25 Role of Extension Educators and Consultants

David W. Hagstrum
Bhadriraju Subramanyam

Many university extension entomologists have extension and research responsibilities, and conduct demonstration projects to solve known or emerging insect problems. Traditionally, extension agents have provided research-based education and training on stored product protection. Over the last three decades the number of extension agents and scientists who spend a portion of their time in this area has decreased, as institutions focus on discipline-related rather than commodity-related positions. Lack of funding for extension and research positions and losses due to positions that were not refilled have contributed to falling numbers. This void in stored-product entomology extension has been filled by a few university and USDA researchers who now provide the bulk of information needed by the grain, food, and pest management industries. A few university scientists have also served as consultants to solve specific insect problems faced by grain and food industry stakeholders. More recently, insect diagnostic laboratories and websites have become an important source of information on stored-product insects (Ascerno 1981).

Fewer chemicals now are available for use in stored-product protection, and more state and federal regulations (FQPA, Montreal Protocol, fumigation management plans) have been implemented to restrict their use. At the same time, consumer demand grows for food free of pesticide residues. Needs in stored-product protection are greater than several decades ago, yet the task of generating and disseminating established and new information cannot be fulfilled by the decreasing number of existing scientists and extension educators. Private consultants specializing in stored-product protection are urgently needed to facilitate the use and proper adoption of monitoring-based pest management and alternative, nonchemical-based IPM programs.

Private consultants who provide research-based education and training in addition to scouting services have been critical to the implementation of IPM programs in field and orchard crops (Lambur et al. 1989). Consultants can provide advice on the optimal use of simple insect pest management methods and provide the expertise needed to use more complex methods. With a greater awareness and adoption of IPM, many exterminators previously referred to as pest control operators are now called pest management professionals. They are correctly called pest management professionals because they use a variety of pest management methods and depend less on chemical pesticides (Bruesch and Mason 2005). At present, few consultants specialize in the area of stored-product protection, and many offer services primarily to the food industry and not throughout the postharvest supply chain. Additionally, confidentiality agreements consultants have with the companies that hire them preclude valuable scientific exchange of the information to the public.

Extension Programs

Extension programs have included bulletins, fact sheets, demonstration projects, and training programs. Printed extension bulletins have been supplemented by online extension bulletins (Hagstrum and

Subramanyam 2009a) that can be updated more easily (VanDyk 2000). For example, in Kansas, the value of probe traps for monitoring insect populations in stored wheat and deciding whether pest management intervention is needed was first demonstrated with cooperating producers (Lippert and Hagstrum 1987). Harein and Clarke (1995) provided a list of training programs that have been offered consistently in the "train-the-trainer" format for university extension entomologists and state Department of Agriculture representatives responsible for stored-product protection.

The online extension bulletins and fact sheets typically provide information on insect biology and management with emphasis on insecticides currently registered for use. This creates an opportunity for consultants to replace researchers and extension educators, working closely with producers, grain elevator managers, food industry sanitarians, and pest management professionals to provide customized management solutions.

The earmarked funding for extension programs of several decades ago is no longer available, and extension effort has now become part of integrated projects supported by federal agencies on a competitive basis. Competitive grants now are required to be multi-authored, multi-institutional, and multi-year projects with outcomes that are widely applicable and implementable. The lack of people working in this area makes it difficult to get consistent funding for federal projects that require large working groups. Consultants have a great potential to enter the stored-product protection arena and to collaborate with university and USDA scientists on funding opportunities, in addition to filling the void created by the loss of extension personnel and services.

Scouting Programs

International trade has increased the likelihood of uncommon insect species being found (Hagstrum and Subramanyam 2009b). More than 1,663 insect species have been associated with stored products, making identification difficult. Monitoring and treating only when insects are detected can eliminate unnecessary sprays or fumigations (Mabbett 1995).

Timing of pest management is critical and requires insect monitoring (Subramanyam 2007). Understanding the problem often involves detective work. Selection of an optimal pest management method may depend on which insect species are present.

