Seed & Grain Readiness and Response

Readiness Framework

User Guide

Seed + Grain
Readiness & Response

Front cover photo(s) credit:
Wheat stem rust, Mary Burrows, Montana State University, Bugwood.org
Western corn rootworm, Winston Beck, Iowa State University, Bugwood.org

Contents

Seed & Grain Readiness and Response (SGRR) represents the arable industry groups: Federated Farmers Arable fedfarm.org.nz, Flour Millers Association flourinfo.co.nz, Foundation for Arable Research far.org.nz, New Zealand Grain and Seed Trade Association nzgsta.co.nz and United Wheat Growers uwg.co.nz.

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Developed by Market Access Solutionz Ltd

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Photos (top): Brown Marmorated Stink Bug, Gary Bernon, USDA APHIS, Bugwood.org (Middle): Pee Weevil, Mariusz Sobieski, Bugwood.org (Bottom): Western corn rootworm, Winston Beck, Iowa State University, Bugwood.org

Section 1.
Introduction

The Seed & Grain Readiness and Response (SGRR) Readiness Framework provides an approach for assessing biosecurity risks in the New Zealand arable sector.

It presents a simplified view of the complex crop/pest associations which arise from large numbers of host crops, and pests, diseases and weeds.

The Readiness Framework comprises three components:

1. **Risk assessment –** to identify biosecurity risks for crops/crop groups and estimate the impact on the sector.
2. **Risk management -** to identify approaches to manage the risks associated with pest groups, specific pests and/or crop groups identified from risk assessment.
3. **Readiness activities –** to develop tools and resources to manage the risks and to support the sector's actions and decisions in response.

This resource will guide the user through the framework to reach outcomes that can inform the development of a programme of work of readiness activities that will prepare the sector to respond to an incursion of an unwanted organism, and inform the actions and decision making in a response.

Section 2.
The Readiness Framework

The core components of the Readiness Framework are based on (i) a high-level risk assessment of pest classes, crop groups and crop value in a **sector-wide risk assessment**, and (ii) a detailed assessment of the relative risks of key sector pests in a **pest-specific risk assessment** to create a short-list of high priority pests.

The outcomes of risk assessment will help to identify and prioritise areas that require **risk management** and provide direction for a work programme for **readiness activities.**

Photo: Wheat

Readiness Framework

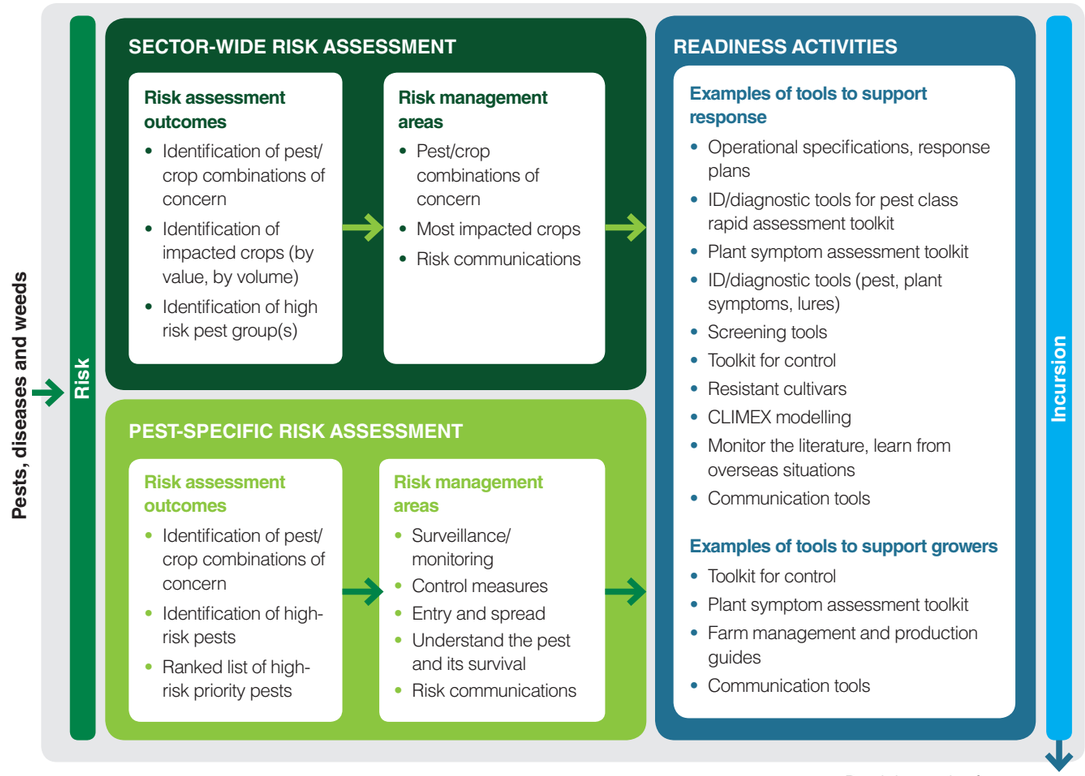

Fig 1. Components of Readiness Framework.

