New developments in entomology, 1997

Integrated pest management for urban landscapes

S. Kristine Braman and Joyce G. Latimer[1]
Departments of Entomology and Horticulture[1], University of Georgia, Georgia Experiment Station, Griffin, GA 30223-1797, USA

ABSTRACT:

The development and implementation of integrated pest management (IPM) for woody ornamentals and turf in the landscape is evolving rapidly in the United States. In an environment characterized by tremendous diversity of plant materials and associated pests, IPM efforts can be more finely focused by adopting key plant/key pest strategies. The difficulties inherent in developing decision rules for aesthetic injury are being addressed in research and education efforts. Opportunities exist for increasing public tolerance of what constitutes acceptable pest pressure through research-based knowledge of pest/damage relationships.

Biologically-based, biorational, and cultural management methods are gradually increasing in availability, consistency of performance, and frequency of use. Particular opportunities exist for the development of pest-resistant plant based management strategies that integrate other control methods.

KEY WORDS IPM, turfgrass, woody ornamentals, biological control, urban pest management

HISTORICAL PERSPECTIVE

This review emphasizes advances in the development and implementation of integrated pest management (IPM) strategies for the urban landscape. Historically, pest management in outdoor, urban reliance on traditional chemical control methods. Alternative management strategies for this system have lagged considerably behind those for traditional agriculture (50). However, the economic impetus of a burgeoning environmental horticulture industry (36, 37) and increasing concern for potential environmental and human health risks associated with pesticide use have fostered renewed effort in research and education relevant to the development and implementation of IPM for the urban landscape.

Impediments to implementation of integrated pest management for landscape and turf have included inadequate pest sampling methods; limited numbers of easily implemented, reliable, and cost-effective alternative pest control methods; and inadequate funding of research on development of alternative pest control methods and information delivery (37, 38, 45, 50). Despite limited funding for research, significant advances have been achieved in each of the many areas that contribute to the development of cohesive, comprehensive IPM programs for the landscape. We emphasize here recent developments in these component areas.

ARTHROPOD PESTS OF WOODY LANDSCAPE PLANTS AND TURF

Tremendous biotic diversity characterizes urban landscapes resulting in a complexity of plant-pest associations requiring some method of definition of focus to render IPM programs even remotely feasible. The key plant/key pest concept (49, 50) has enormous potential for practical application in diverse to consistently experience infestation and damage and to focus management efforts in a cost-effective manner. In a survey of 350 lawn care/landscape maintenance firms, for example, evergreen azaleas were represented in 87% of landscapes (Table 1) and were reported as often requiring insecticide by 35% of the respondents. Deciduous azaleas, however, although only listed as represented in managed landscapes by 68% of respondents, were rated as seldom or never requiring insecticides by 56% of respondents. The most readily available deciduous azaleas are less vulnerable to infestation and damage by the azalea lace bug, the key pest of evergreen azaleas.

At least 26 insect and mites may become at least occasional pests of managed turfgrasses; numerous others affect woody plants. Their characteristics and biology are presented in comprehensive texts both for the specialist and the general IPM practitioner (e.g., 21, 33, 38, 59). Relatively few of these potential pests consistently achieve pest status. Although key pests vary by region, major pest groups for turfgrass include white grubs, billbugs, mole crickets, lepidopterous larvae, chinch bugs and fire ants. The most consistently problematic groups on woody plants include scale insects, mites, lepidopteran and coleopteran borers and foliar feeders, and lace bugs.