During World War II, when Canada could not ship grain, a scouting program was developed to monitor long-term flat storages (Smallman 1944). In Kentucky, a pilot grain-scouting program for insect and moisture problems was started with 15 producers in one county in 1978, and then expanded to six counties (Skinner 1982). Producers paid from 1 to 5 cents per bushel for the scouting service. As a result a number of serious problems were prevented. This was an extension initiative, but this program was unable to be sustained beyond the time limits of the research program. These scouting programs require trained staff and timely help, which consultants can provide. Generally, extension educators and county extension staff are responsible for several areas of expertise other than stored product protection. Many states do not have an extension specialist in the area of stored product entomology. Questions are deferred to researchers working in stored product entomology or pest management professionals.

Diagnostic Laboratories

Identification of insects to species is the first step in effective pest management (Hagstrum and Subramanyam 2006). Species identification is necessary if published information on biology, ecology, and behavior is to be used in designing a pest management program. Also, the type and amount of damage the insects cause varies among species. The methods used for monitoring various species and the developmental stage most vulnerable to pest management programs also differ among insect species. For a broad-spectrum chemical pesticide, the susceptibility of insects to the pesticide and the choice of the best application method are likely to vary with species as well. Diagnostic laboratories in at least 11 states have dealt extensively with stored product insects (Table 1). In most cases, identification services are primarily for state residents, but at least four states will identify insects for nonresidents. These diagnostic laboratories are supported by tax dollars or have a mechanism for cost recovery through fees for services.

In Minnesota, from 1976 to 1979, the sawtoothed grain beetle was the third to fifth most frequent problem in homes handled by the diagnostic laboratory (Ascerno 1981). The number of inquiries about the sawtoothed grain beetle increased through the

Table 1. *Diagnostic laboratories that provide stored-product insect identification services[a].*

http://edis.ifas.ufl.edu/sr010 Lyle Buss Bldg. 970, Natural Area Dr. PO BOX 110620 University of Florida Gainesville, FL 32611-0620 Phone: 352-273-3933 Fax: 352-392-5660 ufinsectid@ifas.ufl.edu	http://ppdc.osu.edu/ The C. Wayne Ellett Plant and Pest Diagnostic Clinic The Ohio State University 110 Kottman Hall 2021 Coffey Road Columbus, OH 43210-1087 Phone: 614-292-5006 Fax: 614-292-4455 ppdc@postoffice.ag.ohio-state.edu
http://www.ppdl.purdue.edu/ppdl/services.html Plant and Pest Diagnostic Laboratory LSPS-Room 101 Purdue University 915 W. State Street West Lafayette IN 47907-2054 Phone: 765-494-7071 Fax: 765-494-3958 ppdl-info@purdue.edu	http://www.clemson.edu/plantclinic Clemson University Plant Problem Clinic 511 Westinghouse Road Pendleton, SC 29670 Phone: 864-646-2133 Fax: 864-646-2178 ppclnc@clemson.edu
http://www.entomology.ksu.edu/DesktopDefault.aspx?tabid=49 Holly Davis gotbugs@ksu.edu Department of Entomology 123 West Waters Hall Manhattan, KS 66506 Phone: 785-532-4739	http://utahpests.usu.edu/uppdl/ Utah Plant Pest Diagnostic Lab Dept. of Biology Utah State University 5305 Old Main Hill Logan, UT 84322-5305 Phone: 435-797-2435 Fax: 435-797-8197
http://pmo.umext.maine.edu/ipddl/ipddl.htm Clay Kirby, Insect Diagnostician University of Maine Cooperative Extension Pest Management Office 491 College Avenue Orono, ME 04473-129 1-800-287-0279 in Maine or 207-581-2963 Fax: 207-581-3881 ckirby@umext.maine.edu	http://www.idlab.ento.vt.edu/ Eric R. Day, Manager Insect Identification Laboratory Department of Entomology Virginia Tech Blacksburg, VA 24061
http://www.entomology.cornell.edu/cals/entomology/extension/idl/index.cfm Insect Diagnostic Laboratory Dept. of Entomology 4140 Comstock Hall Ithaca, NY 14853-2601 diagnosticLab@frontier.com	http://anr.ext.wvu.edu/pests/identification Pest Identification Laboratory West Virginia Department of Agriculture 1900 Kanawha Blvd. East Charleston, WV 25305-0191 Phone: 304-558-2212
http://www.entomology.wisc.edu/research-staff-profile-phil-pellitteri Insect Diagnostic Lab 240 Russell Labs 1630 Linden Drive Madison, WI 53706	

[a] Labs in Florida, Indiana, Ohio, and South Carolina identify insects for nonresidents.

summer and then declined, perhaps as a result of cooler fall and winter temperatures (Figure 1). A private diagnostic laboratory in Kansas (www.alteca.com) sells insects to food-processing companies in specially designed cards to be placed throughout the facility to monitor effectiveness of fogging, fumigation, or heat treatment. They also provide technical training on insect identification and other micro-analytical entomology services such as identification of insect fragments in grain and processed food. Diagnostic laboratories will continue to be important as consultants become active in the postharvest area.

