

SHORT COMMUNICATION

Pest Risk Analysis (PRA) of *Sitophilus granarius* (L). (Coleoptera: Curculionidae) associated with wheat imports into South Sulawesi, Indonesia

Junaidi^{1,2}, Ahdin Gassa³, Baharuddin Patandjengi^{1,3}, Ervina Wijayanti⁴, Shella Satiwi Guci⁵, & Ramli²

Manuscript received: 21 August 2025. Revision accepted: 27 December 2025. Available online: 16 September 2026.

ABSTRACT

The increasing demand for food, combined with advances in transportation and technology, has accelerated international trade and increased the risk of introducing plant pests and diseases from other countries, thereby threatening the sustainability of domestic agriculture. One important preventive measure is the implementation of Pest Risk Analysis (PRA). This study aimed to conduct a PRA by assessing the risk associated with *Sitophilus granarius* (L)., in wheat imported from Germany into South Sulawesi, Indonesia. A qualitative risk analysis approach was used. The results indicated that the likelihood of entry, establishment, and spread of *S. granarius* was categorized as moderate, while the potential economic impact was categorized as high. Based on the combined assessment, the overall risk was classified as moderate. The recommended phytosanitary measures for wheat imports into South Sulawesi include compliance with plant quarantine requirements and additional obligations. Plant quarantine requirements include the provision of a Phytosanitary Certificate issued by the country of origin, entry through designated points of entry, and reporting and submission of the consignment to Plant Quarantine Officers for inspection and quarantine procedures. Additional obligations include ensuring that wheat grain originates from registered producers, is free from *S. granarius* and foreign materials, undergoes the required fumigation treatment before shipment, and passes inspection by the Indonesian Quarantine Authority at the point of entry. Appropriate phytosanitary measures, including treatment, rejection, or destruction of the consignment, may be implemented if the prescribed import requirements are not fulfilled.

Keywords: Pest Risk Analysis (PRA), *Sitophilus granarius*, South Sulawesi, wheat

INTRODUCTION

In the era of free trade and rapid development of information technology, substantial changes have occurred in the tourism, trade, and information sectors. The movement of people, animals, and goods has increased and accelerated from one location to another, including across national borders. Consequently, the quantity of imported agricultural products entering domestic markets has also increased. This increased movement creates greater opportunities for pests and diseases to enter countries, including Indonesia, through the importation of plants, seeds, propagative materials, and other agricultural products, as well as

through human-assisted movement, packaging, and mail. Law No. 21 of 2019 concerning Animal, Fish, and Plant Quarantine, Article 5, Paragraph 3, regulates Pest Risk Analysis (PRA) as an important component of protecting natural resources, particularly in relation to the importation of certain commodities from abroad into the territory of the Republic of Indonesia (Siwi, 2006).

Pest Risk Analysis is conducted in accordance with guidelines issued by the International Plant Protection Convention (IPPC) through the International Standards for Phytosanitary Measures (ISPM) No. 2, Framework for Pest Risk Analysis, and ISPM No. 11, Pest Risk Analysis for Quarantine Pests.

Corresponding author:
Junaidi (Junaidi.sudding@gmail.com)

¹Doctoral Program of Agricultural Sciences, Postgraduate School, Hasanuddin University. Jl. Perintis Kemerdekaan No. KM.10 Tamalanrea Indah, Makassar, Indonesia 90245

²Polbangtan Gowa. Jl. Malino No.KM. 7, Romang Lompoo, Kec. Bontomarannu, Kabupaten Gowa, Sulawesi Selatan, Indonesia 92171

³Department of Plant Protection, Faculty of Agriculture, Hasanuddin University. Jl. Perintis Kemerdekaan No.KM.10, Tamalanrea Indah, Kec. Tamalanrea, Kota Makassar, Sulawesi Selatan, Indonesia 90245

⁴Animal, Fish, and Plant Quarantine Centre of East Java. Jl. Raya Juanda, No. 26, Semalawang, Semabung, Sidoarjo, Jawa Timur, Indonesia 61253

⁵Guidance and Counseling, Faculty of Teacher Training and Education, Tadulako University, Jl. Soekarno Hatta Km. 9 Palu, Sulawesi Tengah, Indonesia 94148

The procedures and activities involved in PRA are clearly described in these standards. Plant PRA is also conducted to fulfill the requirements of Law No. 21 of 2019 concerning Animal, Fish, and Plant Quarantine. In accordance with Indonesian agricultural quarantine procedures, imported commodities must undergo risk assessment to minimize the possibility of introducing quarantine pests (Kurniasih, 2012). This study specifically focuses on *Sitophilus granarius*, a highly destructive primary pest of stored grains that is classified as a Category A1 Quarantine Pest in Indonesia. *Sitophilus granarius* is officially listed as a quarantine plant pest under the relevant Ministry of Agriculture regulations (Ministry of Agriculture, 2020). Therefore, strict monitoring and risk assessment are required for imported commodities that may harbor this pest to prevent its introduction into Indonesia. The importance of studying this species lies in its potential to cause substantial economic losses through both quantitative weight reduction and qualitative deterioration of important commodities such as wheat and rice. Because *S. granarius* is not currently established in Indonesia, a robust PRA is essential to prevent its introduction, which could threaten food security and adversely affect agricultural production and international trade. This approach is consistent with the principles of the Sanitary and Phytosanitary (SPS) Agreement (Kurniasih, 2012). However, developing a PRA scheme or protocol that produces consistent results remains challenging because of variations in the assessment and interpretation of responses to questions within the PRA process (Baker et al., 2005; Agricultural Quarantine Agency, 2021).

Wheat is a vital commodity for food security and industrial processing in Indonesia; however, its increasing import volume may increase the risk of introducing exotic plant pests. Among these pests, *S. granarius* (L.), commonly known as the granary weevil, is recognized as one of the most destructive primary pests of stored grains worldwide because of its ability to develop inside grain kernels and tolerate relatively cool conditions (CABI, 2022). Unlike some other stored-grain weevils, *S. granarius* is flightless, and its geographical distribution is therefore strongly dependent on international trade and human-assisted transportation. This characteristic makes monitoring and phytosanitary measures at points of entry particularly important. Therefore, conducting a Pest Risk Analysis is a critical preventive measure for evaluating the risk posed by *S. granarius* in wheat imported into South Sulawesi and for establishing appropriate phytosanitary and quarantine measures.

A pest can be considered a valid phytosanitary concern when its potential consequences following introduction from another country have been assessed through a scientifically based risk analysis (FAO, 2006b). Thus, PRA can play an important role in formulating policies and ensuring that plant quarantine regulations concerning the importation of pest-associated commodities are scientifically justified and do not constitute unnecessary barriers to market access under the principles of free trade (Siwi, 2006).