Readiness Framework Flowchart

inputs, outputs and process

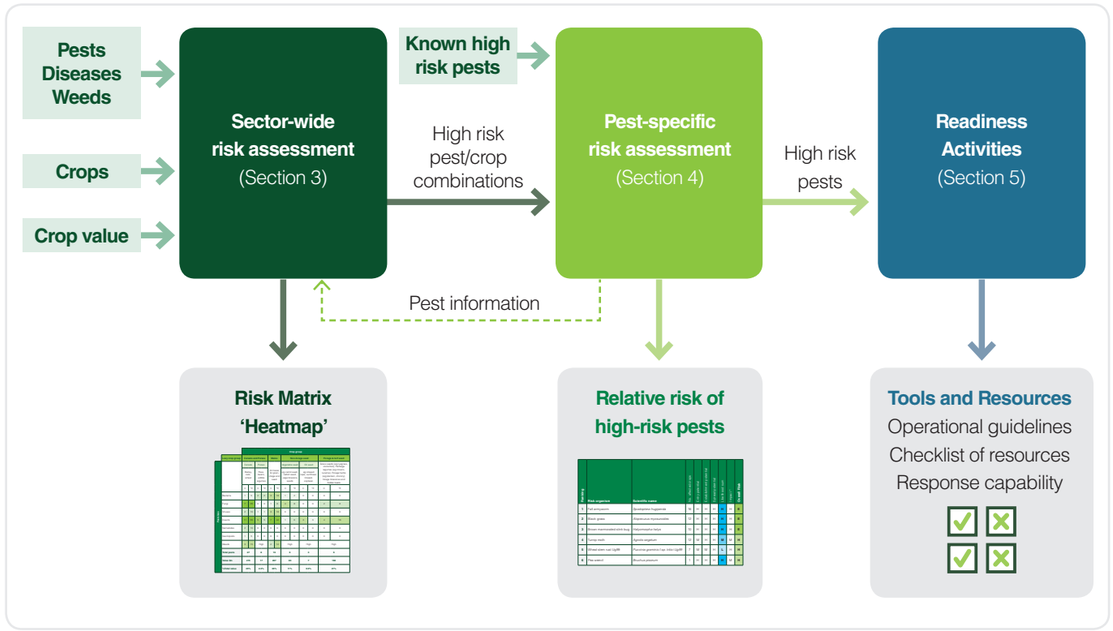

Figure 2. Readiness Framework flowchart

Photo: Brown marmorated stink bug

Section 3.
Sector-wide risk assessment

Purpose: To obtain a high-level view of biosecurity risks of the arable sector.

Outcome: A risk matrix identifying the most important risks based on the association between pest class, crop group and crop value.

A high-level assessment of pests, crop hosts, and crop value that presents a simplified view of the many complex pest/crop associations in the arable sector.

Inputs

Table 1. Risk matrix inputs for sector-wide risk assessment

Inputs	Description
Pest class	Bacteria, fungi, viruses, insects, nematodes, gastropods, weeds
Crop group	Cereals and pulses, maize, forage seed, non-forage (vegetable and oil), and turf seed[1]
Economic value	Crop value at FPOS[2]

[1] Aligned with SGRR biosecurity levy crop groupings (Appendix 2).
[2] Source of economic information from the current Arable production 2018 Economic impact assessment https://www.afic.co.nz/research-strategy/industry-statistics/ (Appendix 3)

Methodology

1. **Pest classes and crop groups** Classify pests to pest classes and assign the classification to the corresponding crop group. Crop groups are aligned to the SGRR biosecurity levy crop groups. If a pest is associated with more than one host crop, count each pest/host association. Record total pest count (**C**) for each crop group (Table 4).
2. **Economic multiplier** Multiply total pest count (**C**) by the economic score and record the result (***E**) for each crop group. Economic scores are assigned to a range of crop values, in increments of $50 million (Table 2). The economic score is used as the economic multiplier.
3. **Heatmap** Generate a 'heatmap' of the risk matrix to obtain a visual representation of the overall risk of each pest class/crop group combination. Apply colour intensity to each cell in the risk matrix based on the value for (i) total pest count (**C**), and (ii) total pest count × economic score (***E**).

Table 2: Economic scores for ranges of crop values

Value $m	0-50	51-100	101-150	151-200	201-250	251-300	300+
Economic Score	1	2	3	4	5	6	7

Table 3: Colour intensities and (descriptive) level of risk used for the risk matrix

Pest class/crop group count (C)	0	1	2	3-4	5-6	7+
Count * economic score (*E)	0	1-5	6-10	11-20	20-30	30+
Colour intensity						
Level of risk	Nil	Low	Low to medium	Medium	Medium to high	High

SECTOR-WIDE RISK ASSESSMENT - Example

In this example, risk assessment was undertaken using the pest list (Appendix 1), and crop economic values (Appendix 3) to generate a risk matrix using the inputs: pest class, crop group, and crop value, to produce Table 4.

