

# / Introduction

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*Management of Grain, Bulk Commodities, and Bagged Products*, Oklahoma State University Publication E-912, was published in 1991. The first edition was sponsored by the USDA Federal Grain Inspection Service (FGIS), partially to help protect grain in the FGIS loan program. The loan program often went for multiple years, and generally the grain was in poor condition due to pests and moisture migration. The second edition, titled *Stored Product Management*, was published by OSU in 1995. It has been widely used by extension educators, researchers, and stored product managers as a practical, easy-to-read reference and “how-to” guide for protecting stored grain and grain products from insects, molds, and vertebrate pests. Demand for the publication still exists, but paper copies are no longer available for distribution.

Many changes in government regulations that influence stored product protection and advances in pest management techniques have occurred in the 16 years since *Stored Product Management* was published. To bring readers up to date, we have developed this companion book, *Stored Product Protection*, which is available online as well as in print. The 1995 edition of *Stored Product Management* is available at this Kansas State University website and contains information not covered here in *Stored Product Protection*.

This new book expands on the 1995 OSU publication. Besides grain, this book includes information on pest management in other raw commodities, food processing facilities, and value-added, finished food products. It begins with biology and ecology

of insects, molds, and vertebrates in storage systems. There are separate chapters on insect pests of grain and legumes, dried fruit and nuts, and processed and durable commodities of both plant and animal origins. The next four sections address various aspects of pest management — prevention methods, monitoring-based methods, decision making, economics, regulations, and marketing.

*Stored Product Protection* is intended as a training manual that will give readers an understanding of pest biology, behavior, and ecology in the marketing system; pest management methods; and pertinent economic and regulatory considerations for various products. Understanding pests is important because pest management is applied ecology (chapters 2–7). Many methods are available for managing pests, and each can be used in a variety of ways (chapters 8–12, 14–17, 26). Because insects readily develop resistance to pest management methods (particularly chemical methods), resistance management programs should be part of all pest management programs (chapter 13). Choosing the best method, and the best time and way of using that method, is complex (chapter 18–20). Properly timed pest management may require a number of monitoring programs (chapters 18, 21–24). Because of the complexity, extension agents and private consultants often play a role in developing integrated pest management programs for field and orchard crops and in developing optimal pest management programs for stored products (chapter 25). Such decisions require cost-benefit analysis, so an understanding of economics is important (chapters 27–29). Several government agencies

oversee regulations concerning food quality, pesticide residues, and worker safety. Pest management programs must meet a variety of regulatory standards (chapters 30-31).

Three new regulations have influenced stored product protection in the United States since publication of the 1995 OSU book. The Food Quality Protection Act (FQPA) of 1996 called for a review of all pesticides registered by the Environmental Protection Agency (EPA) and mandated that exposure limits and use patterns be revised so that the most vulnerable members of human society, such as children and the elderly, would be protected from exposure. Changes in pesticide labels under FQPA and loss of registrations for certain compounds led to alternative methods of pest control for stored products.

The Clean Air Act, as influenced by the international agreement known as the Montreal Protocol, mandated the phase-out and eventual ban of the fumigant pesticide methyl bromide. As a result, much research and development after 1995 dealt with alternatives to methyl bromide (see chapter 14) for stored product protection. The National Organic Program of USDA established regulations as to how foods approved as being “organic” should be produced, stored, and distributed, with widespread impact on the use of synthetic additives and pesticides. Chapter 20 addresses organic considerations that were not even mentioned in the previous book, and low-input or chemical-free control measures are specified in several chapters of this volume.

*Stored Product Protection* is written for individuals involved with grain storage, commodity storage and management, food processing, and pest management. The target audience also includes academic, government, and private sector researchers in these fields, and regulatory personnel. The book focuses on North America, though examples are drawn from stored product experiences in many parts of the world.

The following list of 76 books and book chapters allow the reader to find additional information on subjects covered in this book. The chronological bibliography allows readers to follow the history of stored-product protection by starting at the top of the list or to find a recent discussion of a subject by starting at the bottom.

Howard, L. O. and C. L. Marlatt. 1896. The principal household insects. USDA Bull. 4 (n.s.).

