26 Quarantine

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The term quarantine originated from the Italian word *quarantina* (meaning 40 days) when the Black Death arrived in Europe in 1347 (Ebbels 2003). The incubation period from infection to symptoms was nearly 40 days, so 40 days was the quarantine period for ships suspected of carrying infection. Today, quarantine insects are those of economic importance that may or may not be present in an importing country but are not widely distributed in that country. The terms plant quarantine or plant health in Europe and plant protection in North America cover legislation and regulation designed to minimize the introduction and spread of harmful organisms using inspection, survey, risk assessment, treatment, post-entry quarantine, containment campaigns, and eradication.

International Programs

Worldwide invasive species cost billions of dollars annually in loss of commodities, reduced agricultural productivity and control measures. All countries have a vested interest in preventing the introduction and spread of invasive insect species. Legislative control can be effective in regulating the introduction and establishment of alien insect pests in a country and limiting their spread within that country. Most countries have some legislation restricting the importation of infested commodities. Information on international legislation is available at the International Plant Protection Convention website (https://www.ippc.int/).

Internationally, the International Plant Protection Convention (IPPC) was written in 1951 and revised in 1997 as part of Food and Agriculture Organization (FAO) efforts to help standardize the phytosanitary certification by different countries (Anon. 2001, Tyler and Hodges 2002). A model phytosanitary certificate was developed by FAO (Figure 1).

The World Trade Organization (WTO) enforces Agreement on Application of Sanitary and Phytosanitary Measures, also known as the SPS Agreement, which establishes food safety and animal and plant health standards for international trade. Although SPS allows individual countries to establish their own phytosanitary requirements, it encourages the use of international standards and a science-based approach to develop treatment regulations.

Within Africa, national legislation and regulations are based on Inter-African Plant Phytosanitary and Quarantine Regulations of 1988. Regional enforcement is coordinated by the following groups: Inter-African Phytosanitary Council (IAPSC), Asia and Pacific Plant Protection Commission (APPPC), Caribbean Plant Protection Commission (CPPC), Comunidad Andina (CA), Comité Regional de Sanidad Vegetal del Cono Sur (COSAVE), European and Mediterranean Plant Protection Organization (OEPP), North American Plant Protection Organization (NAPPO), Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA), and Pacific Plant Protection Organization (PPPO).

Two hundred and thirteen contracting parties and their territories have National Plant Protection Organizations (IPPC 2010). The International Plant Protection Convention (IPPC) requires contract-

ing parties to establish, update, and make available lists of regulated pests (Anon. 2003). In the United States these lists are available through the PExD database maintained by United States Department of Agriculture (USDA). They are available to federal and state regulatory personnel as well as exporters in industry to learn requirements of individual countries to allow the import of specific commodities.

United States Programs

The USDA, Animal and Plant Health Inspection Service (APHIS) is the agency responsible for preventing the introduction of invasive exotic species with the potential to cause harm to U.S. agriculture or natural resources (http://www.aphis.usda.gov/). USDA-APHIS provides guidelines, instructions, and procedures for performing inspections of imported commodities, international mail, and passengers arriving in the United States. These are carried out by U.S. Customs and Border Patrol (CBP) personnel stationed at airports, maritime ports, and land points of entry. Cooperative state and federal programs are established to restrict interstate movement of invasive species when domestic quarantines are established.

On inspection, when insects are found to be nonregulated species, the inspector can release the shipment to the importer (Caresche 1969). If the identification of insects is uncertain, the decision may be deferred. If the insect is a regulated pest species, the inspector can have the commodity treated to kill the pest, quarantine the shipment, return the shipment to sender, or have the commodity destroyed. A variety of training programs and materials are available for inspection personnel. Plant Protection and Quarantine (PPQ) unit within APHIS provides treatment descriptions, guidelines, and certification programs for imports and domestic movement in the PPQ Treatment Manual (USDA 2011a) and has developed a curriculum that several universities are now using (USDA 2011b). Similarly, a training manual developed in Africa has an appendix covering inspection of commodities for stored-product insects (Caresche et al. 1969).