The World Trade Organization (WTO), which began operating in 1995, is the international organization responsible for establishing and administering rules governing international trade. The implementation of the Sanitary and Phytosanitary (SPS) Agreement provides a framework for protecting human, animal, and plant health while facilitating international trade. SPS measures include requirements related to food safety, pesticide residues, environmental protection, and phytosanitary protection against plant pests. Agricultural commodities that comply with applicable International Standards for Phytosanitary Measures (ISPMs) are better positioned to meet international phytosanitary requirements and gain access to global markets (FAO, 2006b).

For many developed countries, which generally have greater advantages in science and technology, the SPS Agreement has contributed to strengthening the competitiveness of agricultural products in international markets. At the same time, SPS measures may be used to establish stringent requirements for the entry of foreign agricultural products into domestic markets. Such measures may function as indirect trade barriers if they are not based on scientific evidence or are applied disproportionately (Siwi, 2006). Therefore, SPS measures can serve as important instruments for protecting domestic plant biosecurity, provided that the measures adopted are scientifically justified through an appropriate Pest Risk Analysis (PRA) (FAO, 2006a).

Conducting a Pest Risk Analysis is a fundamental component of scientifically based phytosanitary decision-making under the SPS Agreement (WTO, 1995). PRA helps ensure that phytosanitary measures are based on scientific principles and are proportionate to the level of risk posed by a pest, thereby minimizing the possibility of unnecessary barriers to international trade. The results of PRA provide a scientific basis for formulating quarantine policies and determining appropriate phytosanitary measures for imported commodities.

Sitophilus granarius is classified as a Category A1 Quarantine Pest (Organisme Pengganggu

Tumbuhan Karantina [OPTK] A1) in Indonesia under Ministry of Agriculture Regulation No. 25 of 2020. As an A1 quarantine pest, its introduction into Indonesian territory is strictly prohibited because the species is not known to be present in Indonesia and has the potential to establish and cause significant economic damage. The potential impact of its introduction is considerable because *S. granarius* is a primary pest of stored grains, including wheat, rice, and maize, and can cause both quantitative and qualitative losses. Previous studies have reported that infestation may result in substantial weight loss and deterioration of grain quality, potentially affecting food security and causing economic losses in the agricultural and food-processing sectors.

The importation of wheat (*Triticum aestivum* L.) from Germany into South Sulawesi requires appropriate phytosanitary risk management because of the potential association of imported grain with *S. granarius*. The biological characteristics of *S. granarius* are particularly important in determining appropriate phytosanitary measures because it is an internal feeder whose larvae develop within grain kernels. Consequently, visual inspection alone at points of entry may be insufficient to detect all infestations. In accordance with Law No. 21 of 2019, phytosanitary measures should therefore be selected based on the assessed level of risk. Because wheat is an important industrial raw material, appropriate risk management should balance biosecurity requirements with the need to maintain continuity of trade. Measures such as pre-shipment treatment, including fumigation where scientifically justified and officially approved, may be considered to reduce the likelihood of pest introduction while facilitating safe international trade.

MATERIALS AND METHODS

Research Site. The methodology used for this Pest Risk Analysis (PRA) followed the standard guidelines for plant quarantine risk assessment in Indonesia

(Kurniasih, 2012). The study was conducted from July 2024 to June 2025 at the Animal, Fish, and Plant Quarantine Center of South Sulawesi. The materials and information sources used in this study included the CABI online database and relevant scientific literature.

The qualitative risk analysis was conducted in accordance with the guidelines established by the International Standards for Phytosanitary Measures (ISPM) No. 11, Pest Risk Analysis for Quarantine Pests, and the standards of the International Plant Protection Convention (IPPC). The PRA involved assessing and categorizing the likelihood of pest entry, establishment, and spread, as well as the potential economic consequences based on available scientific references. Identification of *Sitophilus granarius* was based on the morphological characteristics described by Siwi (2006).

Pest Risk Assessment. The data were analyzed using a qualitative risk analysis approach. Technical data for the assessment were collected through a systematic review of scientific literature, international pest databases (e.g., the CABI Digital Library), scientific journals, and historical interception records from the Agricultural Quarantine Agency. The analysis included an Overall Assessment of the Possibility of Entry, Establishment, and Spread (RPMTS).

Assessment criteria were applied using individual weightings for the likelihood of entry, establishment, and spread, as well as the likelihood of economic impact. The resulting scores were categorized into risk levels to obtain an overall risk assessment. The probability criteria used for risk weighting are presented in Tables 1, 2, and 3.

Based on the probability assessment of pest entry into the PRA area, as presented in Table 1, the risk value for the potential entry of the pest was determined. The likelihood of pest entry into the PRA area was categorized into four risk levels: high, moderate, low, and no risk (Table 4).

Based on the probability assessment of pest

Table 1. Risk matrix for determining the likelihood of pests introduction and spread within the territory of the Republic of Indonesia

Likelihood of entry and establishment	Likelihood of spread			
	High risk	Moderate risk	Low risk	No risk
High risk	High risk	Moderate risk	Low risk	No risk
Moderate risk	Moderate risk	Moderate risk	Low risk	No risk
Low risk	Low risk	Low risk	Low risk	No risk
No risk	No risk	No risk	No risk	No risk

Source: FAO (1999).

establishment in the PRA area, as presented in Table 2, the risk value for potential establishment was determined. The likelihood of pest establishment in the PRA area was categorized into four risk levels: high, moderate, low, and no risk (Table 5).

Overall Assessment of Entry, Establishment, and Spread. The overall risk assessment of the likelihood of entry and establishment was conducted by combining the risk values assigned to each component. The risk value for the likelihood of introduction, which represents the combination of the likelihood of entry and establishment, was determined using the matrix presented in Figure 1.

Risk Assessment of the Probability of Entry, Establishment, and Spread. The risk value for the likelihood of pest entry, establishment, and spread within the PRA area was determined by combining the risk values assigned to each component (Agricultural

Quarantine Agency, 2007). The likelihood of introduction, which combines the likelihood of entry and establishment, was subsequently combined with the likelihood of spread using the matrix presented in Table 2 and Table 6.

Based on the assessment of the probability of the pest causing an economic impact in the PRA area, as presented in Table 7, the risk value for potential economic losses was determined. The potential economic impact of the plant pest or quarantine pest in the PRA area was categorized into four risk levels: high, moderate, low, and no risk (Table 8 and 9).

The overall risk value was determined by combining the risk values for the likelihood of entry, establishment, and spread with the potential economic impact (Table 10). The final score was determined based on the lowest score among the assessed components. The procedure for determining the overall risk score for the pest is presented in Table 5.

