



Submissions for Diagnostic Protocols

I. General information

Submission number	2023-012
Title of Proposal	Diagnostic Protocol for detection and identification of <i>Halyomorpha halys</i> (Brown Marmorated Stink Bug)
Submitted by (Country or Organization)	IPPC Contracting Party
IPPC Official Contact Point or RPPO	Australia
Supported by	Australia

2. Contact information

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3. Summary of proposal

Summary of justification for the proposal	<p><i>Halyomorpha halys</i>, the Brown Marmorated Stink Bug (BMSB), is an invasive pest species that threatens a range of agricultural crops, the environment and social amenity plants. BMSB invades buildings in mass numbers and emits an offensive smell making it a nuisance pest as well as an agricultural pest. BMSB can be disseminated not only by fresh produce, but also on a vast range of commodities as a hitchhiker or contaminant pest, meaning testing and treatment for this pest is extensive in international trade. National Plant Protection Organisations often intercept Pentatomidae but a lack of diagnostic keys and reliable DNA barcodes can confound diagnosis and limit taxonomic classification of closely related, look-a-like species from diverse countries. A harmonised international diagnostic protocol for BMSB is a compelling necessity which will facilitate early detection, limit spread and protect agricultural commodities and environmental and social amenities.</p>
Proposed priority	I (high)
Comments	BMSB is a hitchhiker pest that is being detected globally with increasing frequency.

4. Literature review

<p>Literature review</p>	<p><i>Halyomorpha halys</i> (Stål) (Hemiptera: Pentatomidae), commonly known as the Brown Marmorated Stink Bug (BMSB), is an invasive pest species that threatens a range of agricultural crops, the environment and social amenity plants. Native to East Asia, its range has rapidly expanded to the United States, Europe, Canada and to Chile in the Southern Hemisphere. BMSB is an aggressive generalist feeder and attacks ≥300 plant species encompassing a range of fruit and other trees, vegetables, ornamental and agricultural crops. Using needle-like mouthparts, BMSB's feeding can result in depressed or sunken areas or corky spots on fruits, leading to premature fruit abortion, and collapsed and discoloured sweet corn kernels which is especially apparent when cooked. BMSB causes significant damage to agriculture crops, with instances of 100% yield loss reported in pears in the USA. The distinct overwintering abilities of BMSB contribute to its survival and population persistence. During colder months, it seeks shelter in man-made environments such as homes and vehicles which protect it from extreme weather conditions and allow it to enter a state of dormancy. As spring arrives, BMSB emerges from these protected sites to feed and reproduce. BMSB invades homes and sheds in mass numbers and emits an offensive smell making it a household nuisance pest as well as an agricultural pest. Its voracious feeding habit, wide host range, overwintering abilities and dispersal capacity increase the risk of BMSB spreading to new areas. Besides fresh produce, BMSB can contaminate non-commodities such as shipping containers and clothing, often in large numbers, thus increasing the volume of commodities and non-commodity items that can harbour the pest and assist it to spread globally. BMSB belongs to the diverse genus <i>Halyomorpha</i> and its resemblance to other stink bug species in appearance, especially those found in the same habitat or utilize the same host, complicates accurate diagnosis. For example, the native European stink bug species <i>Rhaphigaster nebulosa</i> is superficially similar to BMSB and has in the past been misidentified as <i>H. halys</i> because of similarity in appearance and habitat preference. There are more than 550 Australian species of stink and shield bugs, most in the Family Pentatomidae. There is no comprehensive key available to identify all species of Pentatomidae worldwide. National Plant Protection Organisations often intercept Pentatomidae but a lack of diagnostic keys (as well as reliable DNA barcodes) limits further taxonomic classification. Identification of insects in this taxon is further complicated by different life stages of the pest closely resembling other native bug species. Timely detection and early intervention are crucial for limiting BMSB's establishment and spread, given the substantial management costs associated with eradication. Insecticides recommended to manage BMSB can cause significant environmental impact, their use is regulated, and there are varying pesticide resistance</p>
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	levels in BMSB, so preventing introduction of BMSB is the most effective biosecurity approach. A harmonised international diagnostic protocol for BMSB is a compelling necessity which will ensure accurate and rapid species identification, facilitate containment, aid trade, and allow for the design of effective pest management strategies.
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5. Criteria for prioritization of Diagnostic Protocols