To help reduce the burden on port inspectors and the overall number of interceptions at U.S. ports, the USDA-APHIS has established preclearance programs in a number of exporting countries that include inspection, treatment, and other measures to reduce the risk of accidentally introducing pest species. Preclearance programs can be beneficial to both trading partners as they allow commodities to move to market without interruption; however, they are expensive and can be cost prohibitive because most or all of the cost is the responsibility of the exporting country. These programs are conducted under supervision of USDA-APHIS employees and are typically developed in partnership between APHIS and the exporting country (USDA 2003).

Regulated Insect Pests

The first step for a new import is to develop a pest risk analysis for the pests of the commodity. Some insects are of greater regulatory significance than others, so species lists can be divided into quarantine pests and regulated non-quarantine pests. Regulated non-quarantine pests are those that are of economic importance but are already widespread in a country. The overall number of regulated stored-product insects can vary considerably by country and world region. New Zealand, for example, regulates 110 species of stored-product pests (Table 1), while China lists 18 species, and the European Union lists just a single species (*Alucita sacchari*). The economic consequences of the establishment of these pests have been severe both in terms of costs associated with contamination, yield loss, and the cost of control measures. Additional costs are incurred from trade restrictions that may occur when nonnative insects are established.

Relatively few stored-product insects are quarantine pests because so many already have been distributed worldwide by commerce. Many important stored-product pests in North America are nonnative and have long been established in the United States. These include Indianmeal moth, *Plodia interpunctella* (Europe/Asia); lesser grain borer, *Rhyzopertha dominica* (India/Tropics); confused flour beetle, *Tribolium confusum* (Africa); Mediterranean flour moth, *Ephestia kuehniella* (Europe); European grain moth, *Nemapogon granella* as well as others.

Presently, khapra beetle, *Trogoderma granarium* Everts (Figures 2 and 3) is the main actionable species associated with stored products imported into the United States (Stibick 2007). *Trogoderma granarium* is a serious pest to stored foods, grains, cereals, and spices throughout the world and has been found infesting 96 commodities (Hagstrum and

Model Phytosanitary Certificate

No. _____

Plant Protection Organization of _____

TO: Plant Protection Organization(s) of _____

I. Description of Consignment

Name and address of exporter: _____

Declared name and address of consignee: _____

Number and description of packages: _____

Distinguishing marks: _____

Place of origin: _____

Declared means of conveyance: _____

Declared point of entry: _____

Name of produce and quantity declared: _____

Botanical name of plants: _____

This is to certify that the plants, plant products or other regulated articles described herein have been inspected and/or tested according to appropriate official procedures and are considered to be free from the quarantine pests specified by the importing contracting party and to conform with the current phytosanitary requirements of the importing contracting party, including those for regulated non-quarantine pests.

They are deemed to be practically free from other pests.*

II. Additional Declaration

III. Disinfestation and/or Disinfection Treatment

Date _____ Treatment _____ Chemical (active ingredient) _____

Duration and temperature _____

Concentration _____

Additional information _____

_____

Place of issue _____

(Stamp of Organization) Name of authorized officer _____

Date _____ (Signature) _____

No financial liability with respect to this certificate shall attach to (name of Plant Protection Organization) or to any of its officers or representatives.*

* Optional clause

Figure 1. *FAO model phytosanitary certificate.*

Table 1. *Regulated stored-product insect pests in New Zealand including species that do not breed in storage but can occur in large enough numbers to require pest management*[a].

