Menu of phytosanitary measures

An information report to guide the selection of measures within phytosanitary systems approaches to pest risk management

Consultation draft

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Report details

This is a consultation draft. The authors seek feedback on this report from biosecurity practitioners and researchers.

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Glossary of terms

Terms are defined as they are used in the context of this document.

Appropriate level of protection (ALOP): Under the Sanitary and Phytosanitary Measures (SPS) Agreement, World Trade Organization (WTO) members are entitled to maintain a level of protection they consider appropriate to protect human, animal or plant life or health within their territory.

Commodity. A type of plant, plant product, or other article being moved for trade or other purpose (ISPM 5). In this report, the term is used interchangeably with "regulated article" to cover hosts of pests (such as fresh produce, seed trade, forestry products) and carriers (such as soil, machinery, shipping containers).

Phytosanitary measures. Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (ISPM 5). A measure has the following minimum requirements: it is clearly defined; it is efficacious; it is officially required (mandatory); and it can be monitored and controlled by the responsible NPPO

Phytosanitary systems approach. Integrated measures for pest risk management in a defined manner (and) could provide an alternative to single measures to meet the appropriate level of phytosanitary protection of an importing country. They can also be developed in situations where no single measure is available. A systems approach requires the integration of different measures, at least two of which act independently, with a cumulative effect (ISPM 5).

Registered site. May include production blocks or orchards, packhouses and processing plants, transport hubs, treatment facilities, storage facilities.

Regulated article Any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved (ISPM 5).

Introduction

This report has been developed to provide an information resource for those involved in the development of pest risk management procedures to address biosecurity issues arising from trade. It provides detailed information about phytosanitary measures that can be used to address pest risks. The document is a consultation draft and will be further developed based on feedback and contributions from biosecurity/market access practitioners and researchers over the coming months. We aim to include in future editions of this report additional measures, information on the applications of measures in a broader range of contexts and supporting information and references.

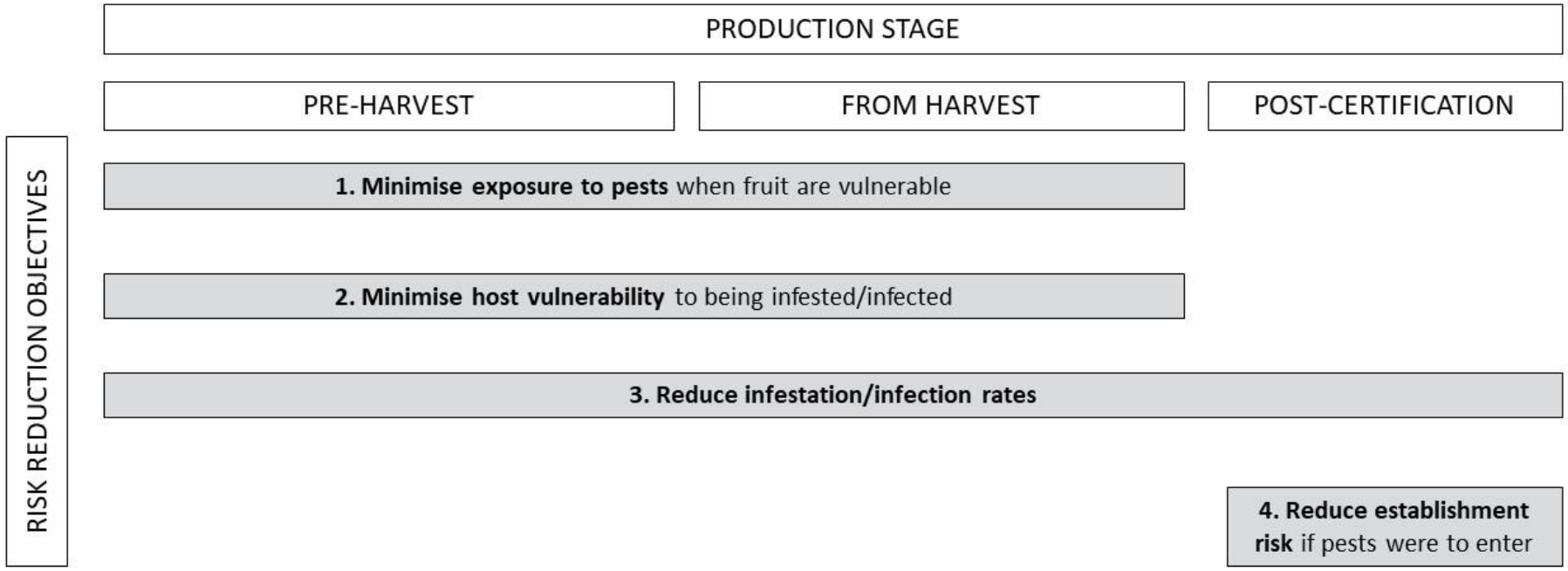
The report is a draft output of a national, collaborative phytosanitary systems approach research project in Australia (2017-2022), supported by funding from Hort Innovation. While the research project is focussed on trade in fresh fruit, this report has been developed to be applicable to trade in any commodity for which there may be phytosanitary requirements. This includes trade in other fresh horticultural produce (such vegetables), nursery products, grain, timber, seeds, and carriers of pests (such as soil, machinery and shipping containers).

Phytosanitary systems approaches are one of four pest risk management pathways for market access recognised under the International Plant Protection Convention. Systems approaches enable the use of multiple measures throughout the production process to reduce the risk of pests or pathogens in a commodity. A wide range of measures can be used. Through the research project noted above, a risk reduction framework has been developed which classifies phytosanitary measures into the four ways that they can reduce risk (risk reduction objectives) and the three broad production stages where they could be applied (Figure 1) (van Klinken et al. 2020).

In the same paper, measures under each risk reduction objective were further classified into categories, again according to how they reduce risk. In this report we extend this work. First, we reviewed the literature more broadly to identify any measures that have been applied or considered for use within a phytosanitary systems approach and incorporated those into our risk framework. In some cases that necessitated the addition or rewording of existing risk categories. Second, we provided a description of each measure category and measure, briefly outlined the evidence that might be required to demonstrate its efficacy in reducing risk and what is required to provide confidence that it has been correctly applied. The evidence of efficacy would be presented in a data package to support a proposal for a new (or revised) protocol, while the correct application of a measure would be verified through agreed implementation arrangements (such as a certification audit). Finally, we have briefly summarised the way that measures are typically used within systems approaches and how measures typically relate to other measures.

The current research project is also supporting the development of modelling tools that guide the selection of an effective mix of phytosanitary measures and validate their efficacy in combination to reduce risks to the level required for trade. Further information can be found at https://research.csiro.au/psa/

Figure 1: The phytosanitary systems approach risk reduction framework, as developed for fresh produce.



Source: van Klinken, R., Fiedler, K., Kingham, L., Collins, K., Barbour, D., 2020. A risk framework for using systems approaches to manage horticultural biosecurity risks for market access. J. Crop Protection. 129 https://doi.org/10.1016/j.cropro.2019.104994

Terms used in this report

In this report we use the term *phytosanitary measures* (or simply "*measures*") as it is defined under the International Standards for Phytosanitary Measures, ISPM 5 and 14. A measure has the following minimum requirements:

- is clearly defined
- is efficacious
- is officially required (mandatory)
- can be monitored and controlled by the responsible NPPO.

This is discussed further in van Klinken et al. (2020, 2021). It is also largely consistent with what we consider to be the intent of the World Trade Organisation's Sanitary and Phytosanitary (WTO-SPS) agreement where phytosanitary measures are any measures applied to negate impacts to animal or plant life or health from the entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms.