The moderate-risk management category was

Table 2. Risk matrix for determining the overall pest risk by combining the likelihood of entry, establishment, and spread with the potential economic impact

Risk associated with the likelihood of entry, establishment, and spread	Potential economic impact			
	High risk	Moderate risk	Low risk	No risk
High risk	High risk	High risk	High risk	High risk
Moderate risk	Moderate risk	Moderate risk	Moderate risk	Moderate risk
Low risk	Low risk	Low risk	Low risk	No risk
No risk	No risk	No risk	No risk	No risk

Source: FAO (1999)

Table 3. Risk categories for the likelihood of pest entry into the PRA area

Risk value	Category	Description
$x \geq 2.5$	High	High likelihood of pest entry into the PRA area
$1.5 \leq x < 2.5$	Moderate	Moderate likelihood of pest entry into the PRA area
$0 < x < 1.5$	Low	Low likelihood of pest entry into the PRA area
$x = 0$	No risk	No likelihood of pest entry into the PRA area

Source: FAO (1999).

Table 4. Risk matrix for combining the likelihood of pest entry and establishment with the likelihood of pest spread

Likelihood of entry and establishment	Likelihood of spread			
	High risk	Moderate risk	Low risk	No risk
High risk	High risk	Moderate risk	Low risk	No risk
Moderate risk	Moderate risk	Moderate risk	Low risk	No risk
Low risk	Low risk	Low risk	Low risk	No risk
No risk	No risk	No risk	No risk	No risk

Source: FAO (1999).

determined through a systematic qualitative matrix analysis based on the principles outlined in ISPM No. 11. The assessment involved cross-referencing the likelihood of introduction, which comprised entry, establishment, and spread, with the potential economic consequences. The methodological framework incorporated technical information on the pest's survival during maritime transportation from Germany, the climatic suitability of Indonesian storage facilities, and documented economic impacts. The

intersection of these variables in the risk matrix resulted in a moderate-risk classification. This classification provides a scientific basis for implementing additional phytosanitary measures beyond routine inspection, including phytosanitary certification and, where required and officially approved, specific treatments to reduce the likelihood of pest introduction.

Risk Management. Risk management is the decision-making process associated with the risk of pest

Table 5. Factors assessed to determine the likelihood of pest entry into the territory of the Republic of Indonesia

No.	Factors assessed	Weight	Scientific rationale/ risk value × weight
1	Likelihood of the pest being carried with the commodity	25%	Risk value × weight = ...
2	Likelihood of the pest surviving during transportation and storage	10%	Risk value × weight = ...
3	Likelihood of the pest surviving control measures in the country of origin	10%	Risk value × weight = ...
4	Likelihood of the pest moving to a suitable host near the point of entry	10%	Risk value × weight = ...
5	Difficulty of detecting and identifying the pest at the importing UPT-KHIT	20%	Risk value × weight = ...
6	Difficulty of freeing the commodity from the pest	25%	Risk value × weight = ...
Total likelihood of entry		100%	1 + 2 + 3 + 4 + 5 + 6 = ...

Source: FAO (1999).

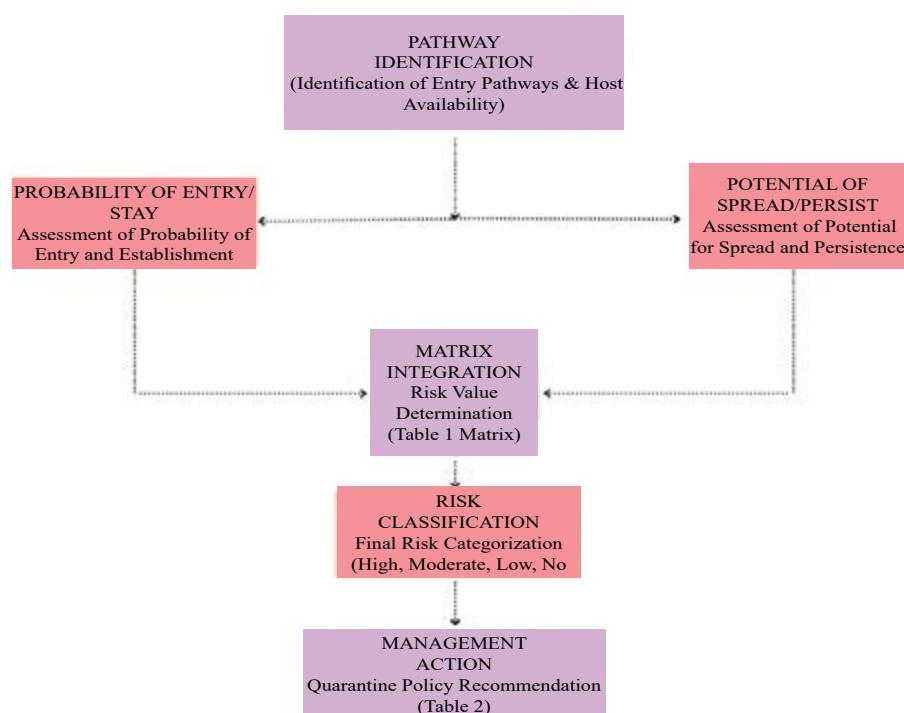


Figure 1. Procedural workflow for assessing the likelihood of pest entry, establishment, and spread in the territory of the Republic of Indonesia.

introduction and spread. The conclusions derived from the risk assessment stage are used to support decisions regarding the level of pest risk and the appropriate phytosanitary measures. The establishment of quarantine requirements is intended to minimize the risk of pest introduction through the movement or importation of pest-associated commodities.

RESULTS AND DISCUSSION

The risk assessment workflow is systematized in Figure 1, which depicts the decision-making stages from initial pathway identification to the final risk determination. The figure demonstrates that the risk matrix (Table 1) serves as a critical decision-making tool for converting qualitative assessment data into standardized quarantine risk categories. By following this framework, the determination of appropriate preventive measures becomes more measurable, transparent, and reproducible for quarantine authorities.

Risk Assessment Introduction (Entry, Establishment, and Spread). Based on the assessment results, the likelihood of *Sitophilus granarius* entering

Indonesia through wheat imported from Germany was categorized as moderate. Although this pest has a high probability of being transported with wheat grains in the egg and larval stages, which are difficult to detect through visual inspection, systematic surveillance by the German plant protection authorities may reduce the likelihood of pest entry to a moderate level. Risk management for imported commodities in Indonesia follows the guidelines established by the Indonesian Quarantine Authority (Kurniasih, 2012).

The likelihood of establishment of this pest in Indonesia was also categorized as moderate. Indonesia's environmental conditions, including suitable temperature and humidity, may support the survival and development of *S. granarius*. Furthermore, the availability of alternative food sources throughout the year in storage facilities, including rice, maize, and peanuts, may increase the likelihood of population persistence and reproduction (Table 11).