Criteria	Information provided by Submitter
1. Need for international harmonization of the diagnostic techniques for the pest (e.g. due to difficulties in diagnosis or disputes on methodology)	<p>BMSB is often misidentified or misclassified due to the range of look-alike stink bug species within the Pentatomidae family of the order Hemiptera. Similarly, morphological similarities among different life stages of BMSB and other pentatomids further compound the challenge of accurate identification. For instance, in the USA, BMSB was misidentified as the native stink bug <i>Euschistus servus</i> for years until a large number of BMSB began entering houses, which was a behaviour different from that observed in native stink bug species. Similarly, in Europe, the presence of BMSB went unnoticed for years due to its mistaken identification as a native pentatomid, <i>Rhaphigaster nebulosa</i>. There is no comprehensive key available to identify all species of Pentatomidae worldwide. A harmonized diagnostics protocol offers several benefits.</p> <ul style="list-style-type: none"> • Provides comparable results and reference material that can continue to aid multiple jurisdictions; for example: <ul style="list-style-type: none"> - harmonised standards for diagnostic results for use in trade - consistent molecular barcode region for identification and differentiation of key taxonomic groups. • Protocols are adequately validated to an international standard which ensures accurate differentiation of species. • Facilitates timely detection and early intervention which will: <ul style="list-style-type: none"> - allow preventative actions and will limit BMSB establishment and/or spread - reduce pesticide usage in eradication - help to prevent the social nuisance created by pest aggregation. • Provides diagnostics tools that can be confidently used to support monitoring and surveillance activities. • Supports high-throughput surveillance and environmental scanning activities (e.g. eDNA, barcoding, metabarcoding and hybridization capture).
2. The relevance of the diagnosis to the protection of plants including measures to limit the impact of the pest.	<p>BMSB is rapidly spreading across the globe and, given its ability to target a large number of plant species, the significance of BMSB diagnostics becomes crucial for safeguarding agriculture and the environment and minimizing its global impact. Accurate and rapid BMSB diagnostics offers several advantages.</p> <ul style="list-style-type: none"> o Early detection and intervention, preventing the pest population reaching unmanageable levels, maintaining the opportunity for eradication and (if eradication is successful) avoiding substantial on-going control costs. o Designing pest management strategies using integrated pest management approaches that can be tailored to the ecological niche in which the pest is found and the pest's population