Herrick, G. W. 1914. Insects injurious to the household and annoying to man. MacMillan Co., New York.

Chapman, R. N. 1921. Insects infesting stored food products. Univ. Minn. Agric. Exp. Sta. Bull. 198.

Metcalf, C. L. and W. P. Flint. 1928. Household insects and pests of stored grains, seeds and cereal products. p. 731-766. In *Destructive and Useful Insects, Their Habits and Control*. 1st edition. McGraw-Hill, New York.

Patton, W. S. 1931. Insects, Mites and Venomous Animals of Medical and Veterinary Importance. Part II. Public Health. H. R. Grubb, Ltd., London.

Austen, E. E. and A. W. McKenny. 1932. Clothes moths and house moths, their life-history, habits and control. British Museum Natural History Economic Series 14.

Hartnack, H. 1939. 202 Common household pests of North America. Hartnack Publishing Co., Chicago.

Cotton, R. T. 1941. Insect Pests of Stored Grain and Grain Products, 1st ed. Burgess Publishing Co., Minneapolis, MN.

Hayhurst, H. and H. Britten. 1942. Insect pests in stored products. Chapman and Hall Ltd., London.

Hinton, H. E. 1945. A Monograph of the Beetles Associated with Stored Products. Vol. I. British Museum (Natural History), London.

Michelbacher, A. E. 1953. Insects attacking stored products. *Adv. in Food Res.* 4: 281-358.

Anderson, J. A., and A. W. Alcock, Eds. 1954. Storage of Cereal Grains and Their Products, 1st ed. American Association of Cereal Chemists, St. Paul, MN.

Metcalf, C. L. and W. P. Flint. 1962. Household insects and pests of stored grains, seeds and cereal products. p. 888-938. In *Destructive and Useful Insects, Their Habits and Control*. 4th edition. McGraw-Hill, New York.

- Cotton, R. T. 1963. Insect pests of Stored Grain and Grain Products: Identification, Habits and Methods of Control. Burgess Publishing Co., Minneapolis, MN.
- Page, A. B. P. and O. F. Lubatti. 1963. Fumigation of insects. *Ann. Rev. Entomol.* 8: 239-264.
- Munro, J. W. 1966. Pests of Stored Products. The Rentokil Library, Hutchinson, London.
- Monro, H. A. U. 1969. Manual of Fumigation for Insect Control, 2nd ed. Agric. Studies Pub. 79. Food and Agriculture Organization of United Nations, Rome.
- Sinha, R. N., and W.E. Muir. 1973. Grain Storage: Part of a system. AVI Publishing Co., Inc., Westport, CT.
- Christensen, C. M. 1974. Storage of Cereal Grains and Their Products, 2nd ed. American Association of Cereal Chemists, St. Paul, MN.
- Ebeling, W. 1978. Urban Entomology. Division of Agricultural Sciences, University of California, Berkeley.
- American Institute of Baking. 1979. Basic Food Plant Sanitation Manual. The Institute, Manhattan, KS.
- Gorham, J. R. 1979. The significance for human health of insects in food. *Ann. Rev. Entomol.* 24: 209-224.
- Christensen, C. M. 1982. Storage of Cereal Grains and Their Products, 3rd ed. American Association of Cereal Chemists, St. Paul, MN.
- Okumura, G. 1982. Stored Product Pests. p. 507-591. In *Handbook of Pest Control, The Behavior, Life History and Control of Household Pests*. 6th edition. Arnold Mallis (ed.) Franzak and Foster Co., Cleveland, OH.
- Baur, F. J. 1984. Insect Management for Food Storage and Processing, 1st ed. American Association of Cereal Chemists, St. Paul, MN.
- Bond, E. J. 1984. Manual of Fumigation for Insect Control. Plant Production and Protection Paper 54. Food and Agriculture Organization of the United Nations, Rome.
- Burkholder, W. E. 1985. Pheromones for monitoring and control of stored-product insects. *Annual Rev. Entomol.* 30: 257-272.
- Sinha, R. N. and F. L. Watters. 1985. Insect Pests of Flour Mills, Grain Elevators, and Feed Mills and Their Control. Canadian Government Publishing Centre, Ottawa, Canada.
- Wilbur, D. A. and R. B. Mills. 1985. Stored Grain Insects. p. 552-576. In R. E. Pfadt (ed.) *Fundamentals of Applied Entomology*. 4th edition. Macmillan Publishing Company, New York.
- Hui, Y. H. 1986. United States Food Laws, Regulations and Standards. John Wiley and Sons, New York.
- Evans, D. E. 1987. Stored products. p. 425-461. In A. J. Burn, T. H. Coaker and P. C. Jepson (eds.) *Integrated Pest Management*. Academic Press, New York.
- Snelson, J. T. 1987. Grain Protectants. Monograph 3. Australian Centre for International Agricultural Research, Canberra, Australia.
- Multon, J. L. 1988. Preservation and Storage of Grains, Seeds and Their By-Products: Cereals, Oilseeds, Pulses and Animal Feed. Lavoisier Publishing Inc., New York.
- Campbell, J. M. 1989. Canadian beetles (Coleoptera) injurious to crops, ornamentals, stored products and buildings. *Agric. Can. Publ.* 1826, Ottawa, Ontario.
- Haines, C. P. and D. P. Rees. 1989. A field guide to the types of insects and mites infesting cured fish. *FAO Fisheries Technical Paper* 303, Rome.
- Bousquet, Y. 1990. Beetles associated with stored products in Canada: an identification guide. *Res. Branch Agric. Can. Publ.* 1837.
- Hill, L. D. 1990. Grain Grades and Standards: Historical Issues Shaping the Future. University of Illinois Press, Urbana.
- Mills, R., and J. Pedersen. 1990. A Flour Mill Sanitation Manual. American Association of Cereal Chemists, St. Paul, MN.