Host Plant Taxonomy. The host plant considered in this analysis was wheat, with the following taxonomic classification: Kingdom: Plantae; Division: Magnoliophyta; Class: Liliopsida; Order: Poales;

Table 6. Component factors assessed for the possibility of pest/pest establishment within the territory of the Republic of Indonesia

No	Factors assessed	Weight	Scientific Rationale/ risk value × weight
1	Availability of host plants in Indonesia	25%	Risk value × weight = ...
2	Suitability of the abiotic environment	25%	Risk value × weight = ...
3	Reproductive capacity and pest survival	20%	Risk value × weight = ...
4	Adaptability of the pest	10%	Risk value × weight = ...
5	Influence of crop cultivation systems and control measures	20%	Risk value × weight = ...
Total likelihood of establishment		100%	1 + 2 + 3 + 4 + 5 = ...

Source: FAO (1999).

Table 7. Factors assessed to determine the likelihood of pest spread in the territory of the Republic of Indonesia

No.	Factors assessed	Weight	Scientific rationale/ risk value × weight
1	Environmental suitability for natural pest spread	30%	Risk value × weight = ...
2	Potential for spread through human activities, including transportation, distribution, commodity movement, and agricultural tools	30%	Risk value × weight = ...
3	Effect of natural barriers on pest spread	10%	Risk value × weight = ...
4	Availability of natural enemies in the PRA area	30%	Risk value × weight = ...
Total likelihood of spread		100%	1 + 2 + 3 + 4 = ...

Source: FAO (1999).

Family: Poaceae; Genus: *Triticum*; Species: *Triticum aestivum* L.

Intended Use. The imported wheat grains are intended primarily as raw materials for the food-processing and flour industries in Indonesia.

Host Plant Visuals. The visual characteristics of the host plant are presented in Figure 2.

Quantity. The commodity is imported in large

Table 8. Results of the assessment of the likelihood of establishment of *Sitophilus granarius*

No	Assessment factor and scientific rationale	Risk
A.	Availability of host plants (alternative hosts and stored-product hosts) • <i>Sitophilus granarius</i> is a stored-product pest that attacks grain commodities in warehouses, including <i>Arachis hypogaea</i> (groundnut), <i>Helianthus annuus</i> (sunflower), <i>Hordeum vulgare</i> (barley), <i>Oryza sativa</i> (rice), <i>Triticum</i> spp. (wheat), <i>Vicia faba</i> (faba bean), <i>Zea mays</i> (maize), and other stored products (CABI, 2021). • The ranking of host preference or suitability among different cereals was reported as wheat > sorghum > rough rice > oats > maize > barley > polished rice (Fouad et al., 2024). • Suitable host commodities are available year-round in government-owned (Bulog) and private warehouses.	High
B.	Abiotic environmental suitability • The reported optimum conditions for development are approximately 30 °C and 70% relative humidity, with development occurring within a temperature range of approximately 11–30 °C (Rees, 2007; Mason & McDonough, 2012). • <i>S. granarius</i> has been reported from several countries in Southeast Asia, including Malaysia, Sri Lanka, and Thailand (CABI, 2021) indicating that the species can occur under climatic conditions present in the region. • The species has also been reported as established in Algeria, Austria, Cyprus, Egypt, Israel, Lebanon, Libya, Morocco, Spain, Switzerland, Syria, Tunisia, Turkey, and the United Kingdom.	High
C.	Influence of storage systems and pest control measures • Poor sanitation and inadequate maintenance of storage facilities may increase the likelihood of pest survival and establishment. Conditions such as moisture accumulation, poor hygiene, and the presence of residual grain may provide favorable conditions for stored-product pests.	High
D.	Reproductive and survival strategies • <i>S. granarius</i> reproduces sexually. Females can lay approximately 150–300 eggs during their lifetime. Eggs are laid individually in grain kernels, and the oviposition site is sealed with a waxy secretion. Eggs hatch after approximately 4–14 days. • The immature stages develop within the grain kernel, and adults emerge after completing development and may infest additional grain kernels.	Moderate
E.	Adaptability of the pest • <i>S. granarius</i> has a broad geographic distribution and has been reported from temperate, dry, and warm regions in Asia, Africa, North America, South America, Europe, and Australia (CABI, 2021). • The species can utilize a relatively broad range of stored cereal commodities and other stored products. • Adaptations associated with its survival in stored products include endosymbiotic associations with bacteria and reduced flight activity, which may contribute to survival under dry storage conditions (Plarre, 2010).	
F.	Minimum population required for pest establishment and development in the PRA area	Not assessed

Table 8. Continued. Results of the assessment of the likelihood for establishment of *Sitophilus granarius*

G. Eradication capability	Moderate
• Adults and pupae can be controlled by phosphine fumigation (CABI, 2021), and methyl bromide has also been reported as an effective fumigant against <i>S. granarius</i> (Aker et al. 2023). • Fumigation of the pupal stage with phosphine at 0.5 g/m³ for 10 days at 20 °C resulted in 100% mortality, while a treatment of 3 g/m³ for 5 days at temperatures above 20 °C has also been reported to be effective (Goto et al., 1996; EPPO, 2012). • Eradication is technically challenging because of the broad range of stored-product commodities that may serve as hosts and the potential for the pest to become widely distributed among storage facilities. • Combined treatments of zeolite and insecticides at the highest tested rates resulted in complete suppression of progeny (Abdelgaleil et al., 2022). • Essential oils of fennel, rosemary, Echinacea, and basil have shown potential for controlling stored-grain pests, with reported mortality of <i>S. granarius</i> ranging from 84.27 and 98.88% (Teke & Mutlu, 2021) • Infrared radiation may provide an alternative approach for developing sustainable control methods against stored-product pests, including <i>Sitophilus</i> spp. In one study, infrared treatment resulted in 50% mortality of adult weevils, although the required exposure time varied depending on whether grain was present and on the post-treatment assessment conditions (Keszthelyi et al., 2021). • Storage warehouses where commodities are stored in bulk may have poor sanitation and damaged structural components. Such conditions may provide inaccessible refuges where insects can survive and may make eradication more difficult. • Eradication may require substantial costs for treatment, disposal or destruction of infested commodities, facility sanitation, and, where applicable, compensation. • Some commodity storage facilities may be difficult to monitor regularly, which can reduce the effectiveness of detection and eradication measures.	
Persistent Potential Risk (RPT) Value	Moderate

Table 9. Results of the economic loss impact assessment of *S. granarius*

No	Assessment Factor & Reason	Risk
A.	Impact of pests on damage and reduced production • Reduces the quality and quantity of grain stored in warehouses, resulting in economic losses (CABI, 2021). • Makes commodities susceptible to fungal attack due to the humidity and heat they generate (Rees, 2007). • The damage causes grain to be vulnerable to attack by other pests, such as the <i>Caulophilus oryzae</i> beetle, which cannot penetrate intact grain (CABI, 2021). • <i>S. granarius</i> metabolism increased humidity and temperature, leading to grain degradation and resulting in the potential complete loss of market value if under field conditions (Lemic et al., 2020).	High (3)
B.	The impact of pests and diseases on human life and health • High populations in storage areas can cause asthma in humans (Heyworth, 1999). • Infestation with <i>S. granarius</i> and <i>S. zeamais</i> significantly reduces the physiological quality of field maize seed and affects commercial grain grading. Maize became inappropriate for human and livestock consumption (Lemić et al., 2021).	Moderate (2)
C.	The impact of pests and diseases on the environment (ecology/native plants, tourism, etc.) • The presence of pests and diseases in storage areas is limited and therefore does not directly impact the environment.	Moderate (2)