Although comparable national figures for landscape use are not available, a national survey of pesticide use on sod farms illustrates that in the United States most of the insecticides applied to turf target soil- dwelling pests (Fig. 1) (42) indicating their importance as key pests. There was a difference among regions in primary pest status. For example, while white grubs were treated with the highest percentage of active ingredient of insecticide in 3 of 5 regions (eastern and western northern U.S. and far

Table 1. Identification of key plants based on occurrence in the landscape and degree of pesticides used (landscape maintenance industry survey)

Percent of responses using insecticide on particular plant material and percent of firms having that plant in serviced landscapes

Plant type	often applied	seldom applied	never applied	plant occurs
Evergreen azalea	35	33	19	87
Deciduous azalea	11	26	30	68
Boxwood	14	27	35	77
Camellia	7	36	33	76
Euonymous	28	30	20	79
Holly	8	37	39	84
Rose	40	16	15	70
Pyracantha/ cotoneaster	28	22	24	74
Oak	3	31	47	80
Juniper	27	29	28	84

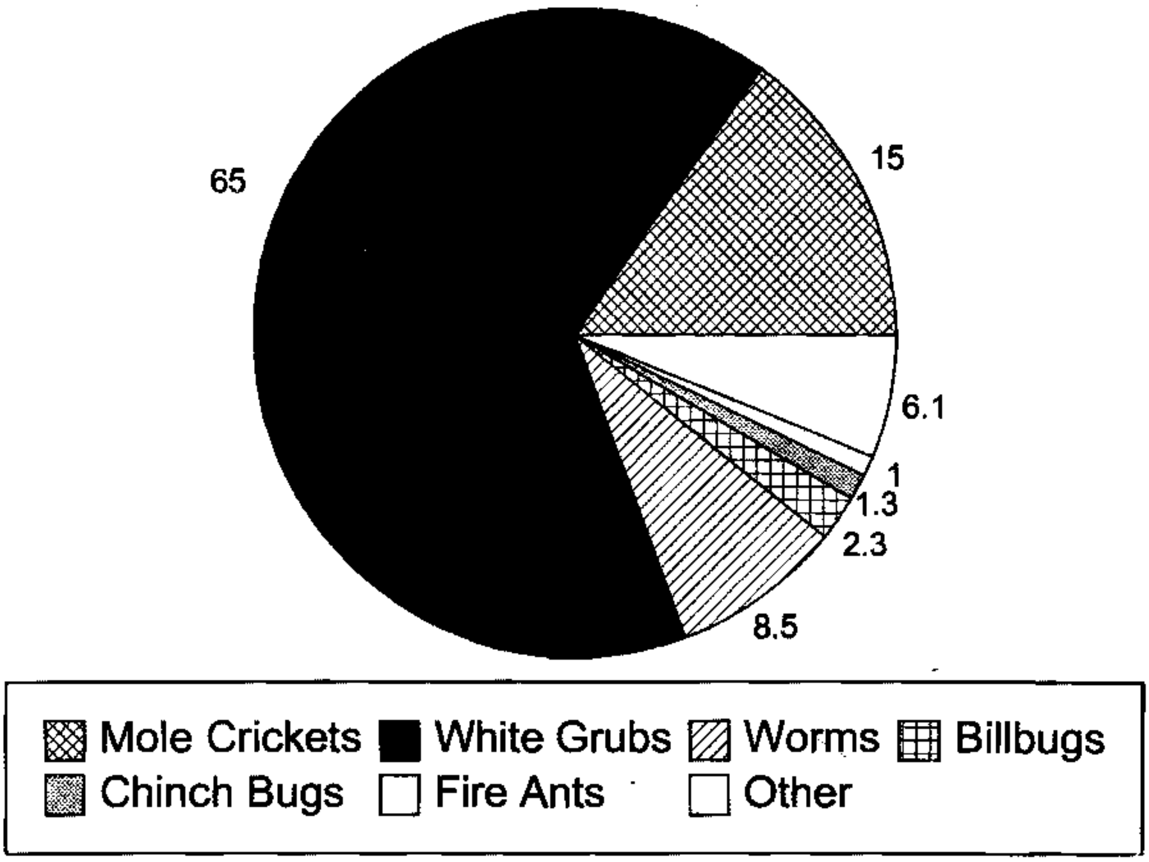

Fig. 1. Percent of insecticides applied for control of different pest categories in turf (Oetting andAllison 1994).

western part of the southern U.S.), in region 4 (south -central U.S) the highest percentage of active ingredient was used against chinch bugs (73%). In region 5 (southeastern U.S. 66.6% of the active ingredient was used for mole cricket control.

