Although our survey did not include questions regarding barriers to the release of beneficials,

Table 9. Answers to the question, 'For each control practice listed below, please indicate if (A) this practice is currently used often, rarely or never; and (B) you expect in the future to use this practice more, the same, or less.'

	(A) Currently, do you use this practice: $P < 0.001$			(B) In the future, do you plan to use this practice:[z] $P < 0.001$		
Practice	Often	Rarely	Never	More	Same	Less
Release beneficials	10.1% (34)	27.7% (93)	62.2% (209)	25.3% (77)	67.8% (206)	6.9% (21)
Select pesticides that conserve beneficials	57.0% (192)	30.7% (103)	12.2% (41)	39.7% (122)	59.0% (181)	1.3% (4)
Use cultural practices that conserve beneficials	54.6% (179)	32.9% (108)	12.5% (41)	37.9% (113)	61.1% (182)	1.0% (3)

[z]Fewer respondents answered the question about future plans than for current practices. Responses shown as % (number).

Table 10. Answers to the question, 'Do you spray for insects or mites on a set schedule, whether you see a pest or not?' as a function of gross sales.[z]

Gross sales	Always	Often	Sometimes	Rarely
< $50,000	5.1% (8)	7.1% (11)	26.9% (43)	60.9% (97)
$50,001–$100,000	2.7% (1)	5.4% (2)	29.7% (12)	62.2% (26)
$101,000–$250,000	4.4% (2)	21.7% (10)	23.9% (11)	50.0% (24)
$250,001–$500,000	0.0%	12.5% (3)	33.3% (8)	54.2% (14)
> $500,000	2.1% (1)	25.6% (10)	38.5% (15)	30.8% (12)
Overall	4.5% (14)	11.6% (36)	27.7% (86)	56.2% (175)

[z]Responses are shown as % (number). (Pearson's χ^2 = 36.8, df = 12, P < 0.001.

surveys by Wawrzysnki et al. (19) and Garber et al. (3) found that non-users were concerned about difficulty coordinating use of pesticides with biocontrol agents (management complexity), not getting the desired level of control, or not being sure how to implement them (lack of information). Similarly, Pennsylvania respondents appeared ambivalent regarding their cost effectiveness. When asked whether they strongly agreed or disagreed with the statement that beneficials for control of key pests are cost effective, 48.4% rated this question in the middle between strongly agree and strongly disagree, while the remainder split evenly on both sides of the question.

In general, the majority of businesses (56%) rarely spray on a set schedule (Table 10). Businesses grossing under $100,000 in 1998 were most likely to report that they 'rarely' spray for insects or mites on a set schedule, whether they see a pest or not (Table 10). Businesses that grossed >$500,000 were more apt to report that they 'often' or 'sometimes' and least likely to report that they 'never' spray on a set schedule, despite the fact that this practice is well documented to be costly and produce myriad problems such as insecticide resistance, resurgence of primary pests, destruction of natural enemies, and release from competition of secondary pests (7). More importantly, spraying on a schedule often results in less effective pest control at a higher cost for pesticides. Perhaps businesses that earn less are more careful about saving money by making sure they are not applying costly pesticides unnecessarily.

Although close to being statistically significant, there was no relationship between how respondents answered the question about spraying on a set schedule and their answer to the question about the use of beneficials (P = 0.064); 36% of respondents answered that they spray on a set schedule and use beneficials. However, 30% of respondents stated that they do not spray on a schedule and that they use beneficials, 19% answered no to both questions, and 15% answered no to beneficials and yes to spraying on a schedule. Clearly, there is a need to educate the industry further about the negative impact of spraying on a schedule, particularly if one is planning to use beneficial insects as part of an IPM strategy.

Chemical control tactics differed significantly among respondents based on their education level and gross sales in 1998 (Table 11). In general, 61, 31, and 8% of respondents reported their use of chemical pesticides to control insects and mites as 'often', 'rarely', and 'never', respectively. Respondents with less than a high school degree were most likely to report using pesticides 'rarely.' Businesses with gross sales under $50,000 were most apt to use chemical pesticides 'rarely' and least likely to report their use as 'often.'