Table 9. Continued. Results of the economic loss impact assessment of *S. granarius*

D.	Their role as vectors for other pests/pests • No role as vectors	Not assessed
E.	Costs for control and eradication • High control costs are required due to the need for fumigation for control and eradication, as well as for extensive warehouse sanitation.	High (3)
F.	Impact on domestic and international trade • Quarantine pest according to EPPO with code CALAGR. • Quarantine pest in India (NBPGR 2005) • A1 Brazil 2018. • Quarantine pest at Japan in 2020	High (3)
G.	Potential to cause social problems • Likely to cause social problems because <i>S. granarius</i> is capable of attacking staple foods in Indonesia. • Reduces the quality and quantity of grain stored in warehouses, resulting in economic losses.	Medium (2)
• Economic Loss Impact Risk (EFI) Value: $3 + 2 + 2 + 3 + 3 + 2 = 14/6$		2.5 High

Table 10. Risk categories for the likelihood of pests/pests settling in the PRA area

Risk value	Category	Description
$x \geq 2.5$	High	The likelihood of pest establishment in the PRA area is high
$1.5 \leq x < 2.5$	Moderate	The likelihood of pest establishment in the PRA area is moderate
$0 < x < 1.5$	Low	The likelihood of pest establishment in the PRA area is low
$x = 0$	No risk	Pest establishment in the PRA area is not expected

Source: FAO (1999).

quantities, typically as bulk shipments, to meet industrial demand.

Packaging Type and Size. Wheat is generally transported in bulk carriers or in large industrial-sized bags, depending on the exporter's logistics and transportation system.

Means and Duration of Transport. The commodity is transported by sea from Germany to South Sulawesi, Indonesia. The duration of the voyage is sufficient for *S. granarius* to survive during maritime transportation and potentially remain associated with the commodity until arrival at the destination.

Treatment Type and Method. The prescribed treatment is fumigation using phosphine (PH_3) at a dose of 2 g/m³ for 96 hours at 20 °C, 120 hours at 16–20 °C, or 196 hours at 10–15 °C.

Point of Entry. The entry point for this PRA is a seaport or other officially designated point of entry in South Sulawesi, Indonesia.

Production Area and Capacity. The production areas are located in agricultural regions throughout Germany and are managed under high-capacity agricultural production systems.

Pests and Management in Origin Country. In Germany, *S. granarius* and other stored-product pests are managed by the relevant plant protection authorities in accordance with national plant protection regulations, including the Plant Protection Act (Pflanzenschutzgesetz, 2012), through surveillance and appropriate pest-control measures.

Cultivation System (GAP). Wheat cultivation in the country of origin follows Good Agricultural Practices (GAP) and applicable national regulations to support crop health and pest monitoring before harvest.

Post-Harvest Handling and Transport (GHP). Post-harvest handling includes grain cleaning to remove foreign materials, such as soil, weed seeds, and other debris, followed by storage in monitored facilities before transportation in bulk carriers.

Table 11. Results of the assessment of the potential for *S. granarius* to spread

No	Assessment Factor & Reason	Risk
A.	Suitability of the cultivation environment and the natural environment • It has a wide host range and is found almost throughout Indonesia and is readily available, supporting its natural spread. Hosts include <i>Oryza sativa</i> (rice), <i>Arachis hypogaea</i> (peanuts), <i>Zea mays</i> (corn), and other stored products. • The Indonesian warehousing system, which stores mixed commodities that are hosts for <i>S. granarius</i>, has the potential to spread the pest.	High
B.	Presence or absence of natural barriers • Indonesia has topography that has the potential to act as natural barriers, such as rivers, seas, hills, mountains, and so on. However, public awareness and compliance with plant quarantine regulations and advances in transport technology remain low. • Indonesia has a topography that has the potential to act as natural barriers, such as rivers, seas, hills, mountains, and other natural barriers. However, the low level of public awareness and compliance with plant quarantine regulations, coupled with advances in inter-island transportation technology, means these natural barriers are not effective in preventing the spread of pests and diseases.	Moderate
C.	Potential for spread through commodities and/or means of transport/vectors/carriers • Insects can spread through infested commodities transported from one place to another using transport, agricultural equipment, packaging, trash cans, wood, and other items (Mason & McDonough, 2012).	High
D.	Use of carrier media after introduction • Carrier media is used as raw material for the food industry.	Moderate
E.	Availability of vectors (for viruses, phytoplasmas, and some nematodes) or carrier agents in the PRA area	Not assessed
F.	Potential natural enemies in the PRA area • <i>Acaropsellina docta</i>, <i>Anisopteromalus calandrae</i>, <i>Bacillus thuringiensis</i>, <i>Beauveria bassiana</i>, <i>Cephalonomia tarsalis</i>, <i>Choetospila elegans</i>, <i>Lariophagus distinguendus</i>, <i>Lonchaea corticis</i>, <i>Pteromalus cerealellae</i>, and <i>Theocolax elegans</i> [<i>Chaetospila elegans</i>] are known as natural enemies (CABI, 2021). • Natural enemies in Indonesia are <i>Bacillus thuringiensis</i> and <i>Beauveria bassiana</i> (CABI, 2021). • Natural enemies play a minimal role in nature and require human intervention.	Moderate
Potential Spread Risk (RPS) Value		Moderate

Phytosanitary Certification System. Each shipment must be accompanied by a Phytosanitary Certificate issued by the German National Plant Protection Organization (NPPO) in accordance with applicable IPPC/ISPM No. 12 requirements. Where required by the importing country's regulations, the certificate should include an appropriate Additional Declaration confirming compliance with the relevant phytosanitary requirements for *S. granarius*.

The identification of the intercepted pest confirmed the species as *Sitophilus granarius* (L.). As illustrated in Figure 2, the specimen exhibits the characteristic morphological features of the granary weevil. Figure 2A shows the elongated snout and reduced functional wings, which distinguish the

species from some other stored-product weevils. Closer examination of the prothorax (Figure 2B) distinctive oval-shaped punctures, which are important diagnostic characteristics. Furthermore, infestation of wheat kernels was characterized by the presence of characteristic exit holes, as shown in Figure 2C.

The pest risk assessment is as follows:

Factors for Assessing the Likelihood of Establishment in the PRA Area. The factors used to assess the likelihood of establishment of the quarantine pest in the PRA area are presented in Table 12.