Photo: Grain

Outcome

Table 4: Risk matrix

		Crop group											
	Levy crop group	**Cereals and Pulses**				**Maize**		**Non-forage seed**				**Forage & turf seed**	
		Cereals		Pulses				Vegetable seed		Oil seed		Grass seeds (eg ryegrass, cocksfoot), Herbage legumes (eg clovers, lucerne), Forage herbs (eg plantain, chicory), forage brassicas and fodder beets	
		Barley, oats, wheat		Peas, beans, edible legumes		All maize for grain, silage and seed		eg carrot seed, radish seed, vege brassica seeds		eg oilseed rape, sunflower, linseed, soybean			
		C	*E	C	*E	C	*E	C	*E	C	*E	C	*E
Pest class	Bacteria	1	7	2	2	3	18	1	2	0	0	0	0
	Fungi	7	49	0	0	1	6	4	8	0	0	2	8
	Viruses	2	14	1	1	3	18	0	0	0	0	0	0
	Insects	11	77	5	5	7	42	1	12	3	3	4	16
	Nematodes	2	14	0	0	0	0	0	0	0	0	0	0
	Gastropods	1	7	0	0	0	0	0	0	0	0	0	0
	Weeds	3	21	High		2	12	High		High		High	
	Total pests	**27**		**8**		**16**		**7**		**3**		**6**	
	Value $m	**317**		**26**		**389**		**78**		**7**		**176**	
	%Total value	**32%**		**2.6%**		**39%**		**7.9%**		**0.7%**		**18%**	

Note: For information on crop groups and pests, see Appendix 1; SGRR biosecurity levy crop groupings, see Appendix 2; and crop value at first point of sale, see Appendix 3.

Interpretation

1. Using the inputs, pest class, crop group and crop value in a sector-wide risk assessment resulted in outcomes that were generally similar to using pest class and crop group only. Multiplying total pest count (C) with an economic score shifted the risk, showing as either an increase or decrease in risk. This shift in risk indicates that crop values influence the level of risk, providing a more detailed and nuanced assessment.

2. The risk matrix indicates that Cereals and Maize are at high risk from insect pests, with Cereals (barley, oats, wheat) also at high risk to fungi. Cereals and maize are also at medium risk from weeds (black grass, waterhemp, horseweed). Cereals are at low-to-medium risk to viruses and nematodes, while maize is also at medium risk to bacteria and viruses.

   Cereals and maize, valued at $317m and $389m representing 32% and 39% of the sector respectively, would also have a higher risk from an economic perspective.

3. The risk matrix also indicates potentially lower risk for pulses to insects, vegetable seed to fungi, and oilseed to insects, shown by decreased colour intensity; while an increase in colour intensity suggests there is increased risk for maize to fungi, and vegetable seed to insects.

4. The economic score for crop value for pulses ($26m) resulted in a value of '1' for the economic multiplier which has contributed to a potential decrease in level of risk for pulses to insects, compared to total pest count only (C). Therefore, pulses may represent a lower risk for the sector from an economic perspective.

5. Sector-wide risk assessment can be used to undertake an initial triage of pests, diseases and weeds to take through to the pest-specific risk assessment by focussing on pest class/crop group/crop value associations that have a higher level of risk. As an outcome of this risk matrix, priority areas for detailed pest assessment could focus on: insects affecting Cereals and Pulses, and Maize; and fungi affecting Cereals.

Photo: Maize dwarf mosaic virus, Craig Grau, Bugwood.org

This can be followed with an assessment of bacteria and viruses affecting Maize, fungi affecting Vegetable seed, insects affecting Pulses, Oil seed, and Forage and Turf seed; and weed species.

In this example, organisms covering a range of high-risk pest class/crop group associations were selected for pest-specific risk assessment and included wheat stem rust (fungi/cereals), pea weevil (insect/pulses), turnip moth (insect/polyphagous), fall armyworm (insect/polyphagous), brown marmorated stink bug (insect/polyphagous), and black grass (weed/cereals).

6. In this risk matrix, weeds are recorded as being associated with cereal and maize hosts, however they are also likely to affect other crop groups. Pest-specific risk assessment of black grass showed that host species include: oats, beet, rape, barley, rye, wheat, maize, carrot, lucerne, bean, pea, and clover (see Pest-specific risk assessment case study). This host crop information can be used to refine the sector-wide assessment.

7. The pests, diseases and weeds used in this assessment predominately affected the Cereals and Maize crop groups. A more comprehensive list of pests that affect Non-forage and Forage and Turf seed, and Pulses, would help provide a more informed view of the sector's more important pest class/crop group associations.

Section 4.
Pest-specific risk assessment

Photo: Fall armyworm, Russ Ottens, University of Georgia, Bugwood.org

Purpose: To obtain a greater awareness of high-risk pests that are potential risks to the New Zealand arable sector by undertaking a technical assessment to determine their relative risks.

Outcome: A single list of high-risk pests affecting the arable sector ranked by relative risks.

A qualitative and technical assessment which evaluates high-risk pests in the New Zealand context to obtain an Overall Risk for each pest.

Overall Risk takes into consideration: crop hosts, pathways, distribution, pest behaviour, recent pest activity, effects on crops, and impact which includes market access, economic, ability for mitigation/control, and other factors.