MONITORING, PEST PREDICTION AND DECISION MAKING

Adequate sampling and an understanding of pest phenology are critical components of IPM programs for any managed system. Forecasting models based on heat accumulations, the influence of soil moisture, or host plant phenology have been developed for a variety of landscape and turfgrass pests or their natural enemies (e.g., 7, 11, 39, 40, 43, 46). A variety of trapping and monitoring approaches are employed in landscape IPM settings. Pheromone traps permit survey and detection, and timing of intervention for such pests as clearwing borers, Japanese beetles, gypsy moth, cutworms, armyworms, sod webworms, bark beetles and others (reviewed in 37, 45, 50).

The development of non-invasive, time efficient means of pest population assessment particularly for unapparent, subterranean pests with patchy distributions such as white grubs or mole crickets remains a critical need. Recent research (11, 41) has examined the issue of sampling plans for white grubs. A threshold of 0.25 European chafer *Rhizotrogus majalis* (Razoumowski) grubs per 11-cm diameter turf plug is based on an assessment of data from 317 residential sites near Rochester, NY (41). This decision rule functions in two steps. First, the age of the lawn, percentage of shading, and percentage of the lawn that is an especially susceptible turf type is assessed. The site is then classified as requiring no sampling or treatment, or should be sampled and a treatment decision made based on these additional data. Advantages to this system of initially incorporating a risk assessment protocol, were a savings in sampling resources and a lessening of the likelihood of erroneously categorizing a site. Additional work of this type is needed.

Pest control decision rules incorporate information concerning the density of the pest of interest, a threshold of unacceptable insect-induced injury, and some means of predicting when that threshold will be reached. Decision making for landscape plants is complicated by the fact that perceived value of ornamental plants is variably affected by aesthetic judgements of consumers or clients of landscape management professionals.

Recent reviews of studies that have sought to develop aesthetic injury levels for pests of ornamental plants have been in general agreement that consumers or survey respondents believe that plants with less than 10% insect or mite- induced injury are damaged and unacceptable (15, 16, 50, 55, 56). The public, in general, has a low tolerance of insect presence or injury. Evaluations of this type provide unique opportunities for altering public perception of what constitutes acceptable pest pressure through education. Definitive research-based results that conclusively indicate no substantial risk to plant health associated with these low levels of damage can support these educational efforts and are a critical research need.

INTERVENTION OPTIONS

Chemical Pest Suppression

Application of inorganic and botanical insecticides was common until the development of synthetic organic insecticides following World War II. Cyclodiene insecticides were used extensively to control insect pests of the landscape during the 1950s and 1960s. Currently, there are several materials commonly recognized as biorational pesticides that are increasingly used for control of landscape pests. These include horticultural oils, insecticidal soaps, azadirachtin-based products, *Bacillus thuringiensis* products, and entomogenous nematodes. Horticultural oils were purchased by 33% of lawn care/ landscape maintenance firms in the metro-Atlanta area (Table 2) and accounted for 42% of the total active ingredient purchased by 159 firms that included pest management in their services.

Insect growth regulators, not previously widely available for use in landscapes have been recently registered or are near registration for use on turf and ornamentals. New chemistry represented by materials such as imidacloprid and fipronil offer increasing options to managers of landscape or recreational turf and ornamentals. Strains of *B.t.* showing effectiveness against scarabaeid grubs may offer additional options to replace less effective bacterial products (53).

