RESEARCH

A Review of Stored-Product Entomology Information Sources

David W. Hagstrum and Bhadriraju Subramanyam

ABSTRACT The field of stored-product entomology deals with insect pests of raw and processed cereals, pulses, seeds, spices, dried fruit and nuts, and other dry, durable commodities. These pests cause significant quantitative and qualitative losses to the multibillion dollar grain, food, and retail industries each year through their feeding, product adulteration, customer complaints, product rejection at the time of sale, and cost associated with their management. The reduction in the number of stored-product entomologists at a time when regulations are reducing the number of chemicals available to manage stored-product insect pests is making full use of the literature on stored-product insects more important. Use of nonchemical and reduced-risk pest management methods requires a greater understanding of pest biology, behavior, ecology, and susceptibility to pest management methods. Stored-product entomology courses have been or are currently offered at land grant universities in four states in the United States and in at least nine other countries. Stored-product and urban entomology books cover the largest total numbers of stored-product insect species (100–160 and 24–120, respectively); economic entomology books (17–34), and popular articles or extension Web sites (29–52) cover fewer numbers of stored-product insect species. A review of 582 popular articles, 182 extension bulletins, and 226 extension Web sites showed that some aspects of stored-product entomology are covered better than others. For example, articles and Web sites on trapping (4.6%) and detection (3.3%) were more common than those on sampling commodities (0.6%). Natural enemies and biological control together were the subjects of only 2.6% of articles and Web sites. Locating and eliminating the source populations may be one of the least expensive and most productive components of an insect pest management program, yet sources of insect infestations were the subject of only 1.2% of articles and Web sites. Insect biology is often oversimplified in popular articles and Web sites; for example, developmental times are often characterized by a single number giving the typical number of days required to complete development from egg to adult, instead of describing how developmental times vary with temperature. Literature is available on the effects of temperature and other environmental factors on the developmental times of 106 species of stored-product insects. This article provides insights into the extent to which stored-product insects are covered in entomology books, entomology courses, popular articles, and extension bulletins and Web sites. Stored-product entomology books and courses are important because the coverage of stored-product insects is limited in urban and other entomology books and courses. In addition to failing to provide training on managing stored-product insect pests, the limited coverage of stored-product insects in many entomology books suggests to students that they are of less economic importance than is the case. We hope that this paper will encourage and facilitate more extensive coverage of stored-product insects in entomology books and courses, popular literature, and Web sites to meet the pest management needs of the grain, food processing, retail, and pest management industries.

Keywords: stored-product insects, popular articles, extension bulletins, Web sites

Stored-product entomology emphasizes insect pests of raw and processed cereals, pulses, seeds, spices, dried fruit and nuts, and other dry, durable commodities. These pests cause significant quantitative and qualitative losses to the multibillion dollar grain, food, and retail industries each year through their feeding, product adulteration, customer complaints, product rejection at the time of sale, and cost associated with their management. Urban entomology books, however, often provide more information on fabric, library, and museum pests than stored-product pests. Several universities offer courses in stored-product or urban entomology, and stored-product insects may be briefly covered in economic, agricultural entomology, or applied entomology courses, and seed technology courses. Although many popular articles and extension bulletins or Web sites are available for stored-product insects, many aspects of stored-product insect biology are not covered adequately. Interceptions of stored-product insects during quarantine inspections provide information on the distribution of stored-product insects and the types of commodities infested.

Recently, the number of stored-product entomologists has de-

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clined in Australia, Canada, the United Kingdom, the United States, and many other countries as a result of the closing of research institutions and a shift from commodity-oriented positions to discipline-oriented positions. At the same time, pesticide and environmental regulations have reduced the number of chemicals that are available to manage stored-product insect pests. Therefore, managing stored-product insect pests is becoming more of a challenge. Full use of the literature on stored-product insects will be increasingly important if the number of stored-product entomologists continues to decline, because management of insects using reduced-risk products and nonchemical methods requires more knowledge and training in pest biology, behavior, ecology, and pest susceptibility to IPM methods.

In 2006, we described many published stored-product entomology books, reviews, and conference proceedings (Hagstrum and Subramanyam 2006), including 45 books and 13 reviews on stored-product entomology written between 1951 and 2006, and 21 conference proceedings published between 1976 and 2003. Fields and Maier (1999) summarized government, university, and industry Web sites where information on stored-product protection is available. Web sites are increasingly important as a quick source of information. Mankin (2005) showed that Web pages with the highest information content were accessed most frequently. He reported that use of the Florida Web site "Feature Creatures," which includes several stored-product insect species, increased 6.3-fold between January 2002 and December 2004.