- Parker, T. A. 1990. Clothes moths. p. 347-375. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 7th edition, Keith Story (ed.) Franzak and Foster Co., Cleveland, OH.
- Parker, T. A. 1990. Hide and carpet beetles. p. 377-413. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 7th edition, Keith Story (ed.) Franzak and Foster Co., Cleveland, OH.
- Walter, V. E. 1990. Stored product pests. p. 501-580. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 7th edition, Keith Story (ed.) Franzak and Foster Co., Cleveland, OH.
- Gorham, J. R. 1991. Ecology and Management of Food-Industry Pests. Food and Drug Administration Tech. Bull. 4. Association of Official Analytical Chemists, Arlington, VA.
- Gorham, J. R. 1991. Insect and Mite Pests in Food: An Illustrated Key. Vol. 1 and 2. USDA Agric. Handbook. 655.
- Sauer, D. B. 1992. Storage of Cereal Grains and Their Products, 4th ed. American Association of Cereal Chemists, St. Paul, MN.
- Pinniger, D. 1994. Insect pests in museums. 3rd edition. Archetype Publications Limited, London.
- Jayas, D. S., N. D. G. White and W.E. Muir. 1995. Stored-Grain Ecosystem. Marcel Dekker, Inc., New York.
- Krischik, V., G. Cuperus and D. Galliard. 1995. Stored Product Management. Circ. E-912. Cooperative Extension Service, Oklahoma State University, Stillwater.
- Ryan, L. 1995. Post-harvest Tobacco Infestation Control. Chapman and Hall, London.
- Hedges, S. A. and M. S. Lacey. 1996a. PCT Field Guide for the Management of Structure-Infesting Beetles, Vol. I. Hide and Carpet Beetles/Wood-Boring Beetles. Franzak and Foster, Cleveland, OH.
- Hedges, S. A. and M. S. Lacey. 1996b. PCT Field Guide for the Management of Structure-Infesting Beetles, Vol. II Stored Product Beetles/Occasional and Overwintering Beetles. Franzak and Foster, Cleveland, OH.
- Subramanyam, B. and D.W. Hagstrum. 1996. Integrated Management of Insects in Stored Products, Marcel Dekker, Inc., New York.
- Vetter, J. L. 1996. Food Laws and Regulations. American Institute of Baking, Manhattan, KS.
- Granovsky, T. A. 1997. Stored Product Pests. p. 635-728. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 8th edition, Dan Moreland (ed.). Franzak and Foster Co., Cleveland, OH.
- Hinderer, C. L. 1997. Hide and carpet beetles. p. 465-500. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 8th edition, Dan Moreland (ed.). Franzak and Foster Co., Cleveland, OH.
- Katz, H. L. 1997. Clothes moths. p.427-462. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 8th edition, Dan Moreland (ed.). Franzak and Foster Co., Cleveland, OH.
- Mueller, D. K. 1997. Pheromones in structural pest management. p. 1155-1185. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 8th edition, Dan Moreland (ed.). Franzak and Foster Co., Cleveland, OH.
- Mueller, D. 1998. Stored Product Protection—A Period of Transition. Insects Limited, Inc., Indianapolis, IN.
- Imholte, T. J. and T.K. Imholte-Tauscher. 1999. Engineering for Food Safety and Sanitation. Technical Institute of Food Safety, Crystal, MN.
- Phillips, T. W., R. C. Berberet and G. W. Cuperus. 2000. Post-harvest integrated pest management. In F. J. Francis (ed.) The Wiley Encyclopedia of Feed Science and Technology, Wiley and Sons, New York.