Host Plant Resistance

The opportunities afforded by pest management through use of resistant plant material are enormous. Although traditional breeding programs have concentrated primarily on horticultural and agronomic aspects of cultivars, entomologists and pathologists are increasingly contributing to the plant improvement effort in the initial stages of screening. Knowledge of pest susceptibility of existing cultivars is invaluable in making recommendations for plant replacement and has been addressed in research and education efforts with increasing vigor during the past few years (e.g., 4, 8, 10, 17, 19, 32, 47, 48, 54, 57, 58, 62). Innovative means of influencing market demand for and increasing production of pest resistant plants have been recently investigated (26, 27, 28, 29, 30) identifying opportunities for cooperation among the landscape and nursery industries.

Currently lack of information about plant susceptibility to even the most common landscape pests continues to hinder greater adoption of the use of resistance as a management strategy. Quisenberry (48) reviewed the literature pertaining to resistance to insects and mites in forage and turfgrasses in the southeast. In this review she cited 56 studies which examined the potential for resistance among 6 grass

Table 2. Pesticides purchased by 159 lawn care and landscape firms (metro-Atlanta area) during 1993.

Insecticide	Frequency of purchase of 159 firms	% total AI
abamectin	1	<1
acephate	68	8
azadirachtin	2	<1
carbaryl	54	8
chlorpyriphos	83	5
cyfluthrin	18	1
diazinon	10	1
dicofol	19	2
dienochlor	2	<1
dimethoate	3	<1
disulfoton	21	4
fluvalinate	7	<1
horticultural oil	53	42
hydramethylnon	101	11
insecticidal soap	26	2
isazophos	3	<1
isofenphos	10	11
lambdacyhalothrin	9	<1
lindane	1	<1
malathion	37	4
trichlorfon	2	<1

species and 9 insect or mite pests. Only 4 studies examined resistance to mole crickets, the most serious turf pest in the southeast and none addressed any white grub species, the most injurious group in the U.S.

Progress will be accelerated upon identification of mechanisms associated with resistance to particular insects and mites. Often, however, there may be several mechanisms imparting resistance against a particular pest even in a fairly narrow group of plant hosts. Several factors, for example, are associated with resistance to azalea lace bug among 17 species of deciduous azaleas (62) including both physical and chemical attributes. Better communication of plant resistance characteristics among those that specify plant material in the landscape, landscape architects (26, 29), will also increase their use.

Biological Control

Biological control in the landscape is complicated by the complexity of plant materials and pests, and the patchiness that characterizes the urban landscape. Inherent difficulties exist in implementing biological control on an area-wide basis when personal property and/or political boundaries often have little relationship with the ecological requirements of implementing this control strategy. The importance of conserving natural enemies and the potential for increasing implementation of biologically-based strategies has been well recognized and addressed in recent efforts (2, 3, 5, 9, 20, 22, 24, 31, 51, 60, 63). Integration of strategies combining biological control with biorational pesticides and host plant resistance is also receiving renewed research effort (3, 63). Beneficial organisms are increasingly available commercially and their value for use in the landscape requires additional study (52).

Cultural Management Strategies

Management efforts are severely hampered by a lack of understanding of even the most common interactions among biotic and abiotic factors. We are seldom able to predict with any certainty where and when prominent pests will reach injurious population numbers. Recent efforts at understanding factors that influence likelihood of infestation and damage have been investigated for chinch bug pests in turfgrass (34, 35) and lace bugs on azaleas (61). Certain parameters in the turf environment such as thatch accumulation and grass species were positively and consistently correlated with chinch bug occurrence. Hopefully this research will generate interest in similar investigation for other pest associations.

Influence of cultural factors such as mowing height, irrigation, and fertility on pests and associated beneficials is largely undefined. Manipulation of the turfgrass environment can be an effective means of pest suppression or enhanced tolerance of injury. Withholding water during Japanese beetle oviposition and egg hatch interval followed by irrigation during the fall feeding period and remedial N fertilization may reduce infestation and promote turf recovery (18).