In this article, we expand the discussion of stored-product entomology information sources covered by Fields and Maier (1999) and Hagstrum and Subramanyam (2006) to include urban and other entomology books, stored-product and urban entomology courses, and popular articles in trade journals, extension bulletins, and extension Web sites. The available information sources are too numerous to be covered in a single paper, but we examined 29 entomology books with some information on stored-product insects, 27 stored-product entomology courses, 582 popular articles, 182 extension bulletins, and 226 extension Web sites. We excluded scientific journals because various aspects of stored-product entomology published in national and international journals are referenced in books and conference proceedings (Hagstrum and Subramanyam 2006).

Methods for Gathering Information

We did a literature search for urban, agricultural, applied, and economic entomology books, and seed technology books and examined each book for information on stored-product insects. We contacted colleagues in 22 countries by e-mail and asked whether they knew of stored-product entomology courses taught in their country. They were asked about the institution where the course was offered and information about the course instructor. The instructors were contacted for details about the number of years the course was taught and approximate numbers of students enrolled in the course each year. We searched Web sites for the land grant colleges in the United States for urban entomology courses and contacted instructors by e-mail for more information about their courses. We searched the table of contents for the trade magazine *Pest Control*, and *Agricultural Research*, a publication from USDA highlighting research by USDA scientists, for articles about stored-product insects. Regular columns on stored-product insects by Linda Mason in *Grain Journal*, a trade magazine for the grain industry, and Bhadriraju Subramanyam in *Milling Journal*, a trade magazine for the milling industry, were also considered. A literature search was done to find published extension bulletins. Specific key words were used in various internet search engines to find Web sites with extension information on stored-product insects. These were often listed under stored grain, kitchen, pantry, or household pests. Extension bulletins or Web sites, and popular articles from 55 other trade journals in our bibliographic database were also considered. We categorized all of these popular articles, and extension bulletins or Web sites by subject.

Urban and Other Entomology Books

We compared the numbers of insect species most commonly included in urban entomology books with those included in economic or stored-product entomology books (Table 1). The numbers of species covered in the articles in *Pest Control* and at extension Web sites are also included in Table 1. The two stored-product entomology books included 100 and 160 species and 24–120 species were included in the nine urban entomology books. Only 16–30 species were included in the economic entomology books. The popular articles and extension Web sites reported 30 and 52 species, respectively. Urban entomology books included 24–61 of the species covered in stored-product entomology books, and economic entomology books included 16–30 of these species. *Pest control* magazine articles included 30 of these species, and extension Web sites included 40 of these species.

The coverage of stored-product insects is often limited in urban entomology books because they primarily focus on urban pests such as ants, roaches, and wood-boring insects. The nine urban entomology books together included 65 of the species and 19 of the families included in stored-product entomology books (Table 2). One-third of these species are in the families Dermestidae and Tenebrionidae.

The Handbook of Pest Control by Mallis (1945) included separate chapters on clothes moths, hide and carpet beetles, and stored-product insects. Some or all of these chapters were written by different authors in the 6th (Okumura 1982), 7th (Parker 1990a,b; Walter 1990), 8th (Katz 1997, Hinderer 1997; Granovsky 1997) and 9th (Black 2004; VanRyckeghem 2004) editions. In the 9th edition, the clothes moths and hide and carpet beetles chapters were combined into a chapter on fabric and museum pests. Much of the information on insect biology has not been updated since 1945 (Wilbur and Mills 1985). The compact disk by Faszulo et al. (2006) on pests in and

Table 1. Number of stored-product insect species mentioned in different publications

Type of publication[a]	U	U	U	U	U	U	U	U	U	E	E	E	PC	W	S	S
Year of publication	1896	1914	1931	1951	1978	1996	1997	2000	2004	1931	1985	1993			2004	2006
Total no. species	26	32	120	60	61	61	38	24	82	17	30	34	30	52	160	100
No. species of > 1 type	25	24	54	47	50	44	35	24	61	16	28	30	30	40	64	55

[a]Urban entomology books (**U**) include Howard and Marlatt (1896), Herrick (1914), Patton (1931), Busvine (1951), Ebeling (1978), Hedges and Lacey (1996a, b), Bennett et al. (1997), Gold (2000) and revision of Mallis (1945) edited by Moreland and Hedges (2004). Economic entomology books (**E**) include Doane (1931), chapter by Wilbur and Mills (1985) and Metcalf and Metcalf (1993). Stored-product entomology books (**S**) include Rees (2004) and Hagstrum and Subramanyam (2006). Articles from Pest Control magazine (**PC**) and extension Web sites (**W**) are also included.