Photo: Brown marmorated stink bug, Kristie Graham, USDA ARS, Bugwood.org

Methodology

1. Generate an initial pest list associated with specific crop hosts (or group of crops).
2. If necessary, triage the initial pest list to create a short-list. Reasons for removing pests from the initial list may include: a lack of information, narrow host/ crop range, impact is on lower value/ importance crops, considered to be low-risk.
3. Complete risk assessment for each pest by reviewing pest biology and scanning the literature for information on host crops, entry potential, establishment potential, spread potential, and impact. Information is obtained from the scientific literature, international and national databases, datasheets (pest risk analyses), industry and government websites, and other sources. Information used to assess the example pests is shown in Appendix 4.
4. Allocate a score (Low, Medium, High) to each risk parameter (entry, establishment, spread, impact) based on a qualitative decision of the technical information, guided by the descriptive information in Table 5.
5. Determine the Likelihood score and Overall Risk score by combining risk parameter scores using the Qualitative Risk Analysis matrices in Table 5. Descriptive definitions for Likelihood score and Overall Risk are given in Table 5.
6. Determine pest rankings and relative risks based on Overall Risk scores.

This method of pest risk assessment was developed by Biosecurity Australia, and is a well-tested approach which has been used for the horticulture sector and adapted for the New Zealand context.

Table 5: Description of qualitative risk parameters for pest-specific risk assessment

<table>
<tr><th>Risk Parameter</th><th>Description</th><th>Scores</th></tr>
<tr><td>Number of host crops</td><td>Number of hosts affected by a pest</td><td>Numerical value</td></tr>
<tr><td>Entry potential</td><td>Assesses the potential of a pest, disease or weed to enter New Zealand taking into account any existing controls at the border (e.g. import health standards, pathways).</td><td>High
Medium
Low</td></tr>
<tr><td>Establishment potential</td><td>Assesses the potential for a pest, disease or weed to establish in New Zealand. Potential may be determined by host availability, alternative hosts, vectors, suitability of the environment, reproductive strategy, existing cultural practices and control measures.</td><td>High
Medium
Low</td></tr>
<tr><td>Spread potential</td><td>Assesses the potential for the pest or disease to spread following establishment on a host plant (or plants) to other susceptible host plants. Factors considered might include suitability of the environment, presence of natural barriers, potential for movement with commodities or by vectors, potential vectors, and potential natural enemies of the pest.</td><td>High
Medium
Low</td></tr>
<tr><td>Likelihood score</td><td>Obtained by combining the descriptive scores for (Entry×Establishment) × Spread, using the Qualitative Risk Matrix for Likelihood Score:
Qualitative Risk Analysis Matrix – Likelihood Score
<table><tr><th rowspan="2">Likelihood</th><th colspan="4">Combine in order of entry, establishment and spread</th></tr><tr><th>High</th><th>Medium</th><th>Low</th><th>Negligible</th></tr><tr><td>High</td><td>High</td><td>Medium</td><td>Low</td><td>Negligible</td></tr><tr><td>Medium</td><td>Medium</td><td>Low</td><td>Low</td><td>Negligible</td></tr><tr><td>Low</td><td>Low</td><td>Low</td><td>Extremely low</td><td>Negligible</td></tr><tr><td>Negligible</td><td>Negligible</td><td>Negligible</td><td>Negligible</td><td>Negligible</td></tr></table>Descriptive definitions of Likelihood:
High: event would be very likely to occur
Medium: event would occur with an even probability
Low: event would be unlikely to occur
Extremely low: event would be very unlikely to occur
Negligible: event would almost certainly not occur</td><td>High
Medium
Low
Extremely low
Negligible</td></tr>
<tr><td>Impact</td><td>Assesses the economic, environmental and social consequences of a pest or disease to affect an industry or the wider New Zealand economy. Examples might be taken from overseas where similar pest or disease incursions have occurred. Impact assessment includes market access impacts, ability for mitigation or control, and other factors.

Impact assessment takes into consideration the economic value of the crop (or crops) affected by the pest, disease, or weed. For example, if the pest affects most seed and grain crops then its impact would score at the high end of the scale, while a pest affecting fewer crops would score at the low end.</td><td>High
Medium
Low</td></tr>
</table>

Table 5: Description of qualitative risk parameters for pest-specific risk assessment

Risk Parameter	Description	Scores
Overall risk	Obtained by combining Likelihood score and impact score using the Qualitative Risk Analysis Matrix for Overall Risk.	Extreme High Medium Low Negligible

Qualitative Risk Analysis Matrix – Overall Risk

Likelihood	Impact (Economic/environmental/social)				
	Negligible	**Low**	**Medium**	**High**	**Extreme**
Extremely High	High	High	Extreme	Extreme	Extreme
High	Medium	High	High	Extreme	Extreme
Medium	Low	Medium	High	Extreme	Extreme
Low	Low	Low	Medium	High	Extreme
Negligible	Low	Low	Medium	High	High

Descriptive definitions of Overall Risk:

- Extreme: Specific action is required immediately to reduce the risk.
- High: Specific action is required to manage the risk. Generic risk treatment plans should be adopted as soon as possible in the interim.
- Medium: Adopt generic risk treatment plans to reduce the risk to suitable levels.
- Low: Manage the risk through routine procedures.
- Negligible: Negligible risk.