OPPORTUNITIES FOR INCREASING IPM IN THE LANDSCAPE

A five year trend in chemical use reported by landscape maintenance firms (29) reveals a decrease in the use of insecticide and an increase in the use of fungicides and especially herbicides. Approximately 55% of pesticide use was in turf, particularly in weed management. We should address this in the development and refinement of landscape IPM programs. This industry is also characterized by a majority of small, undercapitalized firms that are less than 5-10 years old (25). Educational programs must be designed that target these firms as well as the large, well established anchors of the industry.

Particular opportunities exist for research and education regarding the identification and incorporation of beneficials in risk assessment and decision making. Only 8% of 159 landscape firms in the 20 county metro-Atlanta area monitor beneficials and make treatment decisions based on their presence (Braman unpub). Other practices reported by the industry incorporate components of IPM including the fairly extensive use of horticultural oils and timing of treatments based more on monitoring of pest activity than on predetermined applications of pesticides.

REFERENCES CITED

1. **Allsopp, P. G., Niemczyk, H. D. & M. G. Klein. 1995.** Sampling distributions and sequential sampling for third instars of black turgrass ataenius, *Ataenius spretulus* (Haldeman), in control trials. Pedobiologia. 39: 126-131.

2. **Alm, S. R., Yeh, T., J. L. Hanula & R. Georgis. 1992.** Biological control of Japanese, Oriental, and black turfgrass ataenius beetle (Coleoptera: Scarabaeidae) larave with entomopathogenic nematodes (Nematoda: Steinernematidae, Heterorhabditidae). J. Econ. Entomol. 85: 1660-1665.

3. **Balsdon, J. A., S. K. Braman, A. F. Pendley & K. E. Espelie. 1993.** Potential for integration of chemical and natural enemy suppression of azalea lace bug (heteroptera: Tingidae). J. Environ. Hortic. 11: 153-156.

4. **Balsdon, J. A., K. E. Espelie & S. K. Braman. 1995.** Epicuticular lipids from azalea (*Rhododendron* spp.) And their potential role in host plant acceptance by azalea lace bug, *Stephanitis pyrioides* (Heteroptera: Tingidae) Biochem. Syst. Ecol. 23: 477-485.

5. **Balsdon, J. A., S. K. Braman & K. E. Espelie. 1996.** Biology and ecology of *Anagrus takeyanus* (Hymenoptera: Mymaridae), an egg parasitoid of the azalea lace bug (Heteroptera: Tingidae). Environ. Entomol. 25: 383-389.

6. **Blanco-Montero, C. A., T. B. Bennett, P. Neville, C. S. Crawford, B. T. Milne & C. R. Ward. 1995.** Potential environmental and economic benefits of turfgrass in Albequerque. Landscape Ecology. 10: 121-128.

7. **Braman, S. K. & R. J. Beshear. 1994.** Seasonality of predaceous plant bugs (Heteroptera: Miridae) and phytophagous thrips (Thysanoptera: Thripidae) as influenced by host plant phenology of native azaleas (Ericales: Ericaceae. Environ. Entomol. 23: 712-718.

8. **Braman, S. K. & A. F. Pendley. 1992.** Evidence for resistance of deciduous azaleas to azalea lace bug. J. Environ. Hortic. 10: 40-43.

9. **Braman, S. K. & A. F. Pendley. 1993.** Relative and seasonal abundance of beneficial arthropods in centipedegrass as influenced by management practices. J. Econ. Entomol. 86: 494-504.

10. **Braman, S. K., A. F. Pendley, R. N. Carrow & M. C. Engelke. 1994.** Potential resistance in zoysiagrasses to tawny mole crickets (Orthoptera: Gryllotalpidae). Fla. Entomol. 77: 301-305.

11. **Braman, S. K., A. F. Pendley, B. Sparks & W. G. Hudson. 1992.** Thermal requirements, population trends, and parasitism of azalea lace bug. (Heteroptera :Tingidae) J. Econ. Entomol. 85: 870-877.