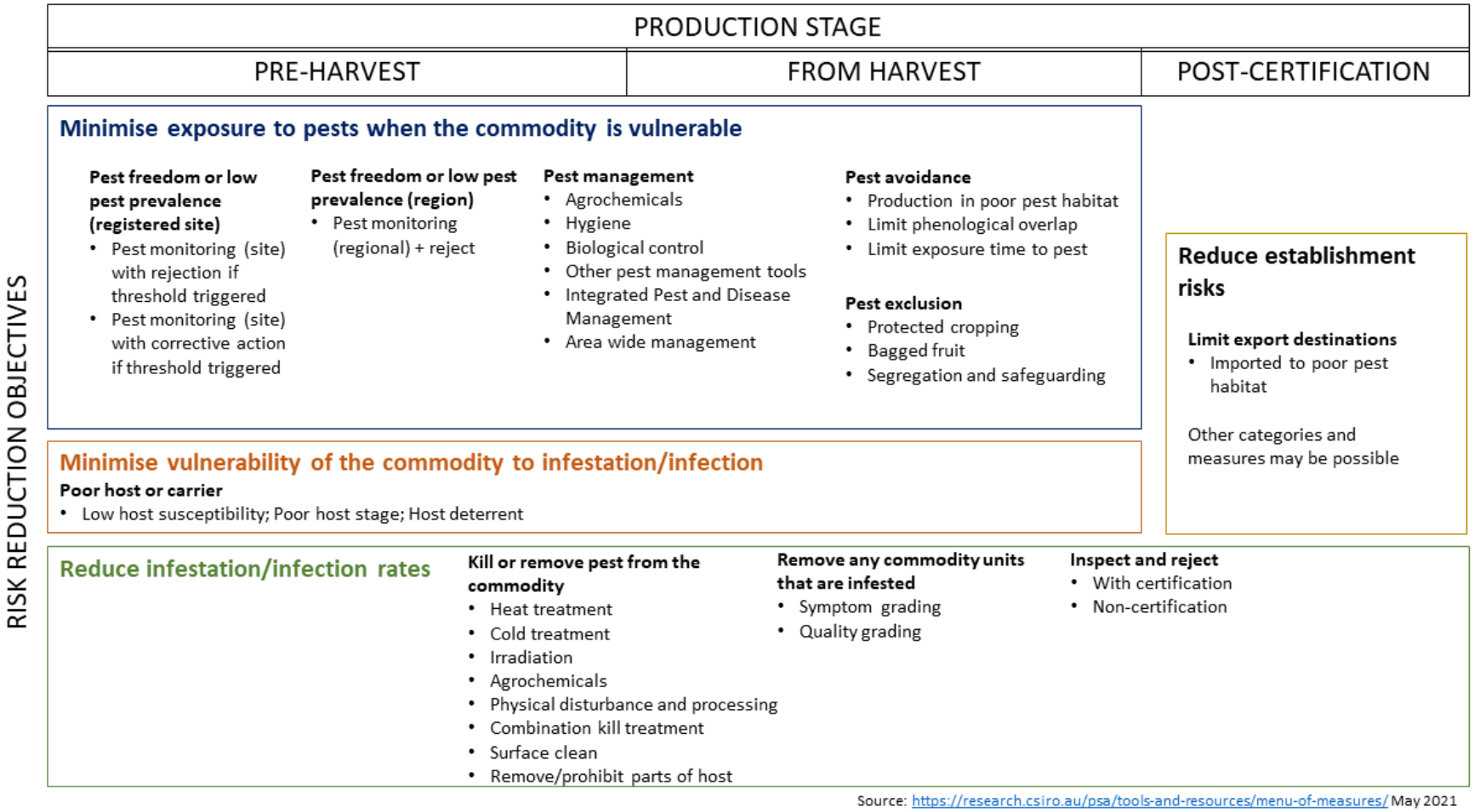
The international standard for phytosanitary systems approaches (ISPM 14) specifies that a system may integrate multiple measures and must include at least two measures that act independently of each other – that is, if one fails it does not affect the other one. Dependent measures may also be used that combine to reduce risk in the same way, such as pest management measures that combine to reduce pest pressure in the field. The WTO-SPS principles also require that the mix of measures is cost effective and least trade restrictive.

In the report we focus on measures that can be specifically included within a phytosanitary systems approach to reduce risk, organised around the structure of the risk reduction framework (Figure 2). Other more general or administrative activities that may also be defined as measures are not included. That includes site or packhouse registration, and traceability systems. In other cases, we consider phytosanitary measures listed in the WTO-SPS as elements within our measures. For example, certification procedures may be needed to help the NPPO monitor and control the application of a risk-reducing measure. These general considerations are discussed further in van Klinken et al. (2021).

For this report, we have adopted the term *commodity* to refer to traded items that may be hosts or carriers of pests of quarantine concern. In regulatory documents, these are typically referred to as 'regulated articles'. In this report, the term commodity may cover fruit, vegetables, other horticulture/nursery products or live plants, timber, grain, seeds, soil, machinery, or containers. Currently, most of the measures are described according to their application in a fruit production context, however, we aim to include a wider range of application examples in future versions of the report.

We use the term *registered site* to refer to a defined management area where a commodity is produced, which may include a farm or orchard, a block within an orchard, a specified area of protected production such as a glasshouse. This term can also cover secure sites - locations along the production/supply chain where a commodity may be stationary for a period of time and at risk of being re-exposed to a pest, for example, a pad on which a refrigerated container is stored and where measures are applied to reduce pest risk.

Figure 2: Overview of phytosanitary measures identified from published trade protocols and scientific literature



Source: https://research.csiro.au/psa/tools-and-resources/menu-of-measures/ May 2021

Your feedback

This document will continue to be revised through review and consultation. We encourage any feedback, which can be provided to Rieks van Klinken (rieks.vanklinken@csiro.au) or through the other co-authors.

Risk reduction objective 1: Minimise exposure to pests when commodity is vulnerable

Within this risk reduction objective, measures can be grouped under 5 categories: Pest freedom or low pest prevalence (at registered sites or within regions), pest management, pest avoidance or pest exclusion.

Pest freedom or low pest prevalence at registered sites: overview

Evidence through monitoring is used to demonstrate that pest density is below an acceptable threshold (often zero detections) within the registered site. Sometimes this can include a buffer zone. Monitoring can vary from one-off visual inspections to targeted trapping. Most often, monitoring is conducted only during the growing season when the commodity is susceptible to becoming infested, in which case it demonstrates "seasonal pest freedom or low pest prevalence". Threshold exceedance triggers a consequence, which may be a corrective action or rejection of the registered site. In these cases, trade will continue or resume only when the corrective action is confirmed, or pest prevalence is brought below the corrective action threshold. Monitoring without a threshold-induced action does not constitute a phytosanitary measure.

Required proof of efficacy: Evidence is required to demonstrate that infestation rates in commodities will be acceptably low provided the detection threshold is not exceeded. This will be influenced by detection efficacy of the surveillance method, surveillance design (such as trapping density, inspection frequency), pest biology (such as mobility, host preferences, conditions required for oviposition) and the potential for pest sources to occur outside of the registered site (in the case of mobile pests). Because monitoring is restricted to the registered site, evidence may be required that monitoring will detect mobile pests that are both already present in the site and moving into the site from surrounding hot spots. A ‘zero tolerance’ threshold may not be sufficient to demonstrate "pest freedom" on the site.

How the measure is certified: Evidence that monitoring is being conducted as agreed, and consequences are being correctly applied where thresholds are exceeded.

How the measure is used: Site-based pest freedom and low pest prevalence (LPP) is the most used measure within a systems approach. Most often it is applied pre-harvest during the growing season, but it can also be applied post-harvest, for example to give confidence that post-harvest infestation of the commodity won't occur in packing facilities. Demonstration that pest pressure is low when commodities are vulnerable will always reduce risk. It may also be used as a primary measure in cases where there is sufficient confidence in the relationship between pest detection thresholds and commodity infestation rate. This is most often the case for lower risk pests, poorer hosts, and where pests are readily detectable.