Research Programs

Researchers often conduct applied research and transfer this technology directly to the end-users. For example, a cowpea warehouse manager in Florida could stand in the doorway of her warehouse in the spring and hear cowpea weevils moving around inside the paper bags in which the cowpeas had been stored the previous fall after being harvested and dried. She wanted to know how the cowpea weevils got into the bags. By sampling cowpeas as they were harvested, researchers found that small numbers of cowpea weevils were infesting the cowpeas in the fields and reproducing in the bags. Offspring slowly developed through the cool winters and emerged from the cowpeas in large numbers in the spring (Hagstrum 1985). Johnson and Valero (2003) determined that organic garbanzo beans needed to be in a freezer for only 14 days to eliminate cowpea weevil infestation.

Reed and Harner (1998) demonstrated to farmers the value of aeration controllers in protecting stored grain. Both the farmers and extension agents were made an integral part of this learning experience. After the demonstration project ended, farmers continued to use the aeration controllers.

Curtis (1984) showed that navel orangeworms laid eggs on almonds remaining in the trees after harvest, but did not lay eggs on almonds that had fallen to the ground. Johnson et al. (2002) showed that combining an initial disinfestation treatment with one of three protective treatments — cold storage (10°C), controlled atmosphere (5% oxygen) storage, or application of the Indianmeal moth granulosis virus — was an effective alternative to chemical fumigation of almonds and raisins for suppression of Indianmeal moth and navel orangeworm populations. Soderstrom et al. (1987), using a sex pheromone that