12. **Buntin, D. G., S. K. Braman, D. A. Gilbertz & D. V. Phillips. 1996.** Chlorosis, photosynthesis, and transpiration of azalea leaves after azalea lace bug (Heteroptera: Tingidae) feeding injury. J. Econ. Entomol. 89: 990-995.

13. **Busey, P. 1990.** Inheritance of host adaptation in southern chinch bug (Heteroptera: Lygaeidae). Ann. Entomol. Soc. Am. 83: 563-567.

14. **Busey, P & B. J. Center. 1987.** Southern chinch bug overcomes resistance in St. Augustinegrass. J. Econ. Entomol. 80: 608-611.

15. **Coffelt, M. A. & P. B. Shultz. 1990.** Development of an aesthetic injury level to decrease pesticide use against orange-striped oakworm. (Lepidoptera: Saturniidae) in an urban pest management project. J. Econ.

Entomol. 83: 2044-2049.

16. **Coffelt, M. A. & P. B. Shultz. 1993.** Quantification of an aesthetic injury level and threshold for an urban pest management program against the orange-striped oakworm. J. Econ. Entomol. 86: 1512-1515.

17. **Crutchfield, B. A. & D. A. Potter. 1994.** Preference of Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae) grubs for cool-season turfgrasses. J. Entomol. Sci. 29: 398-406.

18. **Crutchfield, B. A., D. A. Potter & A. J. Powell. 1995.** Irrigation and nitrogen fertilization effects on white grub injury to Kentucky bluegrass and tall fescue turf. Crop Sci. 35: 1122-1126.

19. **Crutchfield, B. A. & D. A. Potter. 1995.** Tolerance of cool-season turfgrasses to feeding by Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae) grubs. J. Econ. Entomol. 88: 1380-1387.

20. **Davidson, J. A., S. A. Gill & M. J. Raupp. 1992.** Controlling clearwing moths with entomopathogenic nematodes: the dogwood borer case study. J. Arboriculture. 18: 81-84.

21. **Dreistadt, S. H. 1994.** Pests of landscape trees and shrubs: an integrated pest management guide. University of CA, Division of Agriculture and Natural Resources No. 3359. 327 pp.

22. **Dreistadt, S. H. & M. L. Flint. 1995.** Ash whitefly (Homoptera: Aleyrodidae) overwintering and biological control by *Encarsia inaron* (Hymenoptera: Aphelinidae) in northern California. Environ. Entomol. 24: 459-464.

23. **Dreistadt, S. H. & M. L. Flint. 1995.** Landscape pest monitoring methods and training managers to use them. J. Arboric. 21: 1-6.

24. **Dreistadt, S. H. & K. S. Hagen. 1994.** Classical biological control of the acacia psyllid, *Acizzia uncatoides* (Homoptera: Psyllidae), and predator-prey-plant interactions in the San Francisco Bay area. Biological Control. 4: 319-327.

25. **Florkowski, W. J. , C. D. Robacker, J. G. Latimer & S. K. Braman. 1997.** Economic profile of Atlanta landscape maintenance and lawn care firms. HortTechnology. (In press).

26. **Garber, M. P. & K. Bondari. 1992.** Landscape architects as related to the landscape/nursery industry: I. Impact on demand for plant material. J. Environ. Hortic. 10: 69-72.

27. **Garber, M. K. Bondari & G. Wade. 1995.** Educational and marketing programs serving the landscape industry. HortTechnology. 5: 72-77.

28. **Garber, M. P. & K. Bondari. 1996.** Landscape Maintenance Firms: I. Business features and factors influencing industry performance. J. Environ. Hort. 14: 53-57.

29. **Garber, M. P. & K. Bondari. 1996.** Landscape Maintenance Firms: II. Pest management practices. J. Environ. Hort. 14: 58-61.

30. **Garber, M. P. & K. Bondari. 1996.** Landscape Maintenance Firms: III. Opportunities for cooperation in the Landscape/nursery industry. J. Environ. Hort. 14: 62-66.