Table 2. Incidence of each stored-product insect species by publication type

Family	Species	Type of publication[a] U	PC	E	W	S
Anobiidae	*Lasioderma serricorne* (F.)	9	0	2	1	2
	Stegobium paniceum (L.)	8	1	2	1	2
Anthribidae	*Araecerus fasciculatus* (De Geer)	6	0	0	0	2
Bostrichidae	*Dinoderus minutus* (Horn)	3	0	0	0	2
	Prostephanus truncatus (Horn)	1	0	2	0	2
	Rhyzopertha dominica (F.)	6	0	2	1	2
Bruchidae	*Acanthoscelides obtectus* (Say)[b]	7	0	2	1	2
	Callosobruchus maculatus (F.)	4	0	1	1	2
Cleridae	*Necrobia rufipes* (DeGeer)	7	1	1	0	2
Curculionidae	*Sitophilus granarius* (L.)	7	1	3	1	2
	Sitophilus oryzae (L.)	8	0	3	1	2
Dermestidae	*Anthrenus flavipes* Leconte[b]	7	2	1	1	2
	Anthrenus scrophulariae (L.)[b]	9	1	2	1	1
	Anthrenus verbasci (L.)[b]	6	1	0	1	2
	Attagenus unicolor (Brahm)[b]	9	1	3	1	2
	Dermestes ater DeGeer	6	1	0	1	1
	Dermestes lardarius L.	9	1	1	1	2
	Dermestes maculatus Degeer	7	1	0	1	2
	Trogoderma granarium Everts[b]	5	1	2	1	2
	Trogoderma inclusum LeConte[b]	3	1	0	0	2
	Trogoderma variabile Ballion[b]	3	0	0	1	2
Gelechiidae	*Sitotroga cerealella* (Olivier)[b]	7	0	3	1	2
Laemophloeidae	*Cryptolestes ferrugineus* (Stephens)	4	0	1	1	2
	Cryptolestes pusillus (Schonherr)	7	0	1	1	2
	Cryptolestes turcicus (Grouvelle)	3	0	0	1	2
Lophocateridae	*Lophocateres pusillus* Klug	4	0	0	0	2
Mycetophagidae	*Typhaea stercorea* (L.)	3	0	1	1	2
Nitidulidae	*Carpophilus dimidatus* (F.)	5	0	1	1	2
	Carpophilus hemipterus (L.)	6	0	1	1	2
Oecophoridae	*Endrosis sarcitrella* (L.)	3	0	0	0	2
	Hofmannophila pseudospretella (Stainton)[b]	4	0	0	0	1
Ptinidae	*Gibbium psylloides* (Czenpinski)	4	0	0	0	1
	Mezium americanum (Laporte)	4	1	0	1	1
	Niptus hololeucus (Faldermann)[b]	5	1	0	0	1
	Ptinus clavipes Panzer[b]	3	1	0	1	1
	Ptinus fur (L.)[b]	7	1	0	1	1
	Ptinus ocellus Brown	6	1	0	1	2
	Ptinus villager (Reitter)[b]	3	1	0	1	2
Pyralidae	*Anagasta kuehniella* (Zeller)[b]	7	0	3	1	2
	Cadra cautella (Walker)[b]	4	1	0	0	2
	Corcyra cephalonica (Stainton)	2	0	1	0	2
	Ephestia elutella (Hübner)[b]	5	0	1	0	2
	Plodia interpunctella (Hübner)[b]	8	1	3	1	2
	Pyralis farinalis L.[b]	4	1	0	0	2
Silvanidae	*Ahasverus advena* (Waltl)	5	1	2	1	2
	Cathartus quadricollis (Guerin)	4	0	1	0	2
	Oryzaephilus mercator (Fauvel)	7	0	0	1	2
	Oryzaephilus surinamensis (L.)	9	1	3	1	2
Tenebrionidae	*Alphitobius diaperinus* (Panzer)	5	0	0	1	2
	Gnatocerus cornutus (F.)	6	0	1	0	2
	Gnatocerus maxillosus (F.)	6	0	1	0	2
	Latheticus oryzae Waterhouse	5	0	1	0	2
	Palorus ratzeburgii (Wissmann)	3	0	1	0	2
	Palorus subdepressus (Wollaston)	3	0	1	0	2
	Tenebrio molitor (L.)	7	0	3	1	2
	Tenebrio obscurus (F.)	6	0	3	0	1
	Tribolium audax Halstead	3	0	0	0	2
	Tribolium castaneum (Herbst)	9	1	3	1	2
	Tribolium confusum Jacquelin du Val	9	1	3	1	2
	Tribolium destructor Uyttenboogaart	3	0	0	0	2
Tineidae	*Nemapogon granella* (L.)[b]	4	0	0	0	1
	Tinea pellionella L.	8	1	2	1	2
	Tineola bisselliella (Hummel)	8	2	2	1	2
	Trichophaga tapetzella (L.)	8	1	1	0	1
Trogositidae	*Tenebroides mauritanicus* (L.)	8	0	3	1	2