Factors for Assessing the Likelihood of Pests Spread in the PRA Area. The factors used to assess the likelihood of spread of the quarantine pest in the

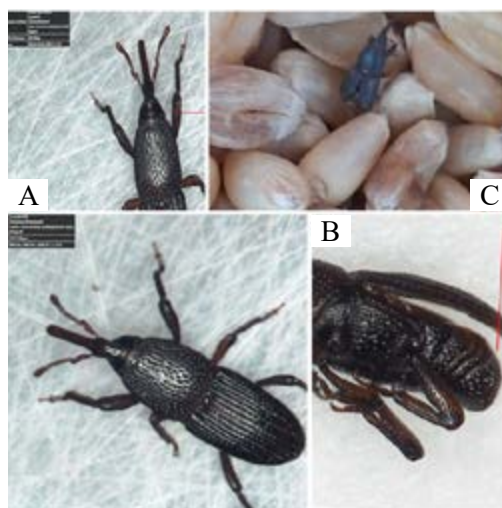


Figure 2. Morphological characteristics of *Sitophilus granarius*. A. Adult, view showing detailed elytra with staped punctures; B. Detail of prothorax showing oval punctures; C. Infestation symptoms on wheat kernels.

Table 12. Risk categories for the likelihood of pests/pests entering, settling, and spreading in the PRA area

Risk value	Category	Description
$x \geq 2.5$	High	The likelihood of pests/pests entering/settling/spreading in the PRA area is high
$1.5 \leq x < 2.5$	Medium	The likelihood of pests/pests entering/settling/spreading in the PRA area is medium
$0 < x < 1.5$	Low	The likelihood of pests/pests entering/settling/spreading in the PRA area is low
$x = 0$	No risk	The pest/pest is unlikely to enter/settle/spread in the PRA area

PRA area are presented in Table 13.

Overall Assessment of the Probability of Entry, Establishment, and Spread (RPMTS). The assessment results were as follows:

Entry potential value : Moderate

Establishment potential value: Moderate

Spread potential value : Moderate

Overall assessment: Moderate $\times$ High $\times$ Moderate = Moderate

The overall assessment indicates that the likelihood of introduction and subsequent spread of *S. granarius* in the PRA area falls within the moderate-risk category.

Assessment of Potential Economic Impact. To assess the potential economic impact resulting from the introduction of the pest, several determining factors were evaluated (Table 14). Based on the assessment presented in the table, the potential economic impact associated with the introduction of *S. granarius* was categorized as high.

Determination of the Overall Risk Value. The risk value associated with the likelihood of entry, establishment, and spread (moderate) was combined

with the potential economic impact (high) to determine the overall risk level. Based on the risk matrix presented in Table 15, the overall risk associated with *S. granarius* was categorized as moderate.

Risk Management. The importation of wheat from Germany into Indonesia requires moderate risk management measures to prevent the introduction and spread of *S. granarius*. Effective phytosanitary treatments are essential to reduce the likelihood of establishment of this pest. Although fumigation remains a commonly used treatment for stored-product pests, irradiation has also been reported as an effective phytosanitary treatment for controlling various stored-product pests and may provide an alternative to chemical treatments (Follett et al., 2013).

Wheat imported into the territory of the Republic of Indonesia must comply with the following quarantine requirements and additional obligations:

Plant Quarantine Requirements. 1) Each shipment must be accompanied by a Phytosanitary Certificate issued by the German NPPO; 2) The commodity must enter Indonesia through officially designated points of entry; 3) The shipment must be reported and submitted

to the Plant Quarantine Officer at the point of entry for the required quarantine measures.

Additional Obligations. 1) Wheat grain must originate from producers registered with the competent

authorities in Germany; 2) Wheat grain must be free from *S. granarius*, as stated in the Additional Declaration on the Phytosanitary Certificate, where such a declaration is required; 3) Wheat grain must be free from leaves, roots, soil, weed seeds, and other

Table 13. Component factors that can result in economic losses

No	Factors assessed	Weight	Scientific Rationale/ risk value $\times$ weight
1	Effect of the pest on damage and reduced production of host plants	25%	Risk value $\times$ weight = ...
2	Negative impact on the environment and humans	25%	Risk value $\times$ weight = ...
3	Role as a vector/carrier for other pests/pests	10%	Risk value $\times$ weight = ...
4	Cost of control and/or eradication	20%	Risk value $\times$ weight = ...
5	Effect of the pest on domestic and/or international trade and potential socioeconomic problems	20%	Risk value $\times$ weight = ...
Total likelihood of establishment		100%	1 + 2 + 3 + 4 + 5 = ...

Table 14. Risk categories for the likelihood of pests/pests causing economic losses in the PRA area

Risk value	Category	Description
$x \geq 2.5$	High	High likelihood of pests/pests causing economic impacts in the PRA area
$1.5 \leq x < 2.5$	Medium	High likelihood of pests/pests causing economic impacts in the PRA PRA area
$0 < x < 1.5$	Low	Low likelihood of pests/pests causing economic impacts in the PRA PRA area
$x = 0$	No risk	Pests/pests not causing economic impacts in the PRA PRA area

Table 15. Assessment factors and risk levels pest in the PRA area

No	Assessment factor and reason	Risk
A.	Possibility of pest/eating being carried by the carrier • <i>S. granarius</i> can attack cereals, including wheat. • Can be carried in grain in the egg and larval stages (CABI, 2021).	High
B.	Possibility of pest/eating being resistant to the applied control system • Official plant protection services in German states are responsible for pest surveillance and pest management in their states. In general, pest control is carried out in accordance with the Plant Protection Act (PFLANZENSCHUTZGESETZ, 2012). • Chemical control is only carried out when the infestation has reached a threshold level that requires control.	Medium
C.	Possibility of pest/eating pests surviving during transit and storage • Egg, larval, or pupal stages can survive in the grain during transit (CABI, 2021). • Eggs are laid individually in the seed cavity, which is then sealed with a waxy mucus secreted by the female (CABI, 2021; Rees, 2007), thus protecting the eggs and larvae inside the grain for survival during transit. • Adults live for 7–8 months and can survive without food for a month or more in cooler conditions (CABI, 2021). • The intensity of grain weevil procreation depends on air temperature, humidity, and amount of available food (Boniecki et al., 2020). • During transit, they can survive and reproduce in the transport vehicle.	High
D.	Possibility of pest/eating pests moving to other hosts in the import environment	High

- Adults *S. granarius* cannot fly but actively walks (CABI, 2021).
- *S. granarius* hosts are likely present in the import environment as commodities stored in the same warehouse, such as *Arachis hypogaea* (groundnut), *Avena sativa* (oats), *Cicer arietinum* (chickpea), *Helianthus annuus* (sunflower), *Hordeum vulgare* (wheat), *Oryza sativa* (rice), *Panicum* (millets), *Pennisetum* (feathergrass), *Secale cereale* (rye), *Sorghum bicolor* (sorghum), *Stored products* (dried stored products), *Triticale*, *Triticum* (wheat), *Triticum aestivum* (wheat), *Vicia faba* (faba bean), *Zea mays* (maize) (CABI, 2021).
- Wheat spilled during transport from the ship to the owner’s warehouse may potentially transfer the pest to other hosts.