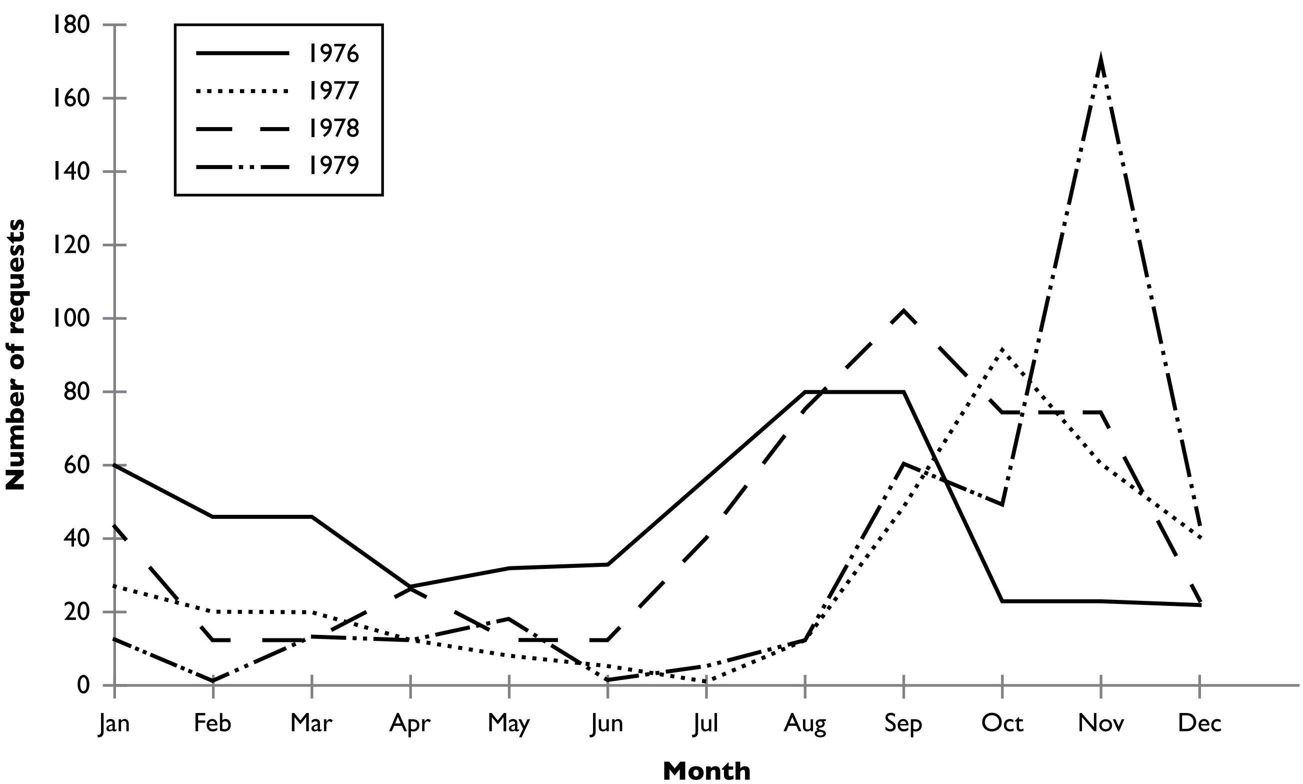

Figure 1. *Sawtoothed grain beetle infestation inquiries (redrawn and used with permission from Ascerno 1981).*

attracts five species of stored product moths, showed the species captured differed among raisin packing plants in the United States, shipping containers, and European warehouses.

Locating and eliminating source populations can be one of the least expensive and most productive components of an IPM program. Vick et al. (1986) used pheromone traps to show the moth problems in grocery distribution warehouses were associated with birdseed and chicken feed. Platt et al. (1998) found stored-product insects most frequently in the flour and pet food aisles of grocery stores. Bowditch and Madden (1996) found that moths were abundant in only 3 of 35 rooms of a confectionary factory. These rooms were used for chocolate refining and nut roasting, and high captures were near infested machinery or a result of insects being attracted to water that was present.

At Kansas State University, a total of six heat treatment workshops were held to train food industry staff about the use of elevated temperatures (50 to 60°C for 24 to 36 hours) for disinfesting food-processing facilities. A total of 350 participants from the U.S. and other parts of the world attended these workshops. During the workshops, the pilot flour and feed mills at Kansas State University were heat-treated with gas and electric heaters, so that participants were part of practical heat treatments, from the beginning to the end.

Research by Kansas State University scientists on the maximum time required to kill adults and the heat-tolerant young larvae of the red flour beetle (Mahroof et al. 2003) showed that these two insect stages were killed 12 hours into the heat treatment. Based on these data, a breakfast cereal manufacturer reduced total heat treatment time to 24 hours, resulting in an annual cost savings of $25,000 (Subramanyam 2010). The cost-effectiveness prompted this company to use heat treatments in their other processing facilities to replace fumigations, which would require sealing the facility and stopping production until the air is safe for workers to continue work.

Consultants

Consultants are routinely used in the grain and food-processing industry as a second, unbiased, pair of eyes and a means of keeping up with new pest management methods and regulations (Gerberg 1991). These consultants often are active faculty members at a university, or retired government, food industry, and university personnel. In some cases, companies hire consultants to provide services as expert witnesses in legal cases. Consultants are valuable because they have knowledge and access to scientific and popular literature (Hagstrum and Subramanyam 2009a) plus relevant practical experiences.

A private consulting company, Precision Grain Management (http://www.grainstoragescience.com), founded and run by an emeritus university faculty member, now provides scouting services. As the only one doing this type of work, the company advised more than 70 elevators in Kansas, Oklahoma and Nebraska from 2003 to 2010 (Hagstrum et al. 2010). The sampling program has improved insect pest management by ensuring that fumigation is done when it is most cost-effective. For example, Precision Grain Management personnel sampled insect populations in 25 flat storages of corn or wheat at elevators in Kansas 116 times between 2003 and 2009, by taking a total of 16,549 grain samples (Hagstrum et al. 2010). The samples were often taken after aeration and fumigation to assure elevator managers that pest management efforts had been effective. Insects were not found in 20 of the flat storages. Insect populations in the grain in the other five flat storages generally did not reach densities that would result in an infested designation on the grain-grading certificate.