Acanthoscelides argillaceus	*Carpophilus freemani*	*Lophocateres pusillus*
Acanthoscelides armitagei	*Carpophilus fumatus*	*Lyctus africanus*
Acanthoscelides obvelatus	*Carpophilus lugubris*	*Maruca vitrata**
Acanthoscelides zeteki	*Carpophilus maculatus*	*Mezium americanum*
Anthrenus pimpinellae isabellinus	*Carpophilus mutabilis*	*Necrobia violacea*
Apate monachus	*Carpophilus mutilatus*	*Niptus hololeucus*
Apomyelois ceratoniae	*Carpophilus obsoletus*	*Opogona sacchari**
Attagenus fasciatus	*Caulophilus oryzae*	*Palorus ratzeburgi*
Attagenus jucundus	*Conopomorpha cramerella**	*Palorus subdepressus*
Attagenus unicolor	*Corcyra cephalonica*	*Pectinophora gossypiella**
Bruchidius incarnatus	*Cryptolestes turcicus*	*Pharaxonotha kirschii*
Bruchus affinis	*Curculio caryae*	*Phradonoma nobile*
Bruchus atomarius	*Curculio sayi*	*Phthorimaea operculella* strain
Bruchus dentipes	*Cydia caryana*	*Prostephanus truncatus*
Bruchus emarginatus	*Cydia nigricana*	*Ptinus villiger*
Bruchus ervi	*Cylas brunneus*	*Pyralis maihotalis*
Bruchus laticollis	*Cylas formicarius elegantulus*	*Scrobipalposis solanivora*
Bruchus lentis	*Cylas puncticollis*	*Sitophilus linearis*
Bruchus luteicornis	*Dinoderus bifoveolatus*	*Stelidota geminata*
Bruchus pisorum	*Dinoderus distinctus*	*Thaumatotibia leucotreta**
Bruchus rufimanus	*Etiella zinckenella*	*Tinea fictrix*
Bruchus rufipes	*Euscepes postfasciatus**	*Tribolium audax*
Bruchus signaticornis	*Gibbium psylloides*	*Tribolium brevicornis*
Bruchus tristiculus	*Glischrochilus fasciatus*	*Tribolium destructor*
Bruchus tristis	*Glischrochilus quadrisignatus*	*Tribolium freemani*
Cadra calidella	*Gnathocerus maxillosus*	*Tribolium madens*
Cadra figulilella	*Hypothenemus areccae*	*Trogoderma anthrenoides*
Callosobruchus analis	*Hypothenemus eruditus*	*Trogoderma glabrum*
Callosobruchus chinensis	*Hypothenemus liberiensis*	*Trogoderma granarium**
Callosobruchus maculatus	*Hypothenemus obscurus*	*Trogoderma grassmani*
Callosobruchus phaseoli	*Latheticus oryzae*	*Trogoderma inclusum*
Callosobruchus rhodesianus	*Leguminivora ptychora*	*Trogoderma ornatum*
Callosobruchus serratus	*Liposcelis decolor*	*Trogoderma simplex*
Callosobruchus subinnotatus	*Liposcelis entomophila*	*Trogoderma sternale*
Carpophilus binotatus	*Liposcelis paetus*	*Trogoderma variabile*
Carpophilus bisignatus	*Liposcelis rufus*	*Zabrotes subfasciatus*
Carpophilus foveicollis	*Liposcelis terricolis*	

[a] Species followed by asterisks are also regulated pests in the United States. In the United States, *Curculio nacum*, *Hypothenemus hampei* and *Cydia splendania* are also regulated pests that can occur in large enough numbers to require pest management during storage.

Subramanyam 2009). The high potential for spread of *T. granarium* through international trade makes this species a continued threat. If *T. granarium* were to become established in the United States it would create market accessibility problems for a number of commodities. Several studies have predicted the risk of establishment of *T. granarium* in different climates (Howe and Lindgren 1957, Banks 1977, Viljoen 1990).

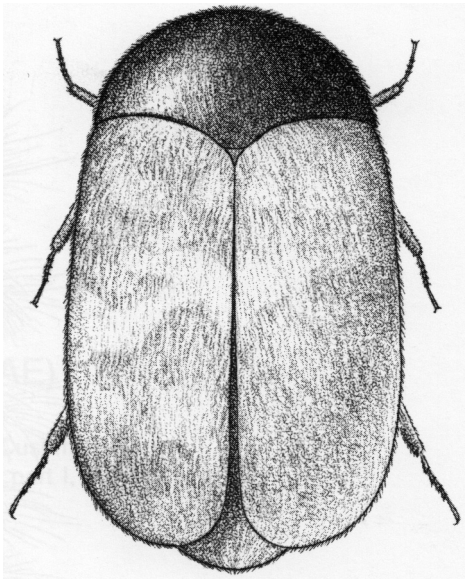

Figure 2. *Khapra beetle adult, Trogoderma granarium, 1.7 to 3 mm long (from Gorham 1991).*

Figure 3. *Khapra beetle, Trogoderma granarium larvae on wheat. Al Barak photo*

Permits are required to import commodities known to harbor *T. granarium* into the United States. This includes grains, seeds, nuts, dried milk, fish meal, meat and bonemeal, dried animal hides, and other products. Phytosanitary certificates are required for restricted commodities from countries that maintain inspection programs.