- Subramanyam, B. and Hagstrum, D. W. 2000. Alternatives to Pesticides in Stored-Product IPM. Kluwer Academic Publishers, New York.
- Fields, P. G. and N. D. G. White. 2002. Alternatives to methyl bromide treatments for stored-product and quarantine insects. 47: 331-359.
- Golob, P., G. Farrell, and J.E. Orchard. 2002. Crop Post-Harvest: Science and Technology. Blackwell Science Ltd., Oxford, U.K.
- Hill, D. S. 2002. Pests of Stored Foodstuffs and Their Control. Kluwer Academic Publishers, Boston.
- Hui, Y. H., B.L. Bruinsma, J.R. Gorham, W. Nip, P.S. Tong, and P. Ventresca. 2002. Food Plant Sanitation. Marcel Dekker, Inc., New York.
- Navarro, S. and R. Noyes. 2002. The Mechanics and Physics of Modern Grain Aeration Management. CRC Press, New York.
- Black, J. 2004. Fabric and museum pests. p. 581-632. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 9th edition, Dan Moreland and Stoy A. Hedges (eds.). GIE Media, Cleveland, OH.
- Phillips, T. W. and E. M. Thoms. 2004. Fumigation. p. 1165-1216. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 9th edition, Dan Moreland and Stoy A. Hedges (eds.). GIE Media, Cleveland, OH.
- Rees, D. 2004. Insects of Stored Products. Manson Publishing, London.
- VanRyckeghem, A. 2004. Stored product pests. p. 747-823. In Handbook of Pest Control, The Behavior, Life History and Control of Household Pests, 9th edition, Dan Moreland and Stoy A. Hedges (eds.). GIE Media, Cleveland, OH.
- Subramanyam, Bh., R. Roesli, J. Bruesch and A. Menon. 2005. Sanitation and pest management. p. 415-431. In Eileen K. Schofield (ed.), Feed Manufacturing Technology, 5th edition, American Feed Industry Association, Arlington, VA.
- Hagstrum, D. W. and Bh. Subramanyam 2006. Fundamentals of Stored-Product Entomology. AACC International, St. Paul, MN.
- Heaps, J. W., Ed. 2006. Insect Management for Food Storage and Processing, 2nd ed. AACC International, St Paul, MN.
- Reed, C. R. 2006. Managing Stored Grain to Preserve Quality and Value. AACC International, St. Paul, MN.
- Hagstrum, D. W., and Bh. Subramanyam. 2009. Stored-Product Insect Resource. AACC International, St. Paul, MN.
- Mueller, D. 2010. Reducing Customer Complaints in Stored Products. Beckett-Highland Publishing. Carmel, IN.
- Phillips, T. W. and J. E. Throne. 2010. Biorational approaches to managing stored product insects. Ann. Rev. Entomol. 55: 375-397.



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