[a]Types of publications include urban entomology books (**U**), *Pest Control* articles (**PC**), economic entomology books (**E**), extension Web sites (**W**) and stored-product entomology books (**S**).
[b]Species that enter diapause.

around homes also has information on stored-product insect pests. Books on clothes moths (Austen and McKenny 1932), insect pests in libraries (Hickin 1985), and insect pests in museums (Pinniger 1994) also provide information on many of these species. In addition, a workbook for urban entomology by Wilson et al. (1977) includes stored-product insects.

Coverage of stored-products insects in other entomology books was generally very limited. Five exceptions among economic entomology books are the following:

1. a chapter on the rice weevil in the book by Wellhouse (1926);
2. a chapter entitled "Insects infesting mills, store-rooms and houses" in a book by Doane (1931);
3. a chapter by Wilbur and Mills (1985) in the economic entomology book edited by Pfadt;
4. a chapter by Granovsky (1989) in an integrated pest management book; and
5. a chapter covering stored-product insects in a book by Metcalf and Metcalf (1993).

Applied entomology and agricultural entomology books by Abivardi (2001a,b), Caswell (1962), Edwards and Heath (1964), Gupta (1967), Nayar et al. (1976), Pradhan (1983) and Pruthi (1969) have some information on stored-product insects. Several seed technology books did not include stored-product insects at all (Black and Bewley 2000, Copeland 1985, Desai 2004, Kelly 1988, McDonald and Kwong 2005). Others briefly covered stored-product insects (Barton 1961, Basra 2006, Roberts 1972, Thomson 1979), and one had a full chapter (Howe 1972). Books on managing insect pests of specific crops such as cocoa (Entwistle 1972) and peanuts (Ordish 1967) have chapters on stored-product insects. A Crop Protection

Compendium (CABI 2005) on compact disk has information on 50 common species of stored-product insects. For some of these species, information was included on the biology, commodities infested, type of damage, geographical distribution, natural enemies, and available pest management methods.

More than 1,660 insect species in 120 families have been reported to be associated with stored products, and almost 470 of these species are natural enemies (Hagstrum and Subramanyam 2009). Some species are cosmopolitan, whereas others are more restricted in their geographical distribution. Many species directly or indirectly cause extensive economic losses to stored commodities worldwide. The limited coverage of stored-product insects and pest management methods for these species in many entomology books gives the false impression that they are of less economic importance than other insect pests associated with crops and urban environment.

Stored-Product and Urban Entomology Courses

Stored-product entomology courses have been or are currently offered at land grant universities in four states in the United States, and in at least nine other countries (Table 3 and text). At Kansas State University, Don Wilbur taught Milling Entomology course from 1949–1968 in the Department of Grain Science and Industry, and later taught Insects of Stored Products course from 1960–1970 in the Department of Entomology. Insects of Stored Products course continues to be offered every even year in the entomology department. Phil Harein offered a stored-product entomology course at the University of Minnesota for 6 years between 1972 and 1978. The course at Southwest University, Chongqing, China, has been taught since the 1940s. Courses at other Chinese universities have been taught for more than 50 years. Other stored-product entomology courses have been taught for 7–20 years.

Two stored-product entomology courses have been offered in Brazil for 9 and 29 years. The course at Federal University of Paraná in Brazil was started by Armando Antunes de Almeida and then taught by Sonia Lazzari and Flavio Lazzari. The course in Portugal is taught by a team of instructors. The stored-product entomology courses by Leda Faroni in Brazil, Noel White in Canada and Francis Fleurat-Lessard in France are offered in engineering departments because of the extensive work by engineers on grain aeration, drying, and quality. We were told that most of the engineering students taking the course do not continue to work on stored-product insects. The courses by Pasquale Trematerra in Italy are taught at the undergraduate and graduate levels. Short courses and guest lectures covering stored-product insects are more common than university courses but often are much more limited in their coverage.

Stored-product entomology courses are often offered only every other year and may have only 1–10 students, although others have had from 11-250 students. Entomologists working with stored-product insects in Australia, Denmark, Germany, Israel, Poland, Sweden, Uganda, and the United Kingdom indicated that they did not know of a course currently being offered in stored-product entomology. Stored-product entomology courses are taught in at least two universities in India (Acharya N. G. Ranga Agricultural University, Rajendranagar, Andhra Pradesh, and Tamil Nadu Agricultural University, Coimbatore), three universities in Thailand (Chiang Mai University, Kasetsart University, and Khon Kaen University), and one other university in China (Zhengzhou Grain College, now Henan University of Grain Engineering Technology) for which we do not have information on dates and numbers of students. China also offers training on stored-product insects as part of their grain storage training program in each province. Stored-product entomology courses evidently have been taught in Iran and Korea, but are not currently available. "Fundamentals of Grain Storage" and "Food and Feed Product Protection" are examples of two courses offered by the Department of Grain Science and Industry, Kansas State University, that provide some information on stored-product entomology, primarily on identification, biology, and management.