Photo: Pea weevil

PEST-SPECIFIC RISK ASSESSMENT - Example

Risk assessment was undertaken for six pests selected from the main priority pests, and agreed by SGRR. These pests, and the rationale for their selection are:

- **Black grass** – weed example
- **Brown marmorated stink bug** – insect example, affects a medium proportion of sector value
- **Fall armyworm** – insect example, affects a medium proportion of sector value
- **Pea weevil** – insect example, affects small proportion of sector value
- **Turnip moth** – insect example, affects large proportion of sector value
- **Wheat stem rust Ug99** – pathogen example

Photo: Black grass

Outcome

For each pest, information on host crops, entry potential, establishment potential, spread potential, and impact was obtained by scanning the scientific literature, international and national databases, datasheets (pest risk analyses), and industry and government websites. The information obtained and used to assess these pests is provided in Appendix 4.

A score of high (**H**), medium (**M**) or low (**L**) is allocated to each parameter based on a qualitative decision of the technical information, and the results are shown in Table 6. Likelihood sum and Overall risk are obtained by combining scores using the Risk analysis matrices in Table 5. Definitions for the scores for Overall Risk, and actions that may be required, are shown in Table 5.

Table 6: Summary of pest-specific risk assessment for six of SGRR's main priority pests. Detailed information is in Appendix 4.

Ranking	Risk organism	Scientific name	No. affected crops	Entry potential	Establishment potential	Spread potential	Likelihood sum	Impact *	Overall Risk
1	Black grass	*Alopecurus myosuroides*	12	H	H	H	**H**	H	**E**
2	Brown marmorated stink bug	*Halyomorpha halys*	10	H	H	H	**H**	H	**E**
3	Fall armyworm	*Spodoptera frugiperda*	16	H	M	M	**L**	H	**H**
4	Turnip moth	*Agrotis segetum*	12	M	H	H	**M**	M	**H**
5	Wheat stem rust Ug99	*Puccinia graminis* f.sp. *tritici* Ug99	7	M	M	H	**L**	H	**H**
6	Pea weevil	*Bruchus pisorum*	1	H	H	H	**H**	M	**H**

Note: *Impact takes into consideration Economic impact of whole NZ arable sector (see Table 5).

Interpretation

1. A summary table of the outcome of risk assessment of six high-risk pests and weeds, black grass, brown marmorated stink bug (BMSB), fall armyworm, pea weevil, turnip moth, and wheat stem rust, is shown in Table 6. This is a list of high-risk pests ranked by relative risk. The information used to review each pest is provided in Appendix 4, and is a valuable resource on the high-risk pests, diseases and weeds that affect the arable sector.

2. The results from risk assessment are summarised:

   i. **Overall,** black grass and BMSB are extreme risks for SGRR; and fall armyworm turnip moth, wheat stem rust and pea weevil are high risk. Although the scores for the risk parameters for the latter four organisms were variable, the Overall Risk was high.

   ii. **Black grass** – Overall risk is **extreme.** Black grass is reported to affect a large number of arable hosts. Its potential for entry is high as incursions have previously occurred, and it has established in NZ. Its impact is assessed as high as up to 71% of sector economic value could be affected including the high volume and high value crops, cereals and maize.

   iii. **Brown marmorated stink bug –** Overall risk is **extreme.** BMSB is polyphagous and affects a large number of arable hosts. Its potential for entry is high as it has often been detected at the border and post-border. Its potential to establish is high as the NZ climate is favourable. Its impact is assessed as high although a medium proportion (39%) of sector economic value could be affected, particularly maize.

Photo: Black grass weed

Section 4

Photo: Pea Weevil, Mariusz Sobieski, Bugwood.org

   iv. **Fall armyworm –** Overall risk is **high.** Fall armyworm is polyphagous and can affect a large number of arable hosts, in particular maize. Its potential for entry is high as a number of detections have occurred in March/April 2022 across the north and central North Island. It is likely to have arrived via wind dispersal from Australia. Fall armyworm has potential to establish and spread in NZ, however, its ability to survive NZ winters is unclear. Its impact is assessed as high, particularly on maize, which contributes to 39% of sector economic value.

   v. **Turnip moth** – Overall risk is **high**. The potential for turnip moth to establish and spread are high, and it affects a large number of hosts. However, its potential for entry and impact are assessed as medium as it is normally associated with leafy plant parts although it could affect up to 77% of sector economic value.

   vi. **Wheat stem rust Ug99** – Overall risk is **high.** Wheat stem rust Ug99 affects a smaller number of hosts, and its potential for entry and establishment are assessed as medium as the NZ climate may be unsuitable. Its potential for spread and impact are assessed as high. It would affect approx. 32% of sector economic value.

   vii. **Pea weevil** – Overall risk is **high**. Pea weevil is monophagous but its potential for entry is high as an incursion has previously occurred, and although it established in NZ, it was eradicated. Its impact is assessed as medium as it affects 2.6% of sector economic value. However, its Overall Risk remains high.

3. Black grass was successfully assessed as a case study for a weed species applying the same qualitative parameters used to assess pests and pathogens. Technical information for black grass was readily available, which could be used to determine its risks in relation to other pests and disease. Pest-specific risk assessment would be an appropriate approach for assessing weed species.