	<p>dynamics. Due to BMSB's pestiferous nature, the time to develop management strategies is very limited when it first enters a new geographic area.</p> <ul style="list-style-type: none"> o Protecting local ecosystems and biodiversity as BMSB's indiscriminate feeding can disturb the ecological balance that exists between native flora and fauna. o Reduction in chemical usage for pest management. Chemicals used against BMSB are subject to regulatory compliance and may be environmentally harmful. o Informs surveillance strategies. o Reduces social nuisance caused by BMSB's overwintering behaviour in buildings and vehicles. <p>The benefit of rapid BMSB diagnosis goes beyond mere pest identification and forms the foundation for protecting agricultural production, ecosystems and social amenities. Early detection also informs pest management strategies that will help limit pest spread and establishment and will preserve the opportunity for eradication.</p>
<p>3. Importance of the plants protected on the global level (e.g. relevant to many countries or of major importance to a few countries).</p>	<p>BMSB is a pest of global significance due to its polyphagous nature and its ability to survive in diverse climatic zones. BMSB is a generalist and is known to attack over 300 plant species, including fruit trees, vegetables, nuts, field crops and woody ornamentals and trees. BMSB's feeding has a direct impact on agriculture production. Worldwide staples like apples, peaches, pears, nectarines and grapes face substantial yield losses due to BMSB injury. In a 2010 US outbreak, peaches in Maryland saw 100% losses, peaches in New Jersey saw 60–90% losses, while apples in the mid-Atlantic reported a one-year loss exceeding \$37 million. Beyond fruit crops, BMSB also attacks various vegetables such as eggplants, okra, cucumber and cauliflower, leading to significant economic losses. Its indiscriminate feeding also extends to the viticulture industry, ornamental plants, and even to the less common speciality crops such as quinces and lima beans. In Europe, the estimated losses reported from various crops in 2019 were €250 million indicating its impact on agricultural production. Due to its indiscriminate feeding and social impact, countries free from BMSB or with established populations, remain vigilant against new introductions or further spread. Any new introduction has capacity to create imbalance among endemic populations, leading to substantial losses. BMSB's invasive nature disrupts the daily lives of people living in infested areas. The pest overwinters in buildings and vehicles and can cause psychological and emotional reactions due to the challenge of managing it, especially as it cannot be easily treated with insecticides.</p>
<p>4. Volume / importance of trade of the commodity that is subjected to the diagnostic procedures (e.g. relevant to many countries or of major importance to a few countries).</p>	<p>BMSB is a voracious feeder and attacks a range of plant species. The volume of trade subjected to biosecurity intervention for BMSB is substantial as it encompasses fruits, vegetables and ornamental plants, valued at billions of dollars annually. For instance, the global fresh fruits and vegetables market size stands at US\$144B in 2022 and is subject to intervention for BMSB including the need for diagnostics. Likewise, the ornamental flower market, valued at \$43B in 2023, will also be</p>

importance to a few countries).	impacted by BMSB. Beyond its impact on various plant species, BMSB is recognized as a well-known hitchhiker. Its overwintering abilities within non-agricultural commodities further influence trade dynamics especially during the movement of goods from BMSB risk countries. Containers, packaging material, passenger luggage, clothing, footwear and even aircraft serve as pathway vectors for BMSB, demanding biosecurity intervention including diagnostics. For example, Australia has BMSB seasonal measures applying to targeted goods manufactured in or shipped from target risk countries that have been shipped between 1 September and 30 April (inclusive). This list of goods is extensive and diverse including items made of wood, stone, ceramics, glass, metals, carpets, locomotives, cars, aircraft, and electrical machinery. A well-defined diagnostic protocol will support diagnostics for BMSB and distinguish closely related species, thus avoiding unnecessary treatments, and focusing resources on detecting and responding to real threats. The protocol will have a far-reaching impact on trade dynamics, as BMSB is a contaminating [hitchhiker] pest as well as a plant pest.																								
5. Other criteria for topics as determined by CPM that are relevant to determining priorities	<p>This submission meets the core criteria outlined in CPM Appendix 8. The submission meets the following Supporting criteria points:</p> <p>Practical</p> <p>1) There is currently no overarching EPPO or IPPC protocol for BMSB.</p> <p>2) There is available expertise for development of the proposed standard.</p> <p>Economic</p> <p>1. The economic value of key BMSB hosts (gross production value (constant 2014-2016) US\$) for the world (Total) listed at FAOSTAT in 2020 includes:</p> <table><tr><td>•Apples</td><td>-</td><td>US\$50</td><td>billion</td></tr><tr><td>•Pears</td><td>-</td><td>US\$16</td><td>billion</td></tr><tr><td>•Grapes</td><td>-</td><td>US\$68</td><td>billion</td></tr><tr><td>•Peaches and nectarines</td><td>-</td><td>US\$18</td><td>billion</td></tr><tr><td>•Tomato-</td><td></td><td>US\$95</td><td>billion</td></tr><tr><td>•Corn</td><td>-</td><td>US\$259</td><td>billion</td></tr></table> <p>Environmental</p> <p>The submission meets points 3 & 4.</p> <p>Strategic-</p> <p>The submission meets points 4 & 5.</p>	•Apples	-	US\$50	billion	•Pears	-	US\$16	billion	•Grapes	-	US\$68	billion	•Peaches and nectarines	-	US\$18	billion	•Tomato-		US\$95	billion	•Corn	-	US\$259	billion
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6. The balance between pests of importance in different climatic zones (temperate, tropics etc) and commodity classes.	<p>The BMSB has become a pest of global concern due to its impact on an extensive range of commodity classes and it’s ability to infiltrate and adapt to diverse climatic zones. Originally native to the temperate regions of China, its unexpected invasion and rapid spread in other temperate areas, particularly North America and Europe have confounded experts as cold winters were once considered to be a natural barrier to its spread. However, the stink bug’s ability to overwinter by sheltering in buildings and vehicles along with the availability of suitable hosts has enabled BMSB’s rapid expansion in regions with seasonal fluctuations and harsh winters. Research has indicated that temperate zones in the southern</p>																								