Urban entomology courses are more common than stored-product entomology courses in the United States and are offered at land grant universities in 10 states (Alabama, California, Florida, Georgia, Hawaii, Indiana, North Carolina, South Carolina, Texas, and Virginia). Books by Bennett et al. (1997), Gold and Jones (2000), and Moreland and Hedges (2004) are available as textbooks for urban entomology courses. Some instructors use assigned readings instead of a textbook because some of the subjects covered in their course are not covered in available textbooks. Economic entomology in the United States and applied entomology courses in other countries may provide some information on stored-product insects, but many insect species are pests of field and orchard crops and quite often little time is devoted to stored-product insect pests.

Popular Articles and Extension Bulletins or Web Sites

Popular articles, extension bulletins, and more recently extension Web sites are sources of information on many aspects of stored-product entomology: 49.0% (n = 486 on biology) covered insect biology, and 51.0% (n = 504 on management methods) were mainly about insect pest management (Table 4). In ranked order, species of dermestids (7.3%), tenebrionids (3.4%), pyralids (3.4%) tineids (3.0%), and fabric pests (clothes moths and carpet beetles, 2.6%) were the most frequently covered insects.

Diapause occurs in 46 stored-product insect species in the families Bruchidae, Dermestidae, Gelechiidae, Oecophoridae, Ptinidae, Pyralidae and Tineidae (Bell 1994); 20 of these species are included in urban entomology books (Table 2). Diapause can make insects less susceptible to pest management and make predicting the time of adult eclosion (larval diapause) or reproduction (adult reproductive diapause) more difficult (Hagstrum and Subramanyam 2006). Yet, only one popular article has been published on diapause. Locating and eliminating the source populations may often be one of the least expensive and most productive components of an insect pest management program; however, sources of insect infestations were the subject of only 1.2% of the articles.

Pantry pests were more frequently the subject of extension Web sites compared with extension bulletins (49 and 15, respectively), whereas grain pests were more frequently the subject of earlier extension bulletins compared with Web sites (24 and 19, respectively). Most extension Web sites were prepared after 1990; most extension bulletins were prepared before 1990. VanDyk (2000) describes how the Internet has affected extension entomology. Web sites make it possible to deliver extension information more quickly the user, facilitates updating information more frequently than printed extension bulletins. Web addresses, however, are frequently changed, and the information available on the Internet is not well organized.

Extension Web sites for stored-product insects were available for 41 states. We did not find Web sites for Connecticut, Hawaii, Maryland, Massachusetts, Nevada, North Carolina, Oregon, South Dakota, and Utah. These states must have had many of the same problems as the other states, but they must not have assigned an

Table 3. Stored-product entomology courses taught in different countries

University	Years	No. students/year	Instructor
1. Southwest University, Chongqing, China	1940s–1988	—	Longshu Li
	1988–present	60	Yongxue Deng
2. Kansas State University, USA	1949–1970	25	Don Wilbur
	1976–1990	—	Bob Mills
	1992–2000	—	Barry Dover
	2002–present	3–9	David Hagstrum
3. Nanjing University of Finance and Economics, China	1957–present	30–70	Song Wei, Wang Mingjie
4. University of Minnesota	1972–1978	15–20	Phillip Harein
5. University of Milan, Italy	1973–1993	—	Luciano Süss
	1993–present	80	Daria P. Locatelli
6. Federal University of Paraná, Brazil	1980–present	6–8	Armando Antunes de Almeida, Sonia and Flavio Lazzari
7. University of Udine, Italy	1985–present	30	Fiorella Chiesa
8. Agricultural University of Athens, Greece	1989–2005	—	Constantin Buchelos
	2005–present	250	Christos Athanassiou
9. Federal University of Viçosa, Brazil	1990–present	5–10	Leda Rita D'Antonio
10. University of Manitoba, Canada	1991–present	1–10	Noel D. G. White
11. High Agronomic Institute/ Technical University, Lisbon, Portugal	1993–present	5–15	Maria Otilia Carvalho, Anna Paula Pereira, Antonio Maia, Antonio Barbosa, Garca Barros, Antonio Mexia
12. High School of Agricultural Engineers, Bordeaux, France	1993–present	11–16	Francis Fluerat-Lessard
13. Purdue University	—	—	Linda Mason
14. University of Molise, Italy	1993–present	30–40, 20–28	Pasquale Trematerra
15. University of Bologna, Italy	1995–2003	—	Piero Baronio
	2003–present	50	Antonio Martini
16. University of Parma, Italy	1995–2003	—	Giorgio Domenichini
	2003–present	50	Pagani Marco
17. University of Piacenza, Italy	1995–present	30	Fabio Molinari
18. Oklahoma State University, USA	1999–2006	6–8	Thomas Phillips
	2009–present	3	George Opit
19. University of Tuscia, Italy	1999–present	15	Adalgisa Guglielmino
20. University of Catania, Itay	2002–present	70	Agatino Russo