Relationship with other measures: It is frequently used in combination with other measures that minimise exposure to pests, such as pest management and pest avoidance measures, and pack-house security measures. This can result in redundancy. An alternative approach is to maintain pest freedom or low

pest prevalence as the measure, and to give discretion to producers as to when they may apply actions a such as pest management to limit the risk of threshold exceedance. However, in some cases some redundancy may be desirable. For example, combining site-based pest freedom with limited phenological overlap will provide added security where pest surveillance is not sufficiently sensitive.

Measures summary (Pest freedom or low pest prevalence at registered sites)

Measures	**Production stage**		
	Pre-harvest	From harvest	Post-certification
Pest monitoring (site) + rejection	Yes	Yes	No
Pest monitoring (site) + corrective action	Yes	Yes	No

Measures in detail: Pest freedom or low pest prevalence at registered sites

Risk reduction objective 1: Minimise exposure to pests when commodity is vulnerable - Pest freedom or low pest prevalence at registered sites

Measure	Production Stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Pest monitoring (site) + rejection If pest detection on the registered site exceeds a threshold (often zero) then the site can no longer trade under the protocol until agreed rectifications have been made.	Pre-harvest From harvest	Evidence is required to support the rejection threshold in relation to the required monitoring methodology.	Monitoring records, and evidence that a system is in place to ensure trade stops under the protocol if the pest threshold is exceeded.	Often used where there is zero tolerance of pest detections within the registered site, or where pests are not sufficiently responsive to corrective actions.	See above. It may be possible to access the market through an endpoint treatment protocol in the event the rejection threshold is exceeded.
Pest monitoring (site) + corrective action If pest detection on the registered site exceeds a threshold (often zero), then a corrective action is	Pre-harvest From harvest	Evidence is required to support both the corrective action and rejection thresholds. In addition, data is required on the efficacy of the corrective action.	Monitoring and corrective action records, and evidence that corrective actions are applied correctly if the	See above. Can only be applied where the detection threshold for rejection is above zero.	See above. Pest management or reducing infestation rates through chemical treatment are used as a corrective action so becomes part of

Measure	Production Stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
required. The corrective action must not interfere with the detection efficacy of the monitoring Ongoing monitoring is often required to demonstrate that the corrective action was effective. The corrective action usually must reduce pest levels below the corrective action threshold within a certain time period. Alternatively, for example, systemic pesticides may be used to address a fruit infestation risk that has resulted from the corrective action threshold being exceeded. Typically, a rejection threshold is also set, where pest detections are too high, or continue for too long.			pest threshold is exceeded.		this measure. In some cases, additional pest management measures may also be triggered to maintain pest pressure below the threshold for rejection

Risk reduction objective 1: Minimise exposure to pests when commodity is vulnerable

Pest freedom or low pest prevalence within a region: overview

Monitoring is used to give confidence that the pest is not established (or, less commonly, is not present above an accepted threshold) within the production area to which the protocol applies. Providing confidence in pest freedom is the responsibility of the National Plant Protection Officer (NPPO) and is most often established through a network of traps or through an active visual surveillance program. Exceedance of the threshold results in the requirement of alternative measures, or rejection from trade until confidence in pest freedom can be re-established. The key difference between the region compared to the site-based measure is that registered sites can be rejected even if no pests are recorded on them. This measure can be applied to a small production region through to national scale. Monitoring can be seasonal (demonstrating seasonal pest freedom) or year-round.

Required proof of efficacy: Evidence that the surveillance regime is sufficient to support pest freedom or low pest prevalence claims across the designated area (see also Pest Freedom or low pest prevalence at registered site).

How the measure is certified: Evidence is provided to support ongoing pest freedom claims. For high risk pests such as some fruit flies that may entail auditable surveillance programmes utilising agreed methodologies. Sites will only be registered under this protocol if they can demonstrate they occur within the PFA area.

How the measure is used: Pest Free Area (PFA) status is commonly used as a stand-alone protocol for managing pre-harvest risks. However, it can be combined into a systems approach with additional measures where confidence in the pest freedom status is insufficient, or where pest detection thresholds are not zero. PFA can also be used as a post-harvest measure, where produce is processed in areas designated as PFA.

Relationship with other measures: Other measures may also be provided as alternatives within a pest free area protocol in the event that pest freedom status is lost.

Measures – summary (Pest freedom or low pest prevalence within a region)

Measures	**Production stage**		
	Pre-harvest	From harvest	Post-certification
Pest monitoring (regional) + rejection	Yes	Yes	No

Measures in detail: Pest freedom or low pest prevalence within a region

Risk reduction objective 1: Minimise exposure to pests when commodity is vulnerable - Pest freedom or low pest prevalence within a region

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Pest monitoring (regional) + rejection If pest detection within the designated region exceeds a threshold (often zero) then no registered sites within that region can trade under the protocol until confidence in pest freedom (or low pest prevalence) is re-established. Alternatively, registered sites may be able to trade if they utilise other methods specified in the same protocol.	Pre-harvest From harvest	Evidence that the surveillance regime is sufficient to support pest freedom or low pest prevalence claims across the designated area (see also Pest Freedom or low pest prevalence at registered site).	Evidence is provided to support ongoing pest freedom claims. For high risk pests such as some fruit flies that may entail auditable surveillance programmes utilising agreed methodologies. Sites will only be registered under this protocol if they can demonstrate they occur within the PFA area.	Pest Free Area (PFA) status is commonly used as a stand-alone protocol for managing pre-harvest risks. However, it can be combined into a systems approach with additional measures where confidence in the pest freedom status is insufficient, or where pest detection thresholds are not zero. PFA can also be used as a post-harvest measure, where produce is processed in areas designated as PFA. In a 'multi pest' systems approach protocol, a PFA can be relied upon to meet all the requirements for one pest, and part of the requirements for another pest attracted to the same lure.	Other measures may also be provided as alternatives within a pest free area protocol in the event that pest freedom status is lost. Segregation and safeguarding measures may be required if the commodity exits the region designated to have pest freedom or low pest prevalence.

Risk reduction objective 1: Minimise exposure to pests when the commodity is vulnerable

Pest management: overview

A wide range of pest management options can be used singly or in combination to minimise exposure risks to pest populations when susceptible hosts or carriers are present. Requirements for pest management measures can range from being very prescriptive (e.g. timing and nature of sprays) to general (e.g. "implementation of IPM" or "presence of biological control agents").

Required proof of efficacy: Evidence is required to give confidence that if the required measures are correctly applied then the pest will remain at acceptable low pest levels when susceptible hosts or carriers are available, across the range of field conditions and pest pressures under which production might occur. This is especially important where pest monitoring is not part of the pest management measure (e.g. calendar-based spraying) or is not included as an additional measure.

How the measure is certified: Evidence needs to be provided that management actions have been undertaken in the agreed way. This is most often done through maintaining an auditable record of treatments, and through on-property audits.

How the measure is used: A common pre-harvest measure which could also be applied to manage post-harvest pest pressure (e.g. to prevent pest establishment in packing facilities). Multiple pest management measures can be required within one protocol where they have different but complementary modes of action. Pest management would not be a measure where it is an optional production practice, or where evidence of compliance does not need to be provided to the NPPO.

Relationship with other measures: Often pest management measures are combined with a "pest monitoring and corrective action or reject" measure. This can lead to redundancy. For example, pest management may not be required on registered sites where pests aren't detected through monitoring or where they can be adequately managed through a corrective action. In such cases pest management can be provided as options to reduce the risk of pests triggering a corrective action or rejection threshold, provided it doesn't affect the surveillance program. Once optional it no longer becomes a phytosanitary measure. Protocols commonly combine multiple pest management measures, such as spraying and field hygiene. These would be ‘dependent measures’ as they all combine to reduce pest pressure in the field. An important consideration in the design of a systems approach, and particularly relevant in the pest management category, is to avoid the inclusion of measures that are incompatible. For example, the requirement for application of systemic pesticides as a corrective action may negatively impact biological control or integrated pest management measures.