31. **Hendrickson, R. M. Jr., Drea. J. J. & M. Rose. 1991.** A distribution and establishment program for *Chilocorus kuwanae* (Silvestri) (Coleoptera: Coccinellidae) in the United States. Proc. Entomol. Soc. Washington. 93: 197-200.

32. **Johnson, M. P., D. A. Potter, and J. Hartman 1993.** Suitability of juniper cultivars for

survival and growth of the bagworm. J. Environ. Hort. 11: 167-170.

33. **Johnson, W. T. & H. H. Lyon. 1988.** Insects that feed on trees and shrubs. 2nd ed. Cornell Univ. Press. Ithaca, N. Y.

34. **Kortier Davis, M. G. & D. R. Smitley. 1990.** Association of thatch with populations of hairy chinch bug (Hemiptera: Lygaeidae) in turf. J. Econ. Entomol. 83: 2370-2374

35. **Kortier Davis, M. G. & D. R. Smitley. 1990.** Relationship of hairy chinch bug (Hemiptera: Lygaeidae) presence and abundance to parameters of the turf environment. J. Econ. Entomol. 83: 2375-2379.

36. **Latimer, J. G., R. D. Oetting, P. A. Thomas, D. L. Olson, J. R. Allison, S. K. Braman, J. M. Ruter, R. B. Beverly, W. Florkowski, C. D. Robacker, J. T. Walker, M. P. Garber, O. M. Lindstrom & W. G. Hudson. 1996.** Reducing the pollution potential of pesticides and fertilizers in the environmental horticulture industry: I. Greenhouse, nursery, and sod production. HortTechnology. 6: 115-124.

37. **Latimer, J. G., S. K. Braman, R. B. Beverly, P. A. Thomas, J. T. Walker, B. Sparks, R. D. Oetting, J. M. Ruter, W. Florkowski, D. L. Olson, C. D. Robacker, M. P. Garber, O. M. Lindstrom & W. G. Hudson. 1996.** Reducing the pollution potential of pesticides and fertilizers in the environmental horticulture industry: II. Lawn care and landscape management. HortTechnology. 6: 222-232.

38. **Leslie, A. R. (Ed.) 1994.** Handbook of Integrated Pest Management for Turf and Ornamentals. Lewis Publishers 660 pp.

39. **Neal, J. W., Jr., M. J. Raupp & L. W. Douglass. 1987.** Temperature-dependent model for predicting larval emergence of the bagworm *Thyidopteryx ephemeraeformis* (Haroosh) (Lepidoptera: Psychidae). Environ. Entomol. 16: 1141-1144.

40. **Neal, J. W. Jr. & R. L. Haldemann. 1992.** Regulation of seasonal egg hatch by plant phenology in *Stethoconus japonicus*(Heteroptera: Miridae), a specialist predator of *Stephanitis pyrioides* (Heteroptera: Tingidae). Environ. Entomol. 21: 793-798.

41. **Nyrop, J. P., M. G. Villani, and J. A. Grant. 1995.** Control decision rule for european chafer (Coleoptera: Scarabaeidae) larvae infesting turfgrass. Environ. Entomol. 24: 521-528.

42. **Oetting, R. D. & J. Allison. 1994.** The biologic and economic assessment of chlorpyrifos and diazinon in ornamentals and sod production. USDA Technical Bulletin Number 1837.

43. **Potter, D. A. 1981.** Seasonal emergence and flight of northern and southern masked chafers in relation to aair and soil temperature and rainfall patterns. Environ. Entomol. 10: 793-797.

44. **Potter, D. A. 1993.** Pesticides and fertilizer effects on beneficial invertebrates and consequences for thatch degradation and pest outbreaks in turfgrass. In. Racke, K. D. & A. R. Leslie (eds.) Pesticides in urban environments: fate and significance. ACS Symposium Series No. 522.

45. **Potter, D. A. & S. K. Braman. 1991.** Ecology and management of turfgrass insects. Annu. Rev. Entomol. 36: 383-406.