extension entomologist to prepare a Web site for stored-product insects. In ranked order, Pennsylvania, Indiana, Ohio, Iowa, Kentucky, Kansas, Virginia, Vermont, Florida, and South Carolina had the most Web sites. Web sites generally covered insect biology and pest management together (216 Web sites) rather than pest management alone (10).

Extension bulletins were published in 32 states, and these included extension bulletins for Connecticut, Hawaii, Massachusetts, North Carolina, Oregon and South Dakota (states for which extension Web sites were not found). In ranked order, Minnesota, California, Kansas, Michigan and Nebraska had the most extension bulletins. Extension bulletins were more likely to focus on pest management alone (77) than Web sites, and many extension bulletins covered both pest biology and management together (105). The United States Department of Agriculture (USDA) prepared 40% of 182 extension bulletins. The later extension bulletins on stored-product entomology were prepared by extension specialists at land grant universities who were supported by funds from USDA.

Many publications on stored-product insect pest management focus on a single method; fumigation (6.3%) and the use of extreme temperatures (5.9%) were covered more often than other insect pest management methods. Articles or Web sites on trapping (4.6%) and detection (3.3%) of stored-product insects were more common than those on sampling commodities to estimate insect densities (0.6%). Traps are useful in locating source populations of stored-product insect pests. Detection methods are important in determining whether commodities are infested. Pest management decisions, however, should be based upon accurate estimates of the densities of stored-product insect pests. The importance of insect identification to effective insect pest management was emphasized in *Pest Control* magazine articles. Insect identification may be emphasized less for grain pests because the grain and food industries rely heavily on fumigants. Natural enemies and biological control together were the subjects of only 2.6% of articles and Web sites.

Table 4. Subjects of popular articles, and extension bulletins or Web sites covering stored-product insects.

Subject	PC[a]	GJ	MJ	AR	TJ	EB	EW	Total	%
Biology									
Anobiidae	2	—	—	—	5	1	17	25	2.5
Bostrichidae	—	1	—	—	—	3	4	8	0.7
Bruchidae	—	—	—	—	—	8	2	10	1.0
Cleridae	3	—	—	—	—	—	—	3	0.3
Curculionidae	1	1	—	—	—	3	4	9	0.9
Dermestids	23	1	—	8	4	13	23	72	7.3
Gelechiidae	—	—	—	—	—	3	2	5	0.4
Laemophloeidae	—	—	—	—	—	—	1	1	0.1
Languriidae	—	—	—	—	—	1	—	1	0.1
Lophocateridae	—	—	—	—	—	1	—	1	0.1
Nitidulidae	1	—	—	—	—	—	4	5	0.5
Ptinidae	4	—	—	—	—	1	2	7	0.7
Pyralidae	5	2	—	1	2	7	16	33	3.4
Silvanidae	1	—	—	—	—	1	10	12	1.1
Tenebrionidae	5	1	—	2	2	4	20	34	3.4
Tineidae	13	—	—	—	3	3	11	30	3.0
Trogosidae	—	—	—	—	—	1	1	2	0.2
Cheese pests	—	—	—	—	—	2	—	2	0.2
Diapause	—	1	—	—	—	—	—	1	0.1
Dried fruit pests	3	—	—	—	—	3	—	6	0.6
Dried flower pests	3	—	—	—	—	—	—	3	0.3
Fabric pests	10	—	—	—	8	1	7	26	2.6
Flour mill pests	—	—	—	—	2	2		4	0.4
Fungus beetles	1	3	—	—	—	—	10	14	1.4
Grain pests	—	4	—	—	4	24	19	51	5.2
Library pests	1	—	—	—	—	—	6	7	0.7
Mites	—	—	—	—	—	—	4	4	0.4
Natural enemies	—	—	—	—	1	—	3	4	0.4
Pantry pests	7	—	—	—	1	15	49	72	7.3
Peanut pests	—	—	—	—	2	—	—	2	0.2
Psocids	4	—	—	—	1	—	—	5	0.5
Source infestation	8	2	—	—	2	—	—	12	1.2
Tobacco pests	—	—	—	—	5	5	—	10	1.0
Subtotal	**96**	**16**	**0**	**11**	**42**	**105**	**216**	**486**	**49.0**
Subject	PC[a]	GJ	MJ	AR	TJ	EB	EW	Total	%
Management Methods									
Pest management	38	17	3	21	13	61	3	156	15.8
Aeration	—	3	—	2	—	—	1	6	0.6
Biological control	2	1	—	15	4	—	—	22	2.2
Detection	12	—	—	9	12	—	—	33	3.3
Fumigation	33	—	4	7	10	7	1	62	6.3
Identification	29	—	—	—	1	—	—	30	3.0
Insecticide	13	2	1	13	7	2	1	39	3.9
Insecticide resistance	4	—	—	1	—	—	—	5	0.5
Packaging	5	—	—	2	3	—	—	10	1.0
Physical control	2	—	—	5	4	—	—	11	1.1
Radiation	1	—	—	5	3	—	—	9	0.9
Sampling grain	—	1		1	2	—	2	6	0.6
Sanitation	7	5	—	—	1	—	—	13	1.3
Temperature	5	9	5	7	23	7	2	58	5.9
Trapping	22	3	4	11	5	—	—	45	4.6
Subtotal	**173**	**41**	**18**	**98**	**87**	**77**	**10**	**504**	**51.0**