Measures – summary (Pest management)

Measures	Production stage		
	Pre-harvest	From harvest	Post-certification
Agrochemicals	Yes	Yes	No
Hygiene	Yes	Yes	No
Biological control	Yes	Yes	No
Other pest management tools	Yes	Yes	No
Integrated pest and disease management	Yes	Yes	No
Area wide management	Yes	Yes	No

Measures in detail: Pest management

Risk reduction objective 1: Minimise exposure to pests when the commodity is vulnerable – Pest management

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Agrochemicals Agrochemicals are used to manage pest pressure in the registered site through killing one or more life stages. A wide range of applications may be used depending on the pest, including insecticides, fungicides, oils, soil drenches and fumigants. They might be applied on a calendar basis (i.e. at set times or intervals, irrespective of	Pre-harvest From harvest	Data is required to demonstrate efficacy of the application regime under the range of field conditions and pest pressures under which production might occur. For risk-based applications the reliability of action thresholds also needs to be demonstrated.	Spray records retained for audit. In the case of risk-based applications, records will also need to demonstrate that triggers for action are being monitored and followed.	A common in-field pest management requirement. Calendar spraying is used most often, whereas risk-based spraying is most consistent with Integrated Pest and Disease Management Principles. MRL (Maximum Residue Limit) requirements may limit the use of chemicals and how and when they are applied.	Typically combined with other measures, including other pest management or monitoring measures. Sprays can also directly reduce infestation rates by killing the pest in or on the commodity, thereby simultaneously addressing two risk reduction objectives. For example, systemic pesticides can kill internal insect feeders and

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
pest pressure) or risk-based (as determined through e.g. pest monitoring, modelling or an environmental trigger).					fungicides can kill pathogens on the commodity's surface, whilst also managing pest populations in the registered site.
Hygiene Practices that minimise opportunities for pest populations to propagate in the registered site (field hygiene), although it could also be applied from harvest. Depending on the pest hygiene practices could include destruction of unharvested or rejected fruit, removal of potential pest reservoirs through pruning, and removal or management of alternative hosts.	Pre-harvest From harvest	Data is required to demonstrate the link between hygiene practices and pest populations during times when fruit are susceptible. For example, to demonstrate that post-harvest destruction of waste fruit will help reduce pest pressure in the following growing season. It often requires a detailed understanding of pest biology.	Practices need to be auditable, which may involve keeping a record of hygiene practices, and auditing the outcome of hygiene practices through orchard or packhouse inspection.	"Field hygiene" is the most commonly required pre-harvest pest management measure, often requiring the post-harvest destruction of unharvested fruit. Removing alternative hosts on the registered site (which we include under hygiene) is also a common requirement. Hygiene practices may also be included in pest management guidelines or be considered as part of standard commercial practices that set unrestricted risk levels. The latter is common for post-harvest facilities, for example in relation to the destruction of reject fruit that may provide a source for pest populations.	Typically combined with other pest management measures. In specifying the level of hygiene required, consideration should be given to avoid excluding opportunities for integrated pest/ disease management or biological controls. For example, retention of refugia for beneficial insects may be necessary to support such measures.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Biological control Use of biological control organisms such as parasitoids and predators to manage pest populations. Depending on the organisms, they may already be present in the registered site and require no additional intervention. Alternatively, timed, inundative releases may be required. This might also include the release of sterile insects (SIT).	Pre-harvest From harvest	Data to demonstrate efficacy under the range of field conditions and pest pressures under which production might occur.	Not always stipulated but could involve providing evidence that the organisms are present, or records of releases in the case of inundative control or SIT.	Only applicable where pest thresholds are not zero. Biological control is rarely identified as a specific measure, but where effective biological control agents are established across the production system it may contribute to setting unrestricted risk levels.	Most often biological control is incorporated into an IPDM package (as a contributory measure) rather than being specified as a stand-alone measure. If biological controls are included as measures in the system, careful design will be required to ensure that a complementary mix of measures are included.
Other pest management tools A wide range of other pest management tools are available. For pest insects these include mass-trapping, repellents applied as a perimeter treatment, Male Annihilation Technique (e.g. MAT blocks) and, inter-cropping.	Pre-harvest From harvest	Data to demonstrate efficacy under the range of field conditions and pest pressures under which production might occur.	Certification requirements will depend on the pest management tool.	Not commonly encountered as stand-alone measures.	Typically incorporated into IPDM rather than being used as stand-alone measures.
Integrated pest and disease management Involves application of multiple pest management options, typically guided by a	Pre-harvest From harvest	Data to demonstrate efficacy under the range of field conditions and pest pressures under which production might occur. That could include demonstrating that pest	Compliance can be assessed through an audit of monitoring and control records and of pest management processes against an	Production systems commonly use IPDM practices, which can contribute to the setting of "unrestricted risk" but its inclusion as a	IPDM is often combined with additional pre-harvest measures aimed at minimised exposure to pests, typically pest monitoring with

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
combination of ongoing pest monitoring, modelling and crop phenology. Typically, the aim is to achieve pest management goals whilst minimising pesticide use within the production system. Industry-specific best management guides typically provide management options under different conditions (such as under high or low pest pressures). This can be considerable leeway for the producer in terms of what management options are applied when and where.		pressures in commercial production systems utilising IPDM are much lower than elsewhere.	Integrated Pest Management document that has been approved by the importing jurisdiction. However, it may be difficult to ascertain what "properly" is, and whether the grower did it "properly".	phytosanitary measure is less common.	corrective action or rejection.
Area wide management Requires coordinated management beyond the registered site. It is particularly relevant for mobile pests. It may require a single management tool such as SIT (Sterile Insect Technology) or utilise IPDM. Pest monitoring is often a component of AWM.	Pre-harvest From harvest	Data to demonstrate efficacy of AWM under the range of field conditions and pest pressures under which production might occur. That could include demonstrating that pest pressures in commercial production systems where AWM is practiced is much lower than elsewhere.	Typically managed by an overarching "authority" as AWM generally spans multiple jurisdictions/land uses.	Rarely used as a measure in its own right. The requirement for coordinated action across multiple jurisdictions and businesses can make it impractical. More commonly AWM principles, especially SIT, may be embedded within a regional pest freedom measure.	Can support a regional LPP or Pest freedom measure. AWM is similar to other pest management measures (such as IPDM or biological control, especially SIT), but needs to be applied area-wide rather than just to the registered site. IPDM, AWM and industry best practice or quality

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
					assurance programs may be used to support a proposal for a protocol, but the contributions of these 'measures' towards ALOP may not be an auditable requirement of a registered site.

Risk reduction objective 1: Minimise exposure to pests when the commodity is vulnerable

Pest avoidance: overview

Pest avoidance is achieved by minimising the overlap of vulnerable host stages with pests in space and time. Avoidance can be partial or complete.

Required proof of efficacy: Evidence is required on the strength of avoidance, and how it may vary under the range of field conditions and pest pressures under which production may occur.

How the measure is certified: Depends on the measure.

How the measure is used: Pest avoidance measures can be used pre-harvest, and from-harvest to minimise the risk of post-harvest infestation through the supply chain.

Relationship with other measures: Pest avoidance measures can be combined with pest management measures (it is easier to manage a pest to a low density threshold when conditions are already poor for the pest) and pest monitoring measures (to establish an a priori expectation that pest pressures will be low).