4. Risk assessment of a larger number of sector pests, such as those listed in Appendix 1, would provide SGRR with a better understanding of the relative risks of the pests, diseases and weed species that affect the arable sector.

5. This list can be used to provide a focus for SGRR to increase sector and grower awareness of the relative risks of its high-risk organisms, and to inform the development of readiness activities including tools/ resources to communicate their risk to the sector.

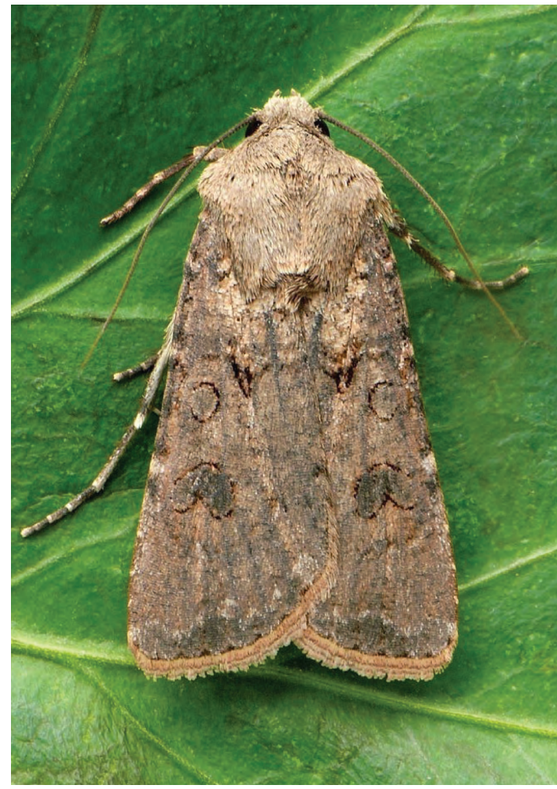

Photo: Turnip moth

Section 5.
Risk management and Readiness activities

Photo: Western corn rootworm, Winston Beck, Iowa State University, Bugwood.org

Purpose: To identify areas for risk management and to inform the development of readiness activities, informed by undertaking risk assessment.

Outcome: A work programme of readiness activities designed to support SGRR and growers to prepare and respond to an incursion.

Risk assessment enables pests (or groups of pests) that present the greatest risks to the sector to be identified and prioritised so that readiness activities can be undertaken to better understand, and to reduce their risks.

Readiness activities include the development of tools/resources, such as operational guidelines and response plans for a group of pests, or for a specific pest.

Examples of readiness activities, listed in Table 7, can be pest-focused (e.g. diagnostic test), or at an all-of-system level (e.g. response exercises and workshops).

Readiness activities:

Potential readiness activities informed by sector-wide and pest-specific risk assessments for the example pests, could include:

1. **Develop an inventory/checklist** of resources that would be required to manage the risks associated with the pest (or groups of pests), to help identify gaps that may need to be filled. For example, a checklist for **turnip moth** might include:

   - ☑ ☒ Knowledge of the host crops that would be affected,
   - ☑ ☒ Availability of diagnostic tools for detection and surveillance, and protocols for their use,
   - ☑ ☒ Availability of agrichemicals for treatment and control, and their regulatory status e.g. on- and off-label use, would insecticides targeting other Lepidoptera species be effective
   - ☑ ☒ Understanding the impact in a New Zealand context
   - ☑ ☒ Communication planning.

2. **Develop a suite of operational guidelines** to specify the requirements for:

   i. movement control (approaches and strategies)
   ii. removal and destruction of host material (methods, protocols)
   iii. pest surveillance (diagnostic tools, protocols, survey area)
   iv. treatment and control (agrichemicals and their use)

   Operational guidelines are based on technical information, and would outline the movement zones, how infested plant material should be removed and destroyed (e.g. incineration, or deep burial), and surveillance requirements (survey area, trap density, timing and frequency).

3. **Increase response capability** by (i) undertaking response planning to determine roles and responsibilities for decision making and governance during a response, and (ii) undertaking workshops and response exercises.

Table 7. Examples of readiness activities, tools and resources for risk management

Risk management areas	Readiness activities	Existing resources and capability (not exhaustive)
Response preparation and support	Operational guidelines, e.g. • Pest surveillance • Movement controls • Host removal and destruction Response planning, • Roles and responsibilities for decision making/ governance • MPI Technical working group Workshops and response exercises	Shared activities with MPI
Communications and Education	Communication plan to increase biosecurity awareness Education Extension activities	FAR website/resources On-farm biosecurity farm planning modules Other resources
Knowledge gaps	Identify current resources and determine knowledge gaps, create inventory of current tools/resources, location of information, capabilities	FAR, MPI, CRIs, other sectors/ networks (NZ and overseas)
Surveillance Monitoring	Identification tools (pest, plant symptoms) Diagnostic tests Lures	MPI, PHEL, CRIs, B3 projects
Control measures	Understand their feasibility/practicality Understand their cost/benefits Agrichemical toolkit • Product list/availability/new registrations • Recommendations to growers, spray guides Cultural control • Alternate crops, early planting, early maturing varieties, resistant cultivars • Crop rotation Biological control Traps	
Entry and spread	Diagnostics and screening Farm management and production guides	MPI PHEL, FAR, other sectors
Pest survival in NZ	Pest risk analysis CLIMEX Modelling	e.g. MPI reports on fall armyworm - Pest risk analysis and Biosecurity Intelligence Report
Increase knowledge on pest(s), Understand the pest(s)	Literature scanning - risk crops, distribution changes, etc. Learn from overseas situations, including management and eradication programmes Other technical information	Scientific and grey literature, international databases (CABI, EPPO, EFSA)