[a]Table summarizes articles in *Pest Control* (**PC**) by various authors from 1949–2006 (see Appendix 1); in *Grain Journal* (**GJ**) by Linda Mason from 1993–2006 (see Appendix 2); in *Milling Journal* (**MJ**) by Bh. Subramanyam from 1999–2006 (see Appendix 3); in *Agricultural Research Magazine* (**AR**) by various authors from 1953–2006 (see Appendix 4); other trade journals (**TJ**) (see Appendix 5); extension bulletins (**EB**) (see Appendix 6); and extension Web sites (**EW**) (see Appendix 7). Appendixes 1–7 are available at http://www.oznet.ksu.edu/grsc_subi/speir/

Similar popular articles and extension bulletins or Web sites are available in other countries. For example, Champ (2003) reviewed many popular articles published in Australia about stored-product insects, and extension bulletins for managing stored-product insect pests are available at the Web site, http://www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/PW/INS/PP/SP/STOREDGRAIN_PUB.HTM.

Insect biology is often oversimplified in popular articles or extension bulletins, and on extension Web sites. For example, developmental times cannot be well characterized by a single number giving the typical number of days required to complete development from egg to adult. Developmental times vary with temperature, relative humidity, and diet as shown in the studies for the 52 species cited in Table 5. Hagstrum and Subramanyam (2006) gave references to studies for another 54 species for which developmental times have been determined over a broad range of temperatures. Many of the stored-product insect species in Table 5 are fabric pests or less common pests of stored products that were not covered by Hagstrum and Subramanyam (2006). Table 6 shows that some of the studies on the effects of temperature on developmental times over a broad range of temperatures were not available before 1950. Future popular articles, and extension bulletins or Web sites need to include information from these studies about the effects of temperature and other environmental factors on insect developmental times.

Quarantine Interceptions

Information on the redistribution of stored-product insects by commerce and the types of commodities infested is available from insect interceptions during quarantine inspections. Quarantine interceptions have been reported for beetles (Aitken 1975, Zimmerman 1990) and moths (Aitken 1984, Solis 1999), both (Olsen 1981) or other families (Aitken 1984). Quarantine interceptions also have been reported for a single family (Scolytidae, Haack 2001), for empty cargo containers (Stanaway et al. 2001), for specific commodities (Ratti and Rampini 1977), for souvenirs (Weidner 1967), and for imported seed (Bhalla et al. 2004; Gupta et al. 2002, 2004, 2005).

Conclusions

Stored-product entomology books and courses are important because the coverage of stored-product insects is limited in urban and other entomology books and courses. Stored-product entomology courses are less common than urban, economic, agricultural or applied entomology courses. The development of books suitable as textbooks for stored-product entomology courses has lagged behind the development of suitable textbooks for urban, economic, and applied entomology courses. The Web site (Kansas State University) cited for appendicies to this paper (http://www.oznet.ksu.edu/grsc_subi/speir) makes it possible to locate many popular articles and extension bulletins or Web sites on stored-product insects more readily. This Web site may be useful to instructors in finding assigned readings for courses.