Measures – summary (Pest avoidance)

Measures	**Production stage**		
	Pre-harvest	From harvest	Post-certification
Production in poor pest habitat	Yes	Yes	No
Limit phenological overlap	Yes	Yes	No
Limit exposure time to pest	Yes	Yes	Yes

Measures in detail: Pest avoidance

Risk reduction objective 1: Minimise exposure to pests when the commodity is vulnerable – Pest avoidance

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Production in poor pest habitat Exposure to pests is limited/prevented by restricting the use of the protocol to places where pest pressure is constrained by poor "habitat". Factors include climate (e.g. less generations per year, or high winter or summer mortalities), the physical habitat (e.g. strawberries grown at ground level are thought to be less susceptible to some fruit flies), a lack of alternative obligatory hosts in the	Pre-harvest From harvest	Surveillance data can be used to show that the pest will be sufficiently uncommon in the region which that the protocol applies, or the commercial properties within that region. Knowledge of the biology, often formalised through modelling (e.g. phenological modelling to show generations per year), can also be used. Combining the two can provide confidence that the habitat will be poor (and pest pressures low) despite inter-year environmental variation.	Protocol only allows registered sites within the agreed region to be registered.	This measure is explicitly used in relatively few systems approach protocols. However, habitat suitability can contribute to estimation of unrestricted risk that sets entry conditions. For example, where the entire production system of the commodity occurs within poor pest habitat.	Poor habitat is often combined with limited phenological overlap. There may be less requirement for other measures such as pest monitoring with corrective action or pest management in areas where habitat is poor for the pest.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
area or by natural enemies.					
Limit phenological overlap Exposure to pests is limited temporally by ensuring that the period when the host is susceptible has limited or no overlap with when physiological and environmental conditions allow the pest to be active or infective. Often this is determined by limiting production and harvest times to specific date ranges. Harvest times can also be calibrated to environmental cues where phenological overlap is expected to vary between years and locations.	Pre-harvest From harvest	Evidence of efficacy is similar to that for poor pest habitat. The phenology of both the host and pest, and any overlap between the two, can vary considerably between years and across production regions. This needs to be considered in any analyses.	Protocol only allows sites within the agreed region to be registered, and the commodity to be harvested during agreed times.	As a measure it is most commonly used to set production and harvest times.	Limited phenological overlap if often combined with poor habitat. There may be less requirement for other measures such as pest monitoring with corrective action or pest management in areas where limited phenological overlap can be demonstrated.
Limit exposure time to pest Exposure time is limited either pre-harvest (e.g. limiting the time harvestable commodity is allowed to remain on the tree) or from harvest (e.g. limiting the time	Pre-harvest From harvest Post-certification	Risk will be a function of exposure time, pest pressure and host susceptibility. Evidence may be required to demonstrate that risk is actually elevated (e.g. when fruit are picked vs on the tree), and that the measures will sufficiently address that.	Relevant production and post-production processes need to be auditable.	This measure could be applied to minimise pre-harvest exposure to pests by ensuring that fruit are picked as soon as they are harvestable, rather than leaving them on the tree for a prolonged time (as can happen for some	Often combined with other measures (such as secure transport from farm to packhouse) to prevent risk of post-harvest infestation.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
from picking to secure transport, or the time at key transitions in the supply chain where there is a risk of post-harvest infestation).				citrus for example). However, it is most commonly used at harvest, and at different points in the post-harvest supply chain where the commodity may be exposed to the pest. Standard production processes often mean that commodities are moved quickly after picking to secure locations (such as cold rooms), for quality and cost reasons. A maximum exposure time (e.g. 24 hours from harvest to secure location) is generally only specified as a phytosanitary measure when this is deemed insufficient.	

Risk reduction objective 1: Minimise exposure to pests when the commodity is vulnerable

Pest exclusion: overview

Partial or complete exclusion of the pest can be established on-farm and throughout the supply chain (to prevent post-harvest infestation). It can be achieved at the block scale (protected cropping), consignment level (secure storage) down to individual fruit level (e.g. bagging). Pest exclusion measures combine physical "infrastructure" (such as insect proof buildings and containers) with management practices (e.g. to maintain the integrity of processing facilities).

Required proof of efficacy: Often established based on the biology of the pest, for example to establish the maximum pore size of an exclosure. It can also be supported empirically through field surveys (comparing pest pressures inside and outside exclosures) or experimentally. This can be important to give confidence in both the physical exclosures and the way they are maintained.

How the measure is certified: Most commonly certified through audit of structures and processes.

How the measure is used: Most protocols will have post-harvest pest exclusion measures. Pre-harvest measures most commonly relate to protected cropping. Secure growing facilities are widely used as a measure for commodities that are grown commercially in that way. Partial exclusion, such as by netting and tunnels, might also contribute to risk reduction but we found no examples of those being stipulated as phytosanitary measures, although it may influence the assessment of unrestricted risk where the entire production system is grown in that way.

Relationship with other measures: Depends on the measure

Measures – summary (Pest exclusion)

Measures	**Production stage**		
	Pre-harvest	From harvest	Post-certification
Protected cropping	Yes	No	No
Bagged fruit	Yes	No	No
Segregation and safeguarding	No	Yes	Yes

Measures in detail: Pest exclusion

Risk reduction objective 1: Minimise exposure to pests when the commodity is vulnerable – Pest exclusion

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Protected cropping Produce is grown within exclosures that prevent or reduce access by pests. Measures typically include specific	Pre-harvest	Efficacy is readily established through surveillance to compare pest pressures inside and outside the exclosure, provided external pest pressures are high and susceptible hosts are	Audit of physical structures and processes	Secure growing facilities are widely used as a measure for commodities that are grown commercially in that way. Partial exclusion, such as	Often combined with a "monitoring with consequence" or "inspect and reject" measure to provide confidence in the exclosure. For vectored

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
requirements for the physical exclosures (such as pore sizes, negative pressure, entry/exit design) as well as management practices to ensure that the integrity of the exclosures remain intact (such as biosecurity practices).		present within the exclosures. Other methods may be needed where external pest pressures are already low, for example through experimentation or using data from other commodities grown in the same way but in higher pest pressure situations.		by netting and tunnels, might also contribute to risk reduction.	diseases the action threshold may be higher for the vector than the disease.
Bagged fruit Fruit are bagged with pest-proof material (sometimes impregnated with pesticide) to exclude pests, typically from before they start becoming susceptible through to harvest.	Pre-harvest	Efficacy can be readily established by exposing bagged, susceptible fruit under commercial conditions to high pest pressure. Efficacy does need to be confirmed under commercial conditions and take into account likely environmental conditions that might affect the integrity of the bagging (such as high rainfall or wind).	Audit of in-field bagging and of management processes.	Rarely used, as probably not economic in many cases. Most relevant for larger or very high-value fruits.	Tends to be combined with other measures that provide confidence that pest exposure is low, presumably under the assumption that bagging doesn't completely exclude pests.
Segregation and safeguarding Physical barriers and processes to prevent access of pests to susceptible commodities from the point of harvest, and to prevent mixing of "protocol" commodity with other produce (that might result in cross-contamination). This	From harvest Post-certification	HACCP can be used to identify points of risk through the supply chain. Measures are often established biologically (e.g. to establish required pore sizes or commodity segregation requirements under storage conditions). In some cases, experimental studies may be needed to establish the level of risk, and the efficacy of specific measures under commercial	Audit of physical structures and processes.	Applies post-harvest and through to market. Segregation and safeguarding practices are likely to be included in all production systems, either as a formal measure or as "production practices" that sets unrestricted risk estimates.	This measure is functionally similar to protected cropping and bagged fruit, but is the terminology most commonly applied to produce from the point of harvest.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
includes secure packhouses, secure transport and packaging of harvested produce, and the spatial or temporal segregation of protocol consignments from other produce.		conditions. Confirmation of efficacy can be obtained through surveillance, provided the produce is exposed to high pest pressure and is susceptible.			

Risk reduction objective 2: Minimise vulnerability of the commodity to infestation/infestation

The measures under this risk reduction objective all fall under one category: poor host or carrier.

Poor host or carrier: overview

Take actions that ensure that the traded commodity is a relatively poor host or carrier for the pest, irrespective of pest pressure.

Required proof of efficacy: The ability of a commodity to host or carry a pest can be challenging to quantify as it can be influenced by a wide range of variables. Standards or principles have been developed for some pests that take into account pest pressure, pest status and host choice.