Table 11. Answers to the question, 'For each chemical control practice listed below, please indicate if you currently use…'

	Often	Rarely	Never
Chemical Pesticides			
	By education level (P = 0.04)		
Less than high school	35.0% (7)	60.0% (12)	5.0% (1)
High school or GED	63.7% (65)	28.4% (29)	7.8% (8)
AA degree or trade school	64.5% (49)	26.3% (20)	9.2% (7)
Bachelor's degree	65.2% (75)	26.1% (30)	8.7% (10)
Graduate degree	43.2% (16)	48.6% (18)	8.1% (3)
	By gross sales (P < 0.001)		
< $50,000	44.4% (71)	42.5% (68)	13.1% (21)
$50,001–$100,000	77.5% (31)	15.0% (6)	7.5% (3)
$101,000–$250,000	72.9% (35)	25.0% (12)	2.1% (1)
$250,001–$500,000	89.7% (26)	6.9% (2)	3.4% (1)
> $500,000	74.4% (29)	20.5% (8)	5.1% (2)
Overall (P < 0.001)	61.0% (216)	30.8% (109)	8.2% (29)
Insecticidal Soaps			
(P = 0.003)	31.6% (109)	41.4% (143)	27.0% (93)
Horticultural Oils			
	By type of business (P = 0.028)		
Production Nursery	33.3% (18)	40.7% (22)	25.9% (14)
Landscape Nursery	54.6% (12)	31.8% (7)	13.6% (3)
Garden Center	13.9% (5)	38.9% (14)	47.2% (17)
Christmas Tree Grower	29.3% (12)	48.8% (20)	22.0% (9)
Greenhouse	31.6% (6)	42.1% (8)	26.3% (5)
Combination Businesses	42.8% (56)	35.9% (47)	21.4% (28)
Overall (P = 0.015)	35.3% (120)	38.5% (131)	26.2% (89)
Natural Products			
	By type of business (P < 0.001)		
Production Nurseries	25.0% (13)	44.2% (23)	30.8% (16)
Landscape Businesses	21.7% (5)	43.5% (10)	34.8% (8)
Garden Centers	47.0% (16)	32.4% (11)	20.6% (7)
Christmas Tree Farms	2.8% (1)	38.9% (14)	58.3% (21)
Greenhouse	47.6% (10)	33.3% (7)	19.1% (4)
Combination Businesses	16.4% (21)	39.8% (51)	43.8% (56)
	By gross sales (P = 0.046)		
< $50,00	22.4% (33)	31.3% (46)	46.3% (68)
$50,001–$100,000	16.2% (6)	43.2% (16)	40.5% (15)
$100,001–$250,000	28.3% (13)	41.3% (19)	30.4% (14)
$250,001–$500,000	20.0% (1)	56.0% (14)	24.0% (6)
>$500,000	33.3% (13)	46.2% (18)	20.5% (8)
Overall (P = 0.001)	23.8% (77)	37.9% (125)	38.8% (128)

Responses shown as % (number).

Respondents were also asked about their use of less toxic alternatives to chemical pesticides. The majority of respondents reported using insecticidal soaps, horticultural oils, and natural products either 'rarely' or 'never' (Table 11). The use of oils and natural products differed, however, by the type of business and in some cases, by gross earnings of the firm. For example, landscapers were most likely to report 'often' using horticultural oils (41%) while garden centers most frequently reported 'never' using them (47%). Christmas tree

farms, production nurseries, and landscape businesses were more likely to report 'rarely' or 'never' using natural products while garden centers (47%) and greenhouse operations (48%) were most likely to report 'often' using them. These findings suggest that increased educational efforts are needed to move the nursery industry toward greater adoption of IPM practices and away from reliance on chemical pesticides, but they may also reflect which type of biorationals work for different types of nurseries. Also, the more money the firm grossed in 1998, the more likely they were to use natural products. In general, these results are similar to reports of the levels of use of insecticides and miticides from a 1984 survey of the nursery industry in Pennsylvania (15). This is surprising considering the impacts of the Food Quality Protection Act of 1996 (FQPA) on the number of pesticides that have either been removed from the market or put on restricted use.

Based on this survey, it is clear that while many nursery operators have taken advantage of modern IPM approaches, there is still a large part of the industry where traditional calendar-based pesticide applications are being used. This situation results from several perceptions and some difficult obstacles:

- *IPM is too expensive*. A recent study showed that IPM practices cost only pennies per plant (16, 17). In addition, pilot IPM programs in commercial nurseries have been conducted in several states demonstrating the economic benefits of IPM (e.g., 1). In addition to pilot studies, in-depth economic analyses of successful IPM approaches should be carried out and the results disseminated throughout the industry.
- *IPM is too difficult to implement*. This is an educational problem. Cooperative extension and state agricultural departments (e.g., the PDA Bureau of Plant Industry) should collaborate in delivering information and educational programming to growers. This collaboration is essential because the plant inspectors, while working for a regulatory agency, have the most contact with growers during the growing season. In addition, the inspectors often discover pest problems. The time of discovery is an excellent 'teachable moment' to pass on advice about IPM.
- *IPM takes too much time*. A proper economic benefits analysis should show that any increased management costs associated with IPM are more than compensated for by increased returns due to lowered costs through pesticide reductions. Moreover, the external regulatory environment and market forces are favorable for IPM practices. As mentioned above the Food Quality Protection Act and amended Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) are placing more restrictions on pesticides that have negative external impacts such as environmental pollution or human health effects. This changing regulatory environment favors the alternatives that are promoted by IPM. Several Natural Resource Conservation Service programs of the USDA also provide incentives for adopting environmentally compatible practices in agriculture. For example, the Environmental Quality Incentive Program will pay farmers who use conservation practices including IPM.