Section 6.
Summary of Readiness Framework

This framework is designed to address the complexity of the large number of pests, crops and pest/crop combinations with complementary approaches to risk assessment with a high-level view of sector-wide risks, and a detailed understanding and relative risks of the high-risk pests.

Sector-wide assessment was able to inform the selection of six organisms for pest-specific assessment. Information from individual pest assessments can help refine the high-level sector assessment.

For example, assessment of black grass showed its host range is wider than cereals (wheat, barley, oats). Additional hosts (beet, rape, rye, maize, carrot, lucerne, bean, pea, clover) can be incorporated back into the risk matrix in the total pest count (C) and 'C x economic multiplier' (*E). Similarly, turnip moth has hosts (beet, Brassicaceae, carrot, sunflower, lucerne, radish, rye, maize) in addition to Cereals and lucerne (Appendix 1).

The outcome of a complementary approach is two-fold:

1. A process for evaluating and refining the assessment of sector-wide risks. A sector risk heat map represents a combination of Pest class x crop group x economic value.
2. Pest-specific risk assessment has evaluated six risk organisms, ranking each according to Entry, Establishment, Spread, and Impact. This assessment is more detailed as it provides a technical evaluation of each pest to assess risk.

Photo: Fall armyworm

Photo: Stem rust

Photo: Black grass weed

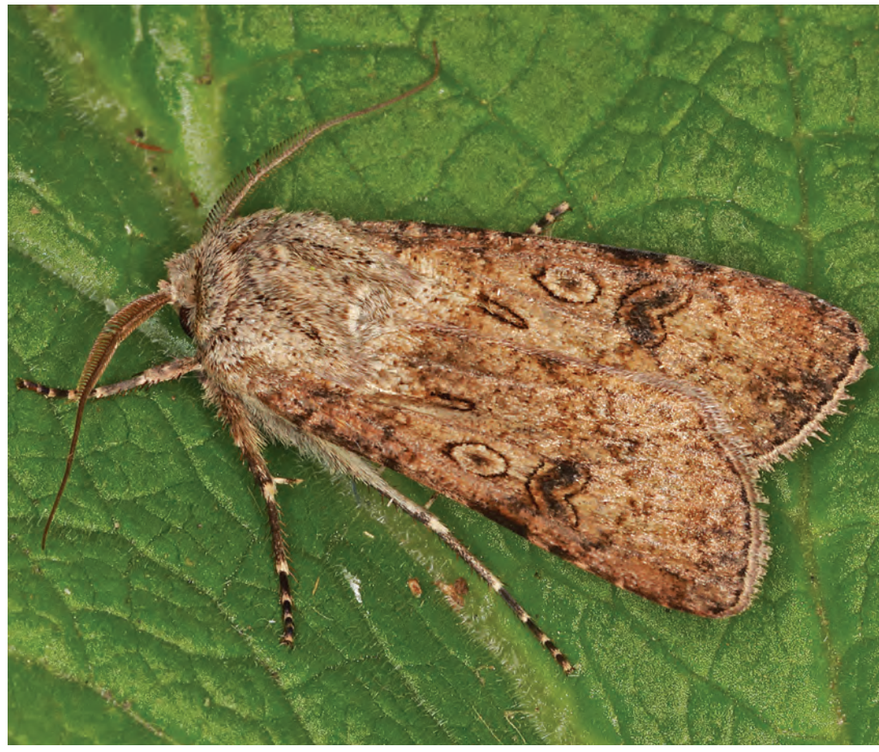

Photo: Turnip moth

Appendix 1.
Arable crops and priority pests

Arable crops and Priority pests (April 2022)

Crop	Pest - common name	Pest - scientific name	Pest class
Cereals – cereals and pulses			
Barley	Barley mild mosaic virus	Genus: *Bymovirus*	virus
	Cereal cyst nematode	*Heterodera filipjevi*	nematode
	Barley stripe rust	*Puccinia striiformis f. sp. hordei*	fungi
	Banded leaf and sheath spot ??	-	fungi
	Turnip moth	*Agrotis segetum*	insect
	Barley stem gall midge	*Mayetiola destructor/hordei*	insect
	Black grass (particularly herbicide resistant)	*Alopecurus myosuroides*	weed
Wheat	Wheat blast	Magnaporthe oryzae	fungi
	New races of wheat stem rust	*Puccinia graminis f.sp tritici* Ug 99	fungi
	Fusarium algeriense	*Fusarium algeriense*	fungi
	Soilborne wheat mosaic virus	Genus: Furovirus	virus
	Karnal bunt	*Tilletia indica*	fungi
	Cereal cyst nematode	*Heterodera filipjevi*	nematode
	Ryegrass bunt	*Tilletia walkeri*	fungi
	Turnip moth	*Agrotis segetum*	insect
	Khapra beetle	*Trogoderma granarium*	insect
	Russian wheat aphid	*Diuraphis noxia*	insect
	Wheat stem sawfly	*Cephus cinctus*	insect
	European wheat stem sawfly	*Cephus pygmeus*	insect
	Larger grain borer	*Prostephanus truncatus*	insect
	Wheat bug	*Nysius huttoni*	insect
	Mediterranean white and conical snails	*Cernuella virgata, Cochlicella acuta*	gastropod
	Black grass (particularly herbicide resistant)	*Alopecurus myosuroides*	weed
Oats	Bacterial leaf streak	*Xanthomonas vasicola*	bacteria
	Oat leafminer	*Chromatomyia fuscula*	insect
	Turnip moth	*Agrotis segetum*	insect
	Black grass (particularly herbicide resistant)	*Alopecurus myosuroides*	weed