How the measure is certified: Requires assurance that only the permitted poor host commodity or stage are being consigned.

How the measure is used: A commonly used measure. It is generally applied to commodities prior to harvest but will also affect the risk of postharvest infestation. Poor host status is also used to estimate unrestricted risk.

Relationship with other measures: Can be used as a stand-alone measure (non-host status). Within a systems approach, poor host or carrier status can greatly reduce overall risk at a given pest pressure and should, therefore, reduce the requirements for other measures. For example, rejection thresholds for pest monitoring with rejection could be expected to be higher for poorer hosts or carriers.

Measures – summary (Poor host or carrier)

Measures	**Production stage**		
	Pre-harvest	From harvest	Post-certification
Low host susceptibility	Yes	Yes	No
Poor host stage	Yes	Yes	No
Host deterrent	Yes	Yes	No

Measures in detail: Poor host or carrier

Risk reduction objective 2: Minimise vulnerability of the commodity to infestation/infestation – poor host or carrier

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Low host susceptibility Only less susceptible cultivars or varieties are permitted to be traded	Pre-harvest From harvest	Determining host susceptibility needs to consider the effect of pest pressure and include the most susceptible stages of the commodity that are likely to be harvested or graded. Conservative no-choice experiments can generally be conducted in the laboratory but results ultimately require testing under field conditions. Methods will depend on the organism. For example, insects can express learning and conditioning behaviours and physiologies. Prior experience and the availability of alternative, more suitable hosts can therefore affect the result. Similarly, some pests will	Requires assurance that only the permitted low-susceptible commodities, varieties or cultivars are being consigned.	Can be used where cultivars or varieties differ significantly in susceptibility. This may include GMOs. However, it may not be practical where a wide diversity of cultivars is grown and traded. At the commodity level it is most often used to help estimate unrestricted risk.	Limiting trade to low susceptible varieties can interact with poor host stage at harvest. Low host susceptibility on its own would require testing the most susceptible host stage.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
		express natural oviposition behaviours in the laboratory whereas other will not. Depending on market access requirements, studies will need to take into account both likelihood of infestation/ infection (and associated symptoms) and subsequent survival and development.			
Poor host stage Commodity needs to be harvested prior to development into a more susceptible stage. At its most extreme this is a conditional non-host.	Pre-harvest From harvest	As for poor host, but with a greater focus on host developmental stage. Data needs to demonstrate that a clearly identifiable (and gradable) stage of the commodity is sufficiently less susceptible than subsequent stages when exposed under the same conditions.	Audits of processes (including grading, training) and of graded commodity.	Most commonly applied to "hard green stage" for commodities such as avocadoes that continue to mature after harvest. Harvest stage may also be factored into estimation of unrestricted risk for commodities where all are harvested by a certain stage for commercial reasons (such as to optimise storage and shelf life).	Poor host stage is functionally similar to quality grading of commodities (see reducing infestation rates). Both require grading, but poor host stage involves excluding developmental stages of commodities on the basis of host susceptibility, whereas quality grading is focussed on using quality standards (such as softness and skin damage) to remove commodities that are mostly likely to be infested.
Host deterrent The addition of substances to the commodity that makes the host less susceptible	Pre-harvest From harvest	As for poor host stage but taking into account the effects of the substance including when it is applied under production conditions.	Audit of the processes. The commodity could also be audited if the applied substance remains detectable.	We found no examples of such measures being used in practice, but they have been suggested by others. Some post-	-

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
or confuses host recognition. This might include physical or chemical oviposition deterrants. Compounds such as koalin clays, coloured posts and coloured mesh have been suggested for fruit flies.			Depending on the substance applied.	production practices such as waxing might affect post-harvest infestation risks.	

Risk reduction objective 3: Reduce infestation/infection rates

The measures under this objective can be organised into three categories: kill/remove pest from the commodity; remove any units of the commodity (such as items of fruit) that are infested; and inspect and reject

Kill/remove pest from commodity: overview

Infestation rates are reduced by either killing the pest or removing it from the commodity. A wide range of methods are possible. These measures are applied to batches or consignments of commodity from the point of harvest, with the exception of agrochemicals that can also be applied pre-harvest.

Required proof of efficacy: Data is required to demonstrate that the risk of residual infestation rates is acceptably low. This needs to consider the range of possible infestation rates prior to treatment, and mortality rates for relevant life stages. Methodologies are well established for some treatments such as cold treatment.

How the measure is certified: Audit of treatment records and processes. In some cases, testing can be conducted to ensure treatments have been applied (e.g. of chemicals) or the commodity can be inspected to ensure treatment was efficacious.

How the measure is used: A diverse and commonly used category of measures. Many of the measures can be used either as a "single point" treatment or as part of a systems approach.

Relationship with other measures: Often combined with other measures (e.g. to minimise pre-harvest exposure to pests) even when applied as a "single point treatment". This may be due to lack of data supporting the single-point treatment or concerns regarding treatment application. When combined with

other measures there is potential for them to be used with a lower mortality threshold. For example, partial mortality or pest removal treatments can be combined with others measures that reduce initial infestation risks.

Measures – summary (kill/remove pest from the commodity)

Measures	**Production stage**		
	Pre-harvest	From harvest	Post-certification
Heat treatment	No	Yes	No
Cold treatment	No	Yes	Yes
Irradiation	No	Yes	No
Agrochemicals	Yes	Yes	No
Physical disturbance and processing	Yes	Yes	Yes
Combination kill treatment	No	Yes	No
Surface clean	Yes	Yes	No
Remove/prohibit parts of the host	No	Yes	No

Measures in detail: kill/remove pest from the commodity

Risk reduction objective 3: Reduce infestation/infection rates - kill/remove pest from the commodity

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Heat treatment Heat is used to kill invertebrates - normally in a short, intense bursts - to minimise negative host quality effects. Sometimes microclimate is modified to maximise mortalities (e.g. vapour heat treatment).	From harvest	There are well established experimental approaches to quantify mortality effects of heat. Results should be confirmed under commercial settings and take into account the time taken for the heat treatments to reach the target life stages. Life stage and time-dependent mortality rates may need to be determined to help	Audit of treatment records and processes. In some cases, testing can be conducted to ensure the treatment has been correctly applied or inspection made of commodity to ensure treatment was efficacious. Certified	Can be used as a single-point treatment. Application is restricted to where heat can cause sufficient pest mortality without undue loss of produce quality. This is likely to be most amenable to surface pests.	check?