E.	Ability to detect and identify the pest	Moderate
	• Egg and pupal stages: Internally carried within the grain is difficult to detect. • Infected grains show symptoms of holes, and the insects are visible to the naked eye when they emerge from the grain (CABI, 2021), making them easy to detect. • Adults can be identified at the point of import using morphometric methods and artificial neural networks (Boniecki et al., 2020). • Rapid, reliable, and sensitive tests can be performed using molecular methods using PCR (Stejskal et al., 2015). • The Agricultural Quarantine Agency’s diagnostic capabilities, including human resources, facilities, equipment, and materials, are adequate for detecting and identifying insects in wheat grain.	
F.	Ability to remove plant pest and quarantine pest from carrier media	Moderate
	• Adults and pupae can be fumigated using phosphine or methyl bromide during pre-shipment procedures (CABI, 2021) • Fumigation against	
	• Adults and pupae can be fumigated using phosphine or methyl bromide as a pre-shipment measure (CABI, 2021). • Fumigation of the pupal stage with 5 g of phosphine for 5 days at temperatures >20 °C (EPPO, 2012), (0.5 g/m³) at 20 °C for 10 days resulted in 100% mortality (Goto et al., 1996).	
Potential Entry Risk (RPM) Value		Medium

foreign materials; 4) Before shipment, the wheat grain must undergo fumigation with phosphine at a dose of 2 g/m³ for 96 hours at 20 °C; 2 g/m³ for 120 hours at 16–20 °C, or 2 g/m³ for 196 hours at 10–15 °C, as required by the applicable phytosanitary regulations; 5) Upon arrival at the designated point of entry, the wheat shipment must undergo health inspection, including visual and, where necessary, laboratory examination, to determine whether it is free from quarantine pests and other regulated plant pests and diseases; 6) If the inspection indicates the presence of a quarantine pest and the shipment cannot be effectively treated or otherwise rendered compliant, the shipment may be subject to destruction or other measures in accordance with applicable quarantine regulations; 7) If the prescribed plant quarantine requirements and additional obligations cannot be fulfilled, importation of wheat from the proposed origin should not be

permitted.

To mitigate the risk of *S. granarius* introduction, appropriate phytosanitary treatments can be implemented. In addition to conventional fumigation, irradiation has been reported as an effective and environmentally favorable phytosanitary measure for the management of stored-product pests (Follett et al., 2013).

CONCLUSION

The pest risk analysis of *Sitophilus granarius* associated with wheat imports from Germany into Indonesia indicated an overall moderate risk. The likelihood of pest entry, establishment, and spread was categorized as moderate, whereas the potential economic impact was categorized as high. Based on the combined assessment of these factors, the overall

risk associated with the introduction of *S. granarius* was classified as moderate. Therefore, appropriate phytosanitary and quarantine measures are required to minimize the risk of its introduction and establishment in Indonesia.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Head of the South Sulawesi Animal, Fish, and Plant Quarantine Center and all staff members for their support and assistance during this study.

FUNDING

This research received no external funding. It was conducted as part of the requirements for the completion of the doctoral study.

AUTHORS' CONTRIBUTIONS

J and AG designed the study and conducted the research. BP supervised the research activities. EW and SSG contributed to data analysis and manuscript preparation. R contributed to manuscript review and editing. All authors read and approved the final manuscript.

COMPETING INTEREST

The authors declare that they have no competing interests.

REFERENCES

- Abdelgaleil SAM, Gad HA, Atta AAM, & Al-Anany MS. 2022. Control of *Sitophilus granarius* and *Sitophilus oryzae* on stored wheat using low-rate combinations of natural zeolite with three insecticides. *J. Stored Prod. Res.* 97: 101975. <https://doi.org/10.1016/j.jspr.2022.101975>
- Aker O, Eser F, & Yildirim C. 2023. Chemical composition and insecticidal activity of *Nepeta italica* L. extracts against *Sitophilus granarius* (L. Linnaeus, 1758) (Coleoptera: Curculionidae) and *Tribolium confusum* Jacquelin du Val, 1863 (Coleoptera: Tenebrionidae). *J. Plant Dis. Prot.* 130(6): 1251–1261. <https://doi.org/10.1007/s41348-023-00775-z>
- Agricultural Quarantine Agency. 2021. *Pedoman analisa risiko organisme pengganggu tumbuhan berdasarkan berdasarkan media pembawa* [Guidelines for pest risk analyze based on carrier media]. Kementerian Pertanian. Jakarta. <https://id.scribd.com/document/938369826/Pedoman-AROPT-Berdasarkan-Media-Pembawa-Tahun-2021>. Accessed on 10 January 2026.
- Agricultural Quarantine Agency. 2007. *Pedoman Surveilensi Organisme pengganggu Tumbuhan (OPT) atau Organisme Pengganggu Tumbuhan Karantina (OPTK) [Surveillance Guidance of Plant Pest Diseases or Regulated Plant Pest and Disease]*. Departemen Pertanian. Jakarta. <https://repository.pertanian.go.id/handle/123456789/5417>. Accessed on 10 January 2026.
- Baker RHA, Sansford CE, Gioli B, Miglietta F, Porter JR, & Ewert F. 2005. Combining a disease model with a crop phenology model to assess and map pest risk: Karnal bunt disease (*Tilletia indica*) of wheat in Europe. In: Alford DV & Backhaus GF (Eds.) *Introduction and Spread of Invasive Species. CPC Symposium Proceedings*. 81: 89–94. *Humboldt University, Berlin, Germany*. https://dlwqtxts1xzle7.cloudfront.net/30656025/031_Baker-libre.pdf?1391815572=&response-content-disposition=inline%3B+filename%3DCombining_a_disease_model_with_a_crop_ph.pdf&Expires=1788424514&Signature=dIzQqu72aGBX6~QkHgKFNHw5qro3YWRCi4OocOHYsGrFd9OkA4Jwv5ygc9kcVo7-W6gdXYXrwePU3CjpdP72lwtUgHMSev7le-XYVsdazcF639LknmI4RwGvS2ZSj0liGLUeN09o0xlyrFQDJn7rz7we8UCVqcIGQEkmtdl5Ui9bK9350vICXVMRI-KGFWcLXHdD-xvgxfzbYj7LUTk56Qzwa1aluaTEGRqaFN0ipxp6ibyR-6y591hPIVH5qKnRP1mQq9uX26Roone8r5zM yLAVr4LRVVrljTJVgKtEUJr~hRWDMjAhQNi3ZT8WKsA7YZrVB84VNVsSf0~gIN4lw__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA. Accessed 15 April 2026.
- Boniecki P, Koszela K, Świerczyński K, Skwarcz J, Zaborowicz M, & Przybył J. 2020. Neural visual detection of grain weevil (*Sitophilus granarius* L.). *Agriculture*. 10(1): 25. <https://doi.org/10.3390/agriculture10010025>
- CABI (Centre for Agriculture and Bioscience International). 2021. *Sitophilus granarius* (grain weevil). CaBI Digital Library, Wallingford, UK. <https://doi.org/10.1079/>