Consumer preferences are also shifting toward 'greener' products; more than 50% of U.S. consumers would preferentially purchase items that are healthier and better for the environment (http://paipm.cas.psu.edu/NewsReleases/NRgreenhouse.html). On the other hand, consumer tolerance of pest damage on ornamentals is more limited (11). Perhaps better consumer education and marketing of green industry products as being grown using IPM would increase consumer tolerance for plants that are not perfect. However, this does not alleviate the obstacles faced by the nursery industry in dealing with state or federal plant inspectors who require that plants for shipping across state lines or overseas be 'clean' of all pests. In fact, this issue alone may account for much of the reluctance of the industry to adopt IPM practices.

Literature Cited

1. Davidson, J.A., C.F. Cornell, M.E. Zastrow, and D.C. Alban. 1988. Making the pilot fly: Maryland researchers implement a trial IPM program in eight nurseries. Amer. Nurs. 167(10):51–60.

2. Dillman, D.A. 2000. Mail and Internet Surveys: The Tailored Design Method, 2nd ed. Wiley, New York, NY.

3. Garber, M.P., W.G. Hudson, J.G. Norcini, R.K. Jones, A.R. Chase, and K. Bondari. 1996. Pest management in the greenhouse and nursery industry: Introduction and perspective. HortTechnology 6:194–200.

4. Higginbotham, J.S. 1993. Pest control: IPM use by nursery growers. Amer. Nurs. 177(12):70–77.

5. Hoover, G. 2002. Collaborative for integrated pest management. Tree Care Industry 13:18–24.

6. Lamboy, J.S. 2002. Level of Adoption of IPM in New York Greenhouses. New York State IPM Prog. Publ. 417.

7. Metcalf, R.L. and W.H. Luckmann. 1994. Introduction to Insect Pest Management, 3rd ed. Wiley & Sons, New York, NY.

8. Raupp, M.J. and C.F. Cornell. 1988. Pest prevention: Treating pests to the IPM method. Amer. Nurs. 167(3):59–62.

9. Reed, D. 1999. Mail dominance. Marketing Week 22(45):41–45.

10. Rhoads, A.F. 1985. Integrated Pest Management — What's it all about? J. Arboriculture 11:369–372.

11. Sadof, C.S., M.J. Raupp, and J.A. Davidson. 1987. Survey finds defoliated plants won't sell. Amer. Nurs. 166(15):37–39.

12. Sellmer, J.C., N. Ostiguy, K. Hoover, and K.M. Kelley. 2004. Survey responses by the Pennsylvania ornamental horticulture industry to IPM and extension education. J. Extension (in press).

13. Sellmer, J.C., N. Ostiguy, K. Hoover, and K.M. Kelley. 2004. Assessing the integrated pest management practices of Pennsylvania nurseries. HortScience (in press).

14. Sellmer, J.C., N. Ostiguy, K. Hoover, and K.M. Kelley. 2004. Assessing the integrated pest management practices of Pennsylvania landscape management and construction operations. J. Arboriculture (in press).

15. Shetlar, D.J. and P.R. Heller. 1984. Survey of insecticide and miticide usage by 158 nurseries in Pennsylvania. J. Environ. Hort. 2:16–20.

16. Thomas, C. 2002. Biological control on greenhouse vegetables. Greenhouse Management & Production 22(9):52–56.

17. Thomas, C. 2002. Control of whiteflies on poinsettias using IPM. Greenhouse Management & Production 22(2):34–37.

18. USDA. 1997. National Agricultural Statistics Survey. Census of Agriculture. <http://www.nass.usda.gov/census/>.

19. Wawrzynski, R.P., M.E. Ascerno, and M.J. McDonough. 2001. A survey of biological controls users in Midwest greenhouse operations. Am. Entomol. 47:228–234.

20. Willits, F.K. and M. Shields. 2001. Pennsylvania's Green Industry: Its Nature and Contribution to the State's Economy. Dept. of Agric. Econ. and Rural Soc., The Pennsylvania State University, University Park, PA.

21. Zar, J.H. 1999. Biostatistical Analysis, 4th ed. Prentice-Hall, Upper Saddle River, NJ.