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
		incorporate heat treatment into a systems approach.	temperature loggers are generally required.		
Cold treatment Cold is used to kill pests, normally through 'prolonged exposure but sudden changes in temperature may be possible for some pests. Temperatures need to be monitored through the treatment regime, with consequences if there is a break in treatment.	From harvest Post-certification	There are well established experimental approaches to quantify mortality effects of cold. Results should be confirmed under commercial settings, taking into account the time it takes for the treatment to reach target life stages. Life stage and time-dependent mortality rates may need to be determined to help incorporate cold treatment into a systems approach. Most studies determine stage and time-dependent mortality at a range of constant temperatures.	Audit of treatment records and processes. In some cases, testing can be conducted to ensure the treatment has been correctly applied or inspection made of commodity to ensure treatment was efficacious. Typically includes the use of temperature loggers.	Restricted to cold sensitive pests and to commodities where exposure to cold does not result in unacceptable loss in quality (typically temperate and sub-tropical fruit). It can be applied prior to shipment, in transit (e.g. "on water") or on arrival. It is most often used as a single-point treatment. However, many commodities are stored at low temperatures with the supply chain making it amenable to being incorporated into a systems approach. There are examples of it being used as a partial mortality treatment.	Where used as a partial mortality treatment it can be combined with other measures to give confidence that prior infestation rates are already very low.
Irradiation Pests are sterilised using irradiation. Dosage and other specifications are stipulated. Work is progressing internationally to establish standardised	From harvest	There are well established experimental approaches to quantify mortality effects of irradiation. Results should be confirmed under commercial settings. Dosages can depend on properties of the commodity and the pest type.	Audit of treatment records and processes. Techniques are being developed to show commodities have been exposed to irradiation.	Used as a single point treatment	Additional measures to minimise infestation rates may be required as even the presence of sterilised pests may be sufficient grounds for consignment rejection.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
conditions that are applicable to a wide range of pests and commodities.					
Agrochemicals Pests can be killed in or on commodities through chemical application. A wide range of chemicals can be used, and can be applied in diverse ways including fumigation, spraying and dipping. Agrochemicals can be applied to commodities prior to harvest (spraying), during the grading process, or following packaging (typically fumigation). Some fumigants such as methyl bromide only work at higher temperatures, so measures often stipulate that core temperatures of the commodity need to be above a threshold before application.	Pre-harvest From harvest	There are well established experimental approaches to quantify mortality effects of agrochemicals on infestation rates in various commodities. Results should be confirmed under commercial settings. Dosages can depend on properties of the commodity (such as size, moisture, skin damage), application method, environmental conditions (e.g. methyl bromide fumigants don't penetrate fruit well at cool temperatures) and the type and stage of pest.	Audit of treatment records and processes.	Pre-harvest application can be used as part of a systems approach whereas post-harvest application is most often used as a single-point treatment. Food safety (MRL) concerns can restrict the use of agrochemicals as a measure, especially for systemic pesticides that are targeting internal feeders. In this case pesticides may be more commonly used for thick-skinned fruit where the skin is not consumed. Chemical application may also have negative quality effects, e.g. if the commodity needs to be heated prior to application.	See also spraying (pest management) which can have a dual effect of managing pest populations and reducing pre-harvest infestation rates in commodities. Often this distinction is not well articulated or quantified.
Physical disturbance and processing Pests in the commodity are killed or removed through the application	Pre-harvest From harvest Post-certification	Experimental work is generally needed to demonstrate stage-specific mortality or removal from physical disturbance or processing. Results need to be	Audit of treatment records and processes.	Food processing can take many forms such as physical disturbance (e.g. maceration, juicing) and the application of heating	This measure could also be classified as "surface clean" or "remove/prohibit parts of

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
of physical disturbance or processing. Treatments can be applied as part of the production system (such as food processing) or specifically applied as a measure.		confirmed under commercial settings, which can be challenging where the application of disturbance is standard across the industry.		or drying. Physical disturbance can also be applied to certain commodities such as soil or mulch in the case of Red Imported Fire Ants.	the plant", depending on the process.
Combination kill treatment Post-harvest kill treatments are combined simultaneously or sequentially to maximise their efficacy whilst minimising any negative impacts such as on fruit quality, cost or treatment duration.	From harvest	As above	Audit of treatment records and processes.	Further literature review required	
Surface clean Pests are removed from the surface, and/or the surface is sterilised, using one or more physical or chemical methods. A wide range of method are possible include brushing, washing with water or detergent, and the use of surface sterilisers.	Pre-harvest From harvest	Can be quantified experimentally using infested commodities and confirmed under a commercial setting. Studies need to take into account the biology of the pest and the diversity of post-harvest production methods.	Audit of treatment records and processes.	Surface cleaning is only possible for certain surface pests and for where treatments don't affect the quality of the commodity, can be audited, and are sufficiently standardised across processing facilities. Surface cleaning practices can be a standard part of a production system in which case it helps set unrestricted risk. It is applied post-harvest	We include surface sterilisation here as that is often conducted at the same time as washing, even though sterilisation could also be classified as heat, cold or agrochemical treatment. Surface cleaning is often done in combination with removal of prohibited plant parts.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
				although in some cases it may be possible to be applied prior to harvest.	
Remove/prohibit parts of the host Removal or prohibition of parts of the host that are most likely to carry the pest.	From harvest	Can be quantified experimentally using infested commodities and confirmed under a commercial setting. Needs to take into account the biology of the pest.	Audit of treatment records and processes.	Used in specific cases where the pest is largely restricted to parts of the commodity that can be readily removed. That may include debarking of timber (for beetle borers) or removal of plants stems and leaves (for some fruits).	Can be combined with surface cleaning or symptom grading measures when the pest is not entirely restricted to the removed part.

Risk reduction objective 3: Reduce infestation/infection rates

Remove any commodity units that are infested/infected: overview

Grading to preferentially remove the subset of the commodity that is at greatest risk of being infested, as assessed either by evidence of being infested or because it is in a particularly susceptible condition. In the case of fruit, grading can occur prior to harvest (e.g. through removal of symptomatic fruit), at harvest and at post-harvest grading steps. Post-harvest grading can be done visually, mechanically (e.g. softness) or using optical technologies.

Required proof of efficacy: Data is required to show that grading will reduce potential infestation rates in the final consignment by an acceptable amount. Quantitative modelling can assist in assessing the potential benefits of grading. When stipulating specifications for grading care needs to be given to ensure that they can be readily applied by both workers and auditors, and that "false positives" that could result in waste are minimised.

How the measure is certified: Audits of processes and of the post-graded commodity against grading requirements.

How the measure is used: Limited to pests where infested units of the commodity are readily detected or predicted. Protocols often specify that commodities need to be "graded", and sometimes specify that it is both for quality and damage/symptoms. However, it is less common for specifications or compliance requirements to be specified. This may in part be due to a lack of supporting data. International exports generally focus on the sale of high-

quality commodities, and there are industry-set quality standards for some commodities and markets. These standards would influence unrestricted risk when not used as a phytosanitary measure, provided benefits can be quantified.

Relationship with other measures: Grading has similarities to inspect and reject measures but differs in rigour and consequence. Quality grading reduces risk by removing infested or highest risk commodity units, thereby reducing infestation rates within the consignment. In contrast, inspect and reject requires confirmation of pest infestation in suspect commodity unit (such as an item of fruit), and once confirmed results in the rejection of the consignment (and sometimes has consequences beyond that).

Measures – summary (Remove any commodity units that are infested/infected)

Measures	**Production stage**		
	Pre-harvest	From harvest	Post-certification
Symptom grading	Yes	Yes	No
Quality grading	Yes	Yes	No

Measures in detail: remove any commodity units that are infested/infected

Risk reduction objective 3: Reduce infestation/infection rates – Remove any commodity units that are infested/infected

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Symptom grading Removing commodity units that show evidence of being infested, either directly (through detecting the pest or its characteristic damage) or indirectly through the presence of more generic symptoms such as bruising that can be associated with that pest.	Pre-harvest From harvest	Need to show that symptom grading is sufficiently sensitive when it comes to detecting and removing infested commodity units. This can initially be determined experimentally, then confirmed under commercial conditions. Detection efficacy will depend on the pest, the pest stage that needs to be detected, the commodity and the detection	Audits of processes and of the post-graded commodity against grading requirements.	Can be an important phytosanitary measure for pests where detection probabilities are high, such as insects that are external feeders on fruit. In very obvious cases it may not be specified as a phytosanitary measure. Optical scanning technologies offers the potential for automated	Symptom grading and quality grading is often done simultaneously.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
In some cases, it requires the commodity to be inspected in a specific way to maximise the likelihood of pest detection.		method (e.g. visual, destructive or optical sensors).		detection of pests or pest symptoms on the commodity.	
Quality grading Quality grading remove grades of commodity that are most likely to be infested. This includes both grades of the commodity (e.g. removal of soft or over-ripe fruit) and removal of items with damage that might have made them more susceptible to becoming infested.	Pre-harvest From harvest	Data is required to show that infestation risk differs with quality or condition of the commodity. This can be determined experimentally and through field survey (in-field and post-harvest). Evidence is also required to show that grading processes are sufficiently accurate. See also poor host stage.	Audits of processes and of post-graded commodities against grading requirements.	Although quality grading is likely to be ubiquitous in production systems, and for some pests and commodities may significantly reduce infestation rates, it is not often specified as a phytosanitary measure. One reason may be the lack of data needed to quantify its benefits.	This measure is similar to minimising host vulnerability by limiting exports to poor host stages but focuses on removing poor quality fruit (over-ripe, soft or damaged) that are most susceptible to infestation. Symptom grading and quality grading is often done simultaneously.