In many cases, popular articles and extension bulletins or Web sites give information for managing insect pests. Popular articles can give a perspective on what scientists have communicated to industry, but also what industry has learned from practical experiences. These articles provide entomology students with examples of how to present information on stored-product entomology to industry

Table 5. Stored-product insect species for which developmental times are known for a broad range of temperatures.

Insect Species	Source
Amphibolus venator (Klug)	Nishi and Takahashi 2002
Amyelois transitella (Walker)	Sanderson et al. 1989, Wade 1961
Anthrenus flavipes (Waterhouse)	Ayyappa et al. 1957
Anthrenus sarnicus (Mroczkowski)	Armes 1990, 1991; Coombs and Woodroffe 1981
Anthrenus verbasci (L.)	Blake 1958, Griswold 1941
Apanteles scutellaris Muesebeck	Cardona and Oatman 1975
Apanteles subandinus Blanchard	Cardona and Oatman 1975
Callosobruchus subinnotatus (Pic)	Lale and Vidal 2003
Carpophilus humeralis (F.)	James and Vogele 2000, Lindgren and Vincent 1953
Carpophilus mutilatus Erichson	James and Vogele 2000
Cephalonomia gallicola Ashmead	Momoi and Tanioka 1982, Yamasaki 1982
Chelonus kellieae Marsh	Powers and Oatman 1984
Chelonus phthorimaeae Gahan	Powers and Oatman 1984
Coelopalorus foveicollis (Blair)	Halstead 1967
Cryptolestes capensis (Waltl)	Lefkovitch 1962
Cryptolestes pusilloides (Steele and Howe)	Lefkovitch 1964
Cryptolestes ugandae Steele and Howe	Lefkovitch 1957
Cylas formicarius elegantulus (Summers)	Mullen 1981
Dasyses rugosella Stainton	Iheagwam and Ezike 1989
Dermestes ater Degeer	Coombs 1981
Dermestes frischii (Kug.)	Amos 1968, Howe 1953
Dermestes haemorrhoidalis Kuster	Coombs 1979
Dermestes peruvianus Laporte de Castelnau	Coombs 1979
Dinoderus minutus F.	Garcia and Morrell 2009
Dufouriella ater (Dufour)	Arbogast 1984
Ectomyelois ceratoniae (Zeller)	Cox 1976
Endrosis lactella (Schiff)	Woodroffe 1951b
Euzopherodes vapidella Mann	Ashamo and Odeyemi 2001
Glischrochilus quadrisignatus (Say)	Luckman 1963, Mussen and Chiang 1974
Haptoncus luteolus (Erichson)	Lindgren and Vincent 1953
Hofmannophila pseudospretella (Stainton)	Woodroffe 1951a
Lepinotus reticulatus Enderlein	Opit and Throne 2008
Liposcelis brunnea Motschulsky	Opit and Throne 2009
Liposcelis tricolor Badonnel	Dong et al. 2007
Lyctus brunneus (Stephens)	Gay 1953
Mezium affine Boieldieu	Howe and Burges 1953b
Microctonus nitidulidis Loan	Weiss and Williams 1980
Murmidius ovalis (Beck)	Halstead 1968
Oryzaephilus acuminatus Halstead	Jacob 1981
Palorus laesiocollis (Fairmaire)	Halstead 1967
Phthorimaea operculella (Zeller)	Cardona and Oatman 1975, Sporleder et al. 2004
Ptinus ocellus Brown	Howe and Burges 1953a
Ptinus pusillus Sturm	Howe 1956
Rhabdepyris zeae Waterston	Abdella et al. 1985
Tinea pellionella (L.)	Cheema 1956
Tineola biselleilla Hum.	Griswold 1944
Tipnus unicolor (Piller and Mitterpacher)	Howe 1955
Trogoderma anthrenoides (Sharp)	Burges and Cammell 1964
Trogoderma versicolor (Creutz)	Hadaway 1956
Venturia canescens (Gravenhorst)	Eliopoulos and Stathas 2003
Xylocoris flavipes (Reuter)	Arbogast 1975, Russo et al. 2004
Zeteticontus utilis Noyes	Blumberg et al. 1984

Table 6. Years during which life history data for stored-product insects were collected.

Time Period (Years)	Frequency
1930–1940	6
1941–1950	19
1951–1960	33
1961–1970	28
1971–1980	32
1981–1990	25
1991–2000	16
2001–	12

Based on Hagstrum and Subramanyam (2006) and Table 5.

and the general public. Communicating with nonentomologists may be an important part of the career responsibilities of many entomologists.

We would like to hear from readers about other courses covering stored-product insects that are currently or have been previously offered so that we can update the present information. We are also interested in hearing about other extension bulletins or Web sites covering stored-product insects. We hope that this article will encourage and facilitate more extensive coverage of stored-product insects in entomology books and courses.

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