Adoption of New Methods

Extension educators and consultants can encourage adoption of new technologies. Automation of monitoring for insects in grain using acoustical methods, methods of converting trap catch to absolute estimates, models predicting insect population growth rates, and more accurate economic thresholds and cost/benefit analysis can improve pest management. Attracticide (lure-and-kill), mass-trapping, and biological control may be useful in some situations. These methods have potential and are being more widely tested and adopted by the grain and food industry. The use of biological control is reviewed in Chapter 17 of this book.

Acoustical methods are commercially available for automatic continuous, non-destructive, remote monitoring of insect populations in stored grain (Mankin et al. 2010 and Chapter 22 of this book), but they are not widely used. Probe traps for automatic, continuous, non-destructive, remote monitoring insects in grain also are being marketed (Flinn et al. 2009), but are not widely used. Methods have been developed for converting these trap catches (Flinn et al. 2009) and those for sticky traps to absolute insect densities (Savoldelli 2006). Many of the tools and techniques have not been adopted because of lack of understanding and risk-averse behavior to newer technologies that deviate from traditional methods.

The decision tools developed for IPM in field and orchard crops have not been widely adopted for the protection of stored products. Sampling-based decision-making is being emphasized, but few economic thresholds have been developed for stored-product pests. The economic threshold is specific for a given species, and is the insect density at which pest management must be applied to prevent economic losses, but below which pest management is not economical (Onstad 1987). The thresholds depend on cost of the pest management method and market value of the commodity being protected. Multiple thresholds need to be considered if more than one pest management method is available, and the threshold must be adjusted as cost of pest management methods or the market values of the stored commodities change. Also, insect population growth models can be useful in predicting future insect densities, preventable commodity damage, and economic losses. The population growth models that have been developed for stored-product insects are listed in Table 7.3 in Hagstrum and Subramanyam (2006). The models can be used to determine when the economic threshold will be reached.

Pheromones and food attractants have been investigated as means of increasing the effectiveness of spot insecticide treatments for the Indianmeal moth (Nansen and Phillips 2004) and navel orangeworm (Phelan and Baker 1987). A Hawaii company (Food Protection Services) has conducted long-term studies on the use of mass trapping to find source populations and reduce cigarette beetle and moth populations in food storage warehouses and bakeries (Pierce 1994,1999). Similar studies were done successfully in a flour mill in Italy (Trematerra and Gentile 2010).

Follow-Up Monitoring

Monitoring is critical to determining whether the instituted pest management was effective. Roesli et al. (2003) used traps for stored-product beetles and moths to gauge the effectiveness of heat treatment in a feed mill. Some species — such as the cigarette beetle, Indianmeal moth, and almond moth — were completely controlled by the heat treatment, and very few insects were captured during the post-heat treatment period, whereas populations of the red flour beetle were captured within two to four weeks. Pest management professionals offering IPM services should monitor insect populations to show clients the degree and duration of insect management obtained due to an IPM intervention.

Mason (2005) suggested that the use of follow-up insect monitoring is an important consideration in selecting a fumigator. Using 15 published studies, Hagstrum and Subramayam (2006, see Table 8.1) showed that pest management was often ineffective. The ineffectiveness of pest management in the studies was a result of the breakdown of insecticides over time, inadequate sealing of facilities before fumigation, insects becoming resistant to pesticides, damage to insect-resistant packaging, diapause, and refuges in which insects could avoid being removed or killed. These studies covered many locations in the marketing system, ranging from the farm to the retail store. Pest management methods included the use of insecticides as protectants, fumigation, fogging with aerosols, sanitation, and insect-resistant packaging. Effectiveness can be influenced by the age structure of the pest population, insect species composition, environmental conditions, improper selection and incorrect implementation of pest management, including the absence of quantitative insect-monitoring methods.

The landscape of stored-product protection in the 21st century is changing and will continue to evolve, with IPM shifting from chemical methods to methods that are environmentally benign. The shrinking number of stored-product protection centers worldwide, and the decreasing number of researchers and educators offers great opportunities for consultants to embrace this area, as they have with field crops, and to develop and implement customized programs for the grain and food industry stakeholders. The new knowledge that the consultants can generate in stored-product protection and the role they can play to meet the needs of the end-users for the foreseeable future is immense.

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