Risk reduction objective 3: Reduce infestation/infection rates

Inspect and reject: overview

The likelihood of infested commodities reaching markets is reduced by removing or preventing sources or consignments that are found to be infested. The commodity is inspected, with a consequence for the consignment, registered site or production system if a pest threshold (typically zero) is exceeded. The measure may stipulate when the inspection has to be conducted (e.g. pre-harvest, pre-grading or post-treatment) and on what (e.g. export grade or reject fruit), how the inspection should be conducted, and the consequence if evidence of infestation/infection is found. Inspection methodologies can vary from general surveillance to targeted sampling and can be once-off or repeated through the season and production system. Threshold exceedance might result in rejection of the consignment, requirement of an additional treatment (such as fumigation), rejection of the consignment and any further consignments from the source in that year, through to cancellation of the protocol until agreed rectifications can be made.

Required proof of efficacy: The ability of inspection to detect infested commodities depends on detection efficacy and sampling regime. Detection efficacy is the key variable that needs to be quantified. Statistical principles for designing the sampling regime are well developed (e.g. ISPM31), at least as applied to consignment sampling. Where multiple inspections are conducted on a consignment then statistics can be used to demonstrate the combined benefit. The production stage and commodity stage on which inspection is being conducted will be important: inspection biased towards commodities that are most likely to be infested (e.g. soft, damaged, reject fruit) will be more sensitive than inspection of commodities following grading. In this case observed infestation rates in rejected fruit will need to be related to infestation probabilities in export fruit. Inspection post-treatment may specify that the pest must be alive to be of concern (indicating that the treatment was ineffective).

How the measure is certified: Records of inspection are kept, and processes, such as pest identification and rejection of consignments if pests are detected, audited.

How the measure is used: Most protocols have an inspect and reject step. In some cases they are applied at various points through the production process and supply chain. For example, it can be applied pre-harvest, in the packhouse, just prior to export and post-border. There is some discussion as to when such inspections constitute a measure as opposed to serving a general audit function for the overall protocol.

Relationship with other measures: This measure differs from grading because the whole consignment (or more) is rejected if the pest is found, rather than the infested item being removed.

Measures - summary

Measures	**Production stage**		
	Pre-harvest	From harvest	Post-certification
Inspect and reject, with certification	No	Yes	No
Inspect and reject, without certification	Yes	Yes	Yes

Risk reduction objective 3: Reduce infestation/infection rates – inspect and reject

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Inspect and reject, with certification The commodity is inspected at point of issuance of the phytosanitary certificate. For fruit this generally requires a standardised sampling and inspection of 600 post packed fruit (or items) from each consignment. Inspection methods vary but can include visual inspection, visual inspection with suspect fruit cut, brown sugar flotation (e.g. for fruit fly), or the cutting of all sampled fruit using an agreed methodology. Fruit inspection is typically of packed fruit, but inspection of "in-line", bulk stored or reject fruit is also possible.	From harvest	The statistics of consignment sampling of fresh produce is well described in ISPM31. The key variable to estimate is detection efficacy of the required inspection methodology. A 600-fruit inspection gives a 95% chance of detecting an infestation rate of 1 in 200 fruit, assuming 100% detection efficacy (ISPM31)	Records of inspection are kept, and processes, such as pest identification and rejection of consignments if pests are detected, audited.	'Inspect and reject' as part of phytosanitary certification is generally a requirement in most protocols, including those relying on single point treatments, PFAs or non-host status. However, it isn't always clear whether it is being included as a measure specifically designed to reduce infestation risk within a consignment below an acceptable level, or whether it serves more of an audit function. Frequently it is included as a non-specific measure to look for a wide range of quarantine pests, as well as to inspect for contaminants and as a compliance check for other measures (such as quality grading and secure packaging). As such it may be a valuable measure in its own right	The same as Inspect and reject (non-certification) but is only conducted when the phytosanitary certificate is issued.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
				for easily detected, lower risk pests. For higher risk or more cryptic pests its value as a measure is likely to be limited to detecting gross failures. Nonetheless, when applied over many consignments it can give confidence that the overall system is working.	
Inspect and reject, without certification The commodity is inspected at any point during production or supply (excepting for issuance of the phytosanitary certificate), with a consequence for the consignment, registered site or production system if a pest threshold (typically zero) is exceeded. Inspection methodologies can vary from general surveillance to targeted sampling and can be once-off or repeated through the season and production system.	Pre-harvest From harvest Post-certification	As for Inspect and reject (certification). Further analyses may be required to determine how risk is reduced through repeated sampling or stratified sampling (e.g. of reject fruit where the pest is expected to most likely be found).	Records of inspection are kept, and processes, such as pest identification and rejection of consignments if pests are detected, audited.	Less common than "inspect and reject at certification. Sometimes it can be quite general, e.g. if an infested fruit is found during grading or in field then the consignment or registered site is rejected (general surveillance). In this case demonstrating compliance could be challenging. 600 fruit inspections are commonly used, sometimes at multiple points from pre-harvest through to packaging. Pre-harvest surveillance for infested commodity may also be required, using pest-specific survey methods that may need	In practice, pre-harvest "inspect and reject" is similar to pre-harvest "pest monitoring and reject", and the consequence (e.g. rejection of the registered site) can be the same. However, "inspect and reject" targets infested commodities whereas "pest monitoring and reject" is based on evidence that the commodity has been exposed to the pest without necessarily demonstrating that the commodity has become infested.

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
				to be repeated through the growing season. Technologies such as optical scanning could potentially be used, but we found no examples in existing protocols.	

Risk reduction objective 4: Reduce establishment risks if pests were to enter

Few protocols include measures under this objective and the measures currently relate to limiting establishment risks. We are currently reviewing the literature and expect to include more measures under this objective soon. We would welcome input here. Additional measures may include:

- Limit export destinations to poor pest habitat
- Restrictions on points of entry, distribution (e.g. to "poor habitat" only) or end-use (e.g. not for planting)
- Restriction of trade volumes
- Restriction on the size of consignments, or individual units (cartons etc) that make up a consignment (Allee effects).
- Only permit cross-hemisphere trade (e.g. where overwintering diapause may prevent counter-seasonal establishment)

Limit export destinations: overview

Establishment risk is reduced by only allowing consignments to arrive at destinations where and when the pest is unlikely to establish if an infested/infected consignment arrived.

Measures in detail: limit export destinations

Risk reduction objective 4: Reduce establishment risks – limit export destinations

Measure	Production stage	Required proof of efficacy	How the measure is certified	How the measure is used	Relationship to other measures
Imported to poor pest habitat Consignments can only be sent to specified markets that are deemed as low establishment risk, or at specified times when the region is low risk. That might be based on poor climatic conditions or lack of hosts.	Post-certification	Establishment risks will depend on the biology of the organism, including its' developmental status after arrival and its ability to survive until the right conditions and breeding hosts become available. Risks can be informed by bioclimatic modelling, habitat requirements (such as for pupation), and the availability of hosts. An understanding of the commodity supply chain post-arrival would assist in this risk assessment.	Phytosanitary certificate specifies origin of produce.	We found few examples of this measure being incorporated into a systems approach. However, poor destination habitat is factored into assessment of unrestricted risk: no phytosanitary requirements may be needed if establishment risk is considered sufficiently low. This measure may also be difficult to implement in environmentally diverse countries where there is little internal control on where imported consignments are sent.	Can be combined with measures that reduce infestation rates in commodities.

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