The Pest Identification (PestID) database, a subsystem of the Agricultural Quarantine Activity Systems (AQAS) database maintained by USDA-APHIS, reported that from 1985 through 2010 *Trogoderma* spp. were intercepted at U.S. ports of entry 666 times, and 559 were identified as *T. granarium*. Of these, 50.8% were found in passenger baggage, 30.4% were general cargo, and the remainder split among mail, ship holds and stores, and other cargo. The introductions came from 43 countries (Table 2), with the overwhelming majority coming from North Africa, South Asia, and the Middle East. In 2011 a total of 162 interceptions of *T. granarium* were made over the first 9 months of the year, prompting APHIS to restrict rice imports to permitted commercial shipments only in order to reduce the number of introductions.

Khapra beetle larvae can easily penetrate packaging and infest stored goods, pet food, and food packets after they get into a home or storage site. Once in a product, they can reproduce and move to cross-infest previously clean materials. Khapra beetle larvae can easily infest, contaminate, and render various processed foods unfit for human consumption. Khapra beetle can enter a quiescent stage where it may hide for many months in convenient cracks, crevices, or other hiding spots. It can then emerge when food becomes available, such as when a stored product comes into contact with a wall in an infested warehouse or grain storage. A sign of infestation may be tracks of wandering larvae in dust on floors or surfaces as larvae scavenger for protein. *Trogoderma* spp. can survive long periods without food, and are able to retrogressively molt when food is not present (Beck 1971a). The larvae may resume growth and molting to maturity, but subsequent molt and regrowth cycles result in lower fecundity food sources (Beck 1971b).

Eliminating infestations is generally achieved through a combination of sanitation and pesticide applications. Large scale infestations, such as storage facilities or warehouses, may require fumigation or heat treatment to eliminate an established popula-

Table 2. *Countries of origin for interceptions of T. granarium at U.S. ports of entry from 1984 through 2010 (Unknown 6%)*[a].

Asia (45%)	Middle East and North Africa (43%)	Sub-Saharan Africa (4%)
China	Bahrain	Mali
India	Egypt	Nigeria
Indonesia	Ethiopia	Senegal
Japan	Iran	Sudan
Laos	Israel	Tanzania
Malaysia	Iraq	Zamibia
Pakistan	Jordan	
Philippines	Kuwait	Europe (1%)
Singapore	Lebanon	Cyprus
Thailand	Qatar	Denmark
	Saudi Arabia	England
Oceania (<1%)	Sri Lanka	Germany
Australia	Syria	Spain
	Tunisia	Ukraine
Central America (1%)	Turkey	
El Salvador	United Arab Emirates	North America (<1%)
Guatemala	Yemen	Canada

[a]US Dept of Agriculture, AQAS-PestID database

tion. Khapra beetle may enter a status of quiescence, often referred to as facultative diapause, where metabolism is low and development is retarded. Under these conditions, *T. granarium* larvae are tolerant of methyl bromide fumigation. Under these conditions *T. granarium* larvae are tolerant of MB fumigation and require high doses to achieve effective control(USDA 2011a).

Several tools are available for trapping and monitoring populations. Floor-placed dome traps use wheat germ oil to attract larvae and a pheromone lure to capture adult males adults (Trece Inc., Adair, OK). A vertical wall-mounted trap developed by USDA (Barak 1989) uses the same lure combination and has the advantage that it is stationary and can be positioned at any height. Aerial traps using the *T. variabile* (warehouse beetle) pheromone lure are often included in *T. granarium* survey efforts because they help to minimize the number of *T. variabile* captures in the *T. granarium* traps. This helps to ease identification of potential *T. granarium* captures.

Interceptions of *T. granarium* in commodities imported into England between 1957 and 1973 ranged from 46 to 131 per year (six to 18 per 1,000 inspections); *T. granarium* was intercepted mostly in rice and peanuts from Burma, India, Nigeria, and Sudan (Freeman 1974).