- cabicompendium.10850. Accessed 6 February 2026.
- EPPO (European and Mediterranean Plant Protection Organization). 2012. Phosphine fumigation of dried fruits and nuts to control various stored product insects. *Bulletin OEPP*. 42(3): 504–506. <https://doi.org/10.1111/epp.2598>
- Follet PA, Snook K, Janson A, Antonio B, Haruki A, Okamura M, & Bisel J. 2013. Irradiation as a quarantine treatment for stored product pests. *J. Stored Prod. Res.* 52: 63–67. <https://doi.org/10.1016/j.jspr.2012.09.004>
- Food and Agriculture Organization (FAO). 2006a. *International standards for phytosanitary measures publication no. 2: guidelines for pest risk analysis*. Secretariat of the International Plant Protection Convention, Food and Agriculture Organisation. United Nations, Rome. <https://www.fao.org/4/a0450e/a0450e.pdf.pdf>. Accessed on 15 March 2026.
- Food and Agriculture Organization (FAO). 2006b. *International standards for phytosanitary measures publication no. 11: pest risk analysis for quarantine pests, including analysis of environmental risks and living modified organisms*. Secretariat of the International Plant Protection Convention, Food and Agriculture Organisation of the United Nations, Rome. <https://www.fao.org/4/a0450e/a0450e.pdf>. Accessed on 15 March 2026.
- Fouad MS, Hassan MH, & Mahmoud AN. 2024. Biological study on the granary weevil, *Sitophilus granarius* (L.) on stored wheat during the different seasons with special reference to its host preference. *J. Plant Prot. & Pathol.* 15(6): 169–172. <https://doi.org/10.21608/jppp.2024.294174.1238>
- Goto M, Kishimno H, Imamura M, Hirose Y, & Soma Y. 1996. Responses of the pupae of *Sitophilus granarius* L., *Sitophilus zeamais* Motschulsky and *Sitophilus oryzae* L. to phosphine and mixtures of phosphine and carbon dioxide. *Res. Bull. Plant. Prot. Service. Jpn.* 32: 63–67.
- Heyworth MF. 1999. Importance of insects in Asthma. *J. Med. Entomol.* 36(2): 131–132. <https://doi.org/10.1093/jmedent/36.2.131>
- Keszthelyi S, Lukács H, & Pál-Fám F. 2021. Effects of different infra-red irradiations on the survival of granary weevil *Sitophilus granarius*: Bioefficacy and sustainability. *Insects*. 12(2): 102. <https://doi.org/10.3390/insects12020102>
- Kurniasih KT. 2012. Analisis risiko organisme pengganggu tumbuhan *Pantoea stewartii* [Pest risk analysis of *Pantoea stewartii*]. Pusat Karantina Tumbuhan dan Keamanan Hayati Nabati. Badan Karantina Pertanian. Kementerian Pertanian, Jakarta.
- Lemic D, Mikac KM, Genda M, Jukić Ž, & Živković IP. 2020. Durum wheat cultivars express different level of resistance to granary weevil, *Sitophilus granarius* (Coleoptera; Curculionidae) infestation. *Insects*. 11(6): 343. <https://doi.org/10.3390/insects11060343>
- Lemić D, Šimunović K, & Živković IP. 2021. Harmfulness of two species of weevils (*Sitophilus granarius* L. and *Sitophilus zeamais* Motsch.) on different maize hybrids. *J. Cen Eur.* 22(1): 178–187. <https://doi.org/10.5513/JCEA01/22.1.3113>
- Mason LJ & McDonough M. 2012. Biology, behavior, and ecology of stored grain and legume insects. In: Hagstrum DW, Phillips TW, & Cuperus G (Eds.). *Stored Product Protection*. pp. 7–20. Kansas State University. Kansas. https://bookstore.ksre.k-state.edu/pubs/stored-product-protection_S156.pdf. Accessed on 9 August 2024.
- Ministry of Agriculture. 2020. *Peraturan Menteri Pertanian Republik Indonesia Nomor 25 Tahun 2020 tentang Jenis Organisme Pengganggu Tumbuhan Karantina [Regulation of the Minister of Agriculture Number 25 of 2020 concerning Types of Quarantine Plant Pests]*. Ministry of Agriculture. Jakarta. <https://jdih.pertanian.go.id/peraturan/permentan-no25-tahun-2020>. Accessed on 15 April 2026.
- Pflanzenschutzgesetz (PflSchG). 2012. *Act on the Protection of Cultivated Plants (Plant Protection Act)*. Federal Ministry of Justice and Consumer Protection, Germany. https://www.gesetze-im-internet.de/pflschg_2012/. Accessed on 15 April 2026.
- Plarre R. 2010. Pheromones in stored-products and material protection—35 years of practical experiences. *Journal für Kulturpflanzen*. 65(5): 173–179. <https://doi.org/10.5073/JfK.2013.05.01>

- Rees D. 2007. *Insects of Stored Grain: A Pocket Reference*. Second Edition. Csiro Publisihng. Collingwood. Australia. <https://desinsectador.com/wp-content/uploads/2018/11/insect-of-stored-grain-david-rees-2006.pdf>. Accessed 6 February 2026.
- Stejskal V, Hubert J, Aulicky R, & Kucerova Z. 2015. Overview of present and past and pest-associated risks in stored food and feed products: European perspective. *J. Stored Prod. Res.* 64: 122–132. <https://doi.org/10.1016/j.jspr.2014.12.006>
- Siwi SS. 2006. Peran ilmu biotaksonomi serangga dalam pembangunan pertanian berkelanjutan di era globalisasi [The role of science on insect biotaxonomy for sustainable agricultural development in the era of globalization]. *Berita Biologi*. 8(1): 1–18.
- Teke MA & Mutlu Ç. 2021. Insecticidal and behavioral effects of some plant essential oils against *Sitophilus granarius* L. and *Tribolium castaneum* (Herbst). *J. Plant Dis. Prot.* 128(1): 109–119. <https://doi.org/10.1007/s41348-020-00377-z>
- WTO (World Trade Organization). 1995. *SPS Agreement. World Trade Organisation agreement on the application of sanitary and phytosanitary measures*. World Trade Organisation, Geneva, Switzerland. https://www.wto.org/english/docs_e/legal_e/sps_e.htm. Accessed 6 February 2026.