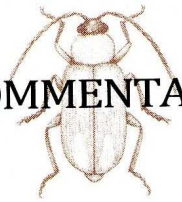

COMMENTARY

Stored Product Entomology in the United States: Perspectives for the Future

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Stored product entomology in the United States, as it relates to insect pest management in bulk grain storage, mills, and food warehouses, has a rich and distinctive past. Among the early research papers in the Journal of Economic Entomology are two by Dean (1911, 1913) describing heat treatments to manage insects inside flour mills. As the 20th Century progressed, research with stored product insects expanded to include basic biological studies, management in stored bulk grains, and host range of specific insect species. During the 1960s and 1970s several Federal laboratories or groups were established in the U.S. for the purpose of research with stored product insects, and research expanded again into different aspects of chemical control, ecology, biology, insect-resistant packaging, and biological control. In recent years, there has been a dramatic reduction in the number of stored product entomologists within the U.S. Federal centers have been closed and staff reductions through retirements have occurred at existing facilities. There has also been a reduction in the number of university entomologists who actively conduct research with stored product insects. This reduction in active researchers poses some significant challenges for the grain and food processing industries. Some examples of future research needs will be described below; however, the order or listing does not indicate a priority. The discussion will focus on the research needs of grain and grain-based products and storage systems, but some of the concepts and ideas could be applicable to other post-harvest environments as well.

The first research need is to integrate economic analyses into applied management programs for stored product insects. Farms, flour mills, food warehouses, distribution centers, and retail stores are businesses, and decisions on insect pest management strategies often will be made according to impact or potential impact on the business. Economic analyses would be particularly useful in the sampling and detection of insect pests, and in making management decisions based on sampling data. For example, there are established techniques for sampling bulk grain, utilizing insect traps to determine species abundance and composition, and estimating insect numbers per unit of grain from probe trap counts (Hagstrum et al. 1985, Flinn et al. 2007). However, there are few published studies that address the costs of selected control strategies for stored bulk grains in the U.S. (Reed et al. 1989, 1993, Flinn et al., 1997). In recent years, only Adam et al. (2010) and Yigezu et al. (2010) directly address the economics of insect sampling in relation to management decisions. Several recent studies have characterized populations of stored product insects in and around milling, processing, and food storage industries (Dowdy and Mullen 1998, Doud and Phillips 2000, Arbogast et al. 2002, Campbell and Mullen 2004). While pheromone traps are commonly used in research studies to sample insect populations (Campbell et al. 2002, Nansen et al. 2006), they are generally sex-specific for one insect species. This requires multiple lures/traps for a single facility to accurately determine species composition, which may be economically limiting in terms of material costs and labor time involved. Perhaps new schemes that include economic analyses could be designed to further develop sampling and monitoring as decision-making tools, and could also involve economic cost/benefit analyses for individual facilities.

A second related research need is for additional knowledge regarding the distribution of insect pests in and around mills, processing plants, and food warehouses. The worldwide phase-out of the fumigant methyl bromide is causing a shift to alternative management strategies such as new fumigants (Campbell et al. 2010ab), heat treatments (Mahroof et al. 2003, Roesli et al. 2003), and aerosol and contact insecticides that can replace some whole-plant treatments (Arthur and Campbell 2007, Arthur 2008). The insect populations in and around mills and warehouses can be important sources for dispersal and colonization after control strategies have been implemented, and awareness and understanding of the resident populations could improve overall pest management.

A third research need is to consider stored product insects as invasive or emerging insect species. Currently, the khapra beetle, *Trogoderma granarium* (Everts), is the only stored product insect in the U.S. that is a quarantine pest. It has a wide host range and has been intercepted in the U.S. on multiple occasions. The dispersal and spread of *Prostephanus truncatus* Horn, the larger grain borer, throughout western and central Africa after accidental introduction from Central America is an

example of how quickly an invasive stored product pest can become established (Golob 1988, Hodges et al. 2003, Nansen et al. 2004). The potential for this insect species to spread northward into the southern U.S. could be accelerated in the near future through climatic changes. Psocids are being seen as potential emerging insect species in Australia, Europe, and the U.S. (Green 2008, Opit &Throne 2008, Nayak & Collins 2008). Their rapid reproductive capacity, ability to persist on different food sources, and tolerance to insecticides compared to stored product beetles indicate a possible change in pest status.

A fourth need is to view stored product insects as affecting people, and not just pests of raw stored commodities or milling and processing facilities. This might require new collaborations between stored product entomologists and traditional urban or medical entomologists. Stored product insects and mites have been considered as human pests due to their potential for carrying and transmitting allergens, contamination with metabolic waste or urticating hairs, or pathogen transfer (Stejskal & Hubert 2008, Larson et al. 2008). Consumers in developed countries are well aware of product contamination caused by stored product insects. The presence of stored product insects in and around urban and suburban habitats, other than in large warehouses and other storage structures, is an area that has received little research attention in the past.

A fifth research need is to develop an approach to integrated pest management (IPM) that is applicable to stored grains and the associated milling, processing, and warehousing industries. We have borrowed extensively from the concepts developed for field crop entomology (Kogan 1998), which rely heavily on sampling and threshold values to determine if a treatment or intervention is warranted (Hagstrum et al. 1999). A management approach that considers a stored product environment as a dynamic ecosystem is certainly desirable, regardless of whether that ecosystem is bulk stored grain in a bin, a large commercial grain elevator, a mill or processing plant, or a food storage or retail outlet (Hagstrum et al. 1999, Platt et al. 1998). However, the needs of a particular industry or facility, the economic costs involved in management, and the research science must be balanced to ensure adoption or implementation of integrated management.

With all of these research needs and a shrinking resource base, it is still vital to continue with existing research programs involving basic, fundamental, and applied research with stored product insects. Basic biological studies coupled with applied research are always necessary to maintain scientific viability and integrity of research. Some recent examples in the U.S. include but are not limited to pathology (Lord 2007) and biochemistry (Oppert et al. 2006) of stored product insects, behavior of selected species in response to biological and environmental stimuli (Mahroof & Phillips 2008, Johnson 2010), stored product insects as models for ecological or genomic studies (Messina 2004, *Tribolium* Sequencing Consortium 2008), susceptibility to alternative or new insecticides (Subramanyam et al. 2007), and impact of insecticides on field populations (Toews et al. 2006). However, important aspects of research with stored product insects, such as insect-resistant packaging, protection of woolen fabrics, and development of detailed sampling plans, are not currently being addressed in existing research programs.

A final area of concern is the dissemination of research information relating to stored product entomology. State and federal support for traditional Extension services is rapidly eroding, and there are the additional challenges of shifting from print to digital communication (VanDyk 2000). There are few land-grant universities that have assigned personnel with Extension responsibilities for stored product insects. Although there are a number of states within the U.S. that publish Extension Bulletins through print and Internet sites, the information relating to management of stored product insects is often lacking, incomplete, outdated, or recycled from other publications and Web sites (Subramanyam and Hagstrum 2009). In many cases, researchers are expected to be directly involved in the transfer of knowledge regarding management of stored product insects to customer and user groups, which may require different communication methods and styles than those customarily employed to discuss research results at scientific meetings.

In conclusion, this commentary is not a comprehensive review of past or current research on stored product insects, either in the U.S. or other parts of the world, nor does it provide a comprehensive description of future needs as they relate to stored grains, the milling industry, or processed food warehouses. Unfortunately, the trends in stored product entomology outlined here, particularly the decline in the number of specialists, are occurring in other countries as well. Reference citations are used for illustrative purposes, and the inclusion of specific references does not imply added significance.

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