	<p>hemisphere including southern South America, southeast and southwest regions of Australia and large areas of New Zealand are conducive to BMSB establishment. While BMSB's adaptability to temperate regions is well documented, some studies have indicated it is an emerging threat to moist tropical and subtropical climatic zones, especially with climate change. This threat looms larger over prime horticultural production areas.</p>
<p>7. Number of labs undertaking the diagnosis.</p>	<p>Hundreds of plant protection organisation laboratories and research institutes worldwide actively diagnose BMSB. Significant efforts are underway in various diagnostics laboratories worldwide to monitor the entry, presence, establishment or spread of BMSB. For example, several laboratories in Europe including the Natural History Museum, UK (entomology collections), Agroscope in Switzerland, and Julius Kuhn-Institut in Germany play a significant role in monitoring the pest's presence and population dynamics to design control methods accordingly. Similarly, USDA Agricultural Research Services' (ARS) laboratories play an active role in monitoring and surveillance of BMSB due to its significant impact on US agriculture. Collaborations among research institutes, national plant protection organizations and global networks are currently being established to understand this invasive pest to limit its spread. In Australia, biosecurity laboratories, such as those under the Commonwealth Department of Agriculture, Fisheries and Forestry, along with state and territory agricultural department facilities are established to monitor BMSB entry through international trade. In addition to this, the Commonwealth Scientific and Industrial research organization, Department of Agriculture and Fisheries (Biosecurity Queensland) and several research organizations and universities (e.g. University of New South Wales) have dedicated research programs focused on BMSB diagnostics, monitoring, and assessing its potential impacts on Australian agriculture.</p>
<p>8. Feasibility of production of a protocol, including availability of knowledge and expertise.</p>	<p>The production of an annex to ISPM 27 to harmonise diagnostic approaches for detection and identification of BMSB is highly feasible. Research that has advanced our knowledge of BMSB biology, diagnosis, and management practices has been widely published and provides strong foundations for diagnostic protocol development. Advances in molecular diagnostics including PCR and barcoding can aid in identifying different life stages of BMSB that resemble or are indistinguishable morphologically from closely related stink bug species and support high-throughput diagnostic activities. There is ample BMSB diagnostic expertise globally with many recognised authorities. However, representation of specific regional expertise on closely related <i>Halyomorpha</i> species that could confound diagnostics from diverse countries would be a valuable inclusion in a BMSB diagnostic protocol. In Australia, a range of diagnosticians and molecular experts are actively involved in BMSB diagnostics and research to support diagnostics, with a focus on preventing its entry through</p>

	international trade. For example, the Commonwealth Department of Agriculture, Fisheries and Forestry and the University of New South Wales, Australia, currently have a project dedicated to developing diagnostic methodologies for BMSB. This includes revision of the genus <i>Halyomorpha</i> and closely allied taxa and the development of an improved diagnostics key for BMSB.
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