Eradication of established populations

There have been numerous occurrences where *T. granarium* has been able to establish populations in the United States and other foreign locations. Eradication of these populations is often difficult and expensive. *Trogoderma granarium* was introduced in California before 1946 but incorrectly identified as *Attagenus piceus* and spread to 16 counties in California, five in Arizona, and three in New Mexico before being correctly identified in 1953 (Armitage 1956, 1958). By 1958, 51,000 premises in 27 states had been inspected, and the pest was eradicated in the United States by 1966. The cost of eradications was $8.4 million spent by federal government and an additional $6.5 million spent by property owners (Klassen 1959). From 1978 to 1983, it was again established in the United States, and 25 infestations in California, Maryland, Michigan, New Jersey, New York, Pennsylvania, and Texas were discovered and eradicated (Kennedy et al. 1991). More recently, a khapra beetle infestation was discovered in a Connecticut residence in 2006. It was determined to

be an isolated infestation, and the population was eliminated through sanitation, reinspection, and insecticide applications.

Khapra beetle infestations reported in Baja California in December 1954 were apparently from infested products originating in the United States. In Mexico total of 25 million cubic feet of storage space at 92 properties infested by khapra beetle were successfully fumigated with methyl bromide by September 1961. Additional introductions and eradications of khapra beetle have occurred in Australia (Emery et al. 2008), Japan (Sonda 1968), South Africa (Banks 1977), and Tanzania (Banks 1977).

Other quarantine stored-product insect pests

Within the United States, legislation restricts the movement of commodities infested with sweet potato weevil, *Cylas formicarius*, into some states in which it is not yet established. This species is an actionable species in Asia, and there have been eradication programs for sweet potato weevil and West Indian sweet potato weevil, *Euscepes postfasciatus* in Japan (Moriya and Miyatake 2001). In Asia, potato tuber moth, *Phthorimaea operculella*, is also an actionable species. In Africa, legislation restricts movement of larger grain borer, *Prostephanus truncatus*, between countries (Tyler and Hodges 2002). *Prostephanus truncatus* has been introduced into Israel (Calderon and Donahaye 1962) and Iraq (Al-Sousi et al. 1970) with maize imported from the United States. It was not detected for several months. Malawi has restrictions on the importation of tobacco and tobacco products infested with cigarette beetle, *Lasioderma serricorne*, and tobacco moth, *Ephestia elutella*.

References

Al-Sousi, A. J., H. El-Haidari and J. N. Al-Ami. 1970. Outbreaks and records Iraq. Larger grain borer on maize. FAO Plant Prot. Bull. 18: 92-93.

Anon. 2001. Guidelines for phytosanitary certificates. International Standards for Phytosanitary Measures No. 12. Food and Agriculture Organization of the United Nations, Rome.

Anon. 2003. Guidelines on lists of regulated pests. International Standards for Phytosanitary Measures No. 19. Food and Agriculture Organization of the United Nations, Rome.

Armitage, H. M. 1956. The khapra beetle problem in California. J. Econ. Entomol. 49: 490-493.

Armitage, H. M. 1958. The khapra beetle suppression program in the United States and Mexico. Pages 89-98 in: E. C. Becker (Ed.). Proc. 10th Int. Congr. Entomol.

Banks, H. J. 1977. Distribution and establishment of *Trogoderma granarium* Everts (Coleoptera: Dermestidae): climatic and other influences. J. Stored Prod. Res. 13: 183-202.

Barak, A.V. 1989. Development of a new trap to detect and monitor khapra beetle (Coleoptera: Dermestidae). J. Econ. Entomol. 82: 1470-1477.

Beck, S.D. 1971a. Growth and Retrogression in Larvae of *Trogoderma glabrum* (Coleoptera: Dermestidae). 1. Characteristics Under Feeding and Starvation Conditions Ann. Entomol. Soc. Am. 64: 149-155.

Beck, S.D. 1971b. Growth and Retrogression in Larvae of *Trogoderma glabrum* (Coleoptera: Dermestidae). 2. Factors Influencing Pupation. Ann. Entomol. Soc. Am. 64: 946-949.

Calderon, M. and E. Donahaye. 1962. Outbreaks and records. Israel. First record of Prostephanus truncatus in stored grain. FAO Plant Protection Bulletin 10: 43-44.