46. **Potter, D. A. , M. P. Jensen & F. C. Gordon. 1989.** Phenology and degree-day relationships of the obscure scale (Homoptera: Diaspididae) and associated parasites in pin oak in Kentucky. J. Econ. Entomol. 82: 551-555.

47. Ranney, T. G. & J. F. Walgenbach. 1992. Feeding preference of Japanese beetles for taxa of birch, cherry, and crabapple. J. Environ. Hort. 177-180.

48. Quisenberry, S. S.. 1990. Plant resistance to insects and mites in forage and turf grasses. Fla. Entomol. 73: 411-421.

49. Raupp, M. J., J. A. Davidson, J. J. Holmes & J. L. Hellman. 1985. The concept of key plants in integrated pest management for landscapes. J. Arboric. 11: 317-322.

50. Raupp, M. J. C. S. Koehler & J. A. Davidson. 1992. Advances in implementing integrated pest management for woody landscape plants. Annu. Rev. Entomol. 37: 561-585.

51. Raupp, M. J., R. G. Van Driesche & J. A. Davidson. 1993. Biological control of insect and mite pests of woody landscape plants: concepts, agents and methods. Maryland Cooperative Extension Service Publication. 39 pp.

52. Raupp, M. J., M. R. Hardin, S. M. Braxton & B. B. Bull. 1994. Augmentative releases for aphid control on landscape plants. J. Arboric. 20: 241-249.

53. Redmond, C. T. & D. A. Potter. 1995. Lack of efficacy of in vivo- and putatively in vitro-produced *Bacillus popilliae* against field populations of Japanese beetle (Coleoptera: Scarabaeidae) grubs in Kentucky. J. Econ. Entomol. 88: 846-854.

54. Reinert, J. A. 1982. A review of host resistance in turfgrasses to insects and Acarines with emphasis on the southern chinch bug. Pp 3 - 12, In. H. D. Niemczyk & B. G. Joyner (eds.) Advances in turfgrass entomology. Hammer Graphics, Inc. Piqua, Ohio.

55. Sadof, C. S. & C. Alexander. 1993. Limitations of cost-benefit-based aesthetic injury levels for manageing twospotted spider mites. J. Econ. Entomol. 86: 1516-1521.

56. Sadof, C. S. & M. J. Raupp. 1997. Aesthetic thresholds and their development. In L. G. Higley & L. P. Pedigo (eds.) Economic thresholds for integrated pest management. Univ. Of Nebraska Press, Lincoln, NE. (In press).

57. Schultz, P. B. 1993. Host plant acceptance of azalea lace bug (Heteroptera: Tingidae) for selected azalea cultivars. J. Entomol. Sci. 28: 230-235.

58. Smith-Fiola. 1995. Pest-resistant ornamental plants. Rutgers Cooperative Extension Publication.

59. Tashiro, H. 1987. Turfgrass insects of the United States and Canada. Cornell Univ. Press. Ithaca, NY.

60. Terry, L. A., D. A. Potter, and P. G. Spicer. 1993. Insecticides affect predatory arthropods and predation on Japanese beetle (Coleoptera: Scarabaeidae) eggs and fall armyworm (Lepidoptera: Noctuidae) pupae in turfgrass. J. Econ. Entomol. 86: 871-878.

61. Trumbule, R. B. & Denno, R. F. 1995. Light intensity, host plant irrigation, and habitat-related mortality as determinants of the abundance of azalea lace bug (Heteroptera: Tingidae). Environ. Entomol. 24: 898-908.

62. Wang, Y. 1996. Identification of azalea genotypes resistant to azalea lace bug (Heteroptera:Tingidae) and possible resistance mechanisms. MS Thesis, Univ of Georgia.

63. Zuparko, R. L. & D. L. Dahlsten. 1994. Host plant resistance and biological control for linden aphids. J. Arboric. 20: 278-281.