Caresche, L., G. S. Cotterell, J. E. Peachey, R. W. Rayner and H. Jacques-Felix. 1969. Handbook for Phytosanitary Inspectors in Africa. Organization of African Unity/Scientific Technical and Research Commission, Lagos, Nigeria.

Curl, L. F. 1964. Mexico-United States cooperative plant pest programs. J. Econ. Entomol. 57: 450-452.

Ebbels, D. L. 2003. Principles of Plant Health and Quarantine. CABI Publishing, Wallingford, UK.

Emery, R.N., E. Ernestos Kostas, M. Chami. 2008. An urban eradication of khapra beetle in Western Australia. In: D.L. Guo, S. Navarro, Y. Jian, T. Cheng, J. Zuxun, L. Yue, L. Yang, W. Haipeng (Eds.), Proceedings of the 8th International Conference on Controlled Atmospheres and Fumigation in Stored Products, 21-26 Sept. 2008, Chengdu, China, Sichuan Publishing House of Science and Technology, Chengdu, China.

Freeman, J. A. 1974. A review of changes in the pattern of infestation in international trade. EPPO Bull. 4: 251-273.

Gorham, J. R. 1991. Insect and Mite Pests in Food: An Illustrated Key. Vols. 1 and 2.

Agricultural Handbook 655. USDA, Washington, DC.

Hagstrum, D. W. and Bh. Subramanyam. 2009. Stored-Product Insect Resource. AACC International, St. Paul, Minnesota.

Howe, R. W. and D. L. Lindgren. 1957. How much can the khapra beetle spread in the U.S.A. J. Econ. Entomol. 50: 374-375.

(IPPC) International Plant Protection Convention. 2010. Directory of National Plant Protection Organizations and Regional Plant Protection Organization. https://www.ippc.int/file_uploaded/1264592888_Nppo_directory_2010.pdf. Date accessed, Sept, 23, 2011.

Kennedy, M., D. Orr and M. J. Shannon. 1991. Regulatory and inspection functions in the U.S. Department of Agriculture. Pages 505-518 in: J. R. Gorham (Ed.). Ecology and Management of Food-Industry Pests. FDA Tech. Bull. 4.

Association of Official Analytical Chemists, Arlington, Virginia.

Klassen, W. 1959. Eradication of introduced arthropod pests: theory and historical practice. Misc. Publ. Entomol. Soc. Am. 73: 1-29.

Moriya, S. and T. Miyatake. 2001. Eradication programs for two sweet potato pests, *Cylas formicarius* and *Euscepes postifasciatus*, in Japan with special reference to their dispersal activity. Japan Agricultural Research Quarterly 35: 227-234.

Sonda, M. 1968. The status of *Trogoderma granarium* Everts and *T. varium* (Matsumura and Yokoyama) (Coleoptera: Dermestidae) as pests of stored products in Japan. J. Stored Prod. Res. 4: 23-30.

Stibick, J. 2007. *New Pest Response Guidelines: Khapra Beetle.* USDA–APHIS–PPQ–Emergency and Domestic Programs, Riverdale, MD.

Tyler, P. S. and R. J. Hodges. 2002. Phytosanitary measures against larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), in international trade. Integrated Pest Management Reviews 7: 279-289.

(USDA) U.S. Department of Agriculture. 2003. Commodity Preclearance Program Management Guidelines. http://www.aphis.usda.gov/import_export/plants/plant_imports/downloads/preclearance_guidelines.pdf. Date accessed, Sept. 22, 2011.

(USDA) U.S. Department of Agriculture. 2011a. USDA-APHIS-PPQ Treatment manual. http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf. Date accessed, Sept. 26, 2011.

(USDA) U.S. Department of Agriculture. 2011b. APHIS-PPQ_ Plant Biosecurity Curriculum http://www.nationalplantboard.org/docs/plant_biosecurity_curriculum.pdf Date accessed, Sept. 26, 2011.

Viljoen, J. H. 1990. The occurrence of *Trogoderma* (Coleoptera: Dermestidae) and related species in southern Africa with special reference to *T. granarium* and its potential to become established. J. Stored Prod. Res. 26: 43-51.

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S156 – 26 April 2012