Crop	Pest - common name	Pest - scientific name	Pest class
Maize - maize			
Maize	Maize lethal necrosis disease (MLND)	Maize chlorotic mottle virus (MCMV) and Sugarcane mosaic virus (SCMV) or any cereal viruses in Potyviridae	virus
	Rio IV Maize virus	-	virus
	Zea mosaic virus	Genus: Potyvirus	virus
	Downy mildew	*Peronosclerospora philippinensis*	fungi
	Bacterial wilt	*Pantoea stewartii*	bacteria
	Cornstunt spiroplasma	*Spiroplasma kunkelii*	bacteria
	Stalk rot/leaf blight	*Pantoea ananatis*	bacteria
	Fall armyworm	Spodoptera frugiperda	insect
	Western corn rootworm	*Diabrotica virgifera virgifera*	insect
	Northern corn rootworm	*Diabrotica barberi*	insect
	Southern corn rootworm	*Diabrotica undecimpunctata*	insect
	Khapra beetle	*Trogoderma granarium*	insect
	Spotted stalk borer	*Chilo partellis*	insect
	Brown marmorated stink bug (BMSB)	*Halyomorpha halys*	insect
	Waterhemp	*Amaranthus tuberculatus*	weed - glyphosate-resistant
	Horseweed	*Conyza canadensis*	weed - glyphosate-resistant
Op/hybrid veg - vegetable seed/non-forage seed			
Brassicas	Verticillium wilt	*Verticillium* spp.	fungi
	Brassica leaf beetle	*Phyllotreta striolata*	insect
	Pollen beetle/rape beetle	*Brassicogethes aeneus*	insect
Carrot	Zebra chip	*Candidatus* Liberibacter *solanacearum*	bacteria
Radish	Fusarium wilt	*Fusarium oxysporum f.sp. raphani*	fungi
	Colletotrichum higginsianum	*Colletotrichum higginsianum*	fungi
Forage brassicas - vegetable seed/non-forage seed			
	Verticillium wilt	Verticillium spp.	fungi
	Pollen beetle/rape beetle	*Brassicogethes aeneus*	insect

Crop	Pest - common name	Pest - scientific name	Pest class
Oilseed crops - oil seed/non-forage seed			
OSR	Rape stem weevil	*Ceutorhynchus napi*	insect
Sunflower	Sunflower stem weevil	*Cylindrocapturus adspersus*	insect
	Sunflower moth	*Homoesoma electellum*	insect
Legume crops - pulses/cereals and pulses			
Bean	Pseudomonas syringae pv. syringae	*Pseudomonas syringae pv. syringae*	bacteria
	Xanthomonas axonopodis	*Xanthomonas axonopodis*	bacteria
	Legume pod borer	*Maruca vitrata*	insect
Peas	Pea early browning virus	Genus: Tobravirus	virus
	Pea weevil	*Bruchus pisorum*	insect
	Western flower thrips	*Frankliniella occidentalis*	insect
	Legume pod borer	*Maruca vitrata*	insect
	Pea aphid	*Acyrthosiphon pisum*	insect
Lucerne and clover - forage & turf seed			
Lucerne	Alfalfa weevil	*Hypera postica*	insect
	White fringed weevil	*Naupactus leucoloma*	insect
Red/white clover	Clover springtail	*Sminthrus viridus*	insect
	Turnip moth	*Agrotis segetum*	insect
Grass seed crops - forage and turf seed			
Cocksfoot	Choke disease	*Epichloe typhina*	fungi
Fescue			
Ryegrass	Ryegrass bunt	*Tilletia walkeri*	fungi

Appendix 2.
Biosecurity levy crop groups

Photo: Chertsey clover

Crop Groups	Definition	Including, but not limited to
Cereals	All feed wheat, barley and oats, all milling wheat, barley and oats and cereal silage defined as cereal or pulse crops grown, harvested and imported for silage or processed or stored for animal feed or for human consumption	Feed wheat, feed barley, brewing barley, milling wheat, milling rye corn, cereal silage, oats, and triticale, quinoa, spelt, buckwheat and sorghum
Maize	Maize that is grown or imported into New Zealand for grain, seed, silage, or grazing.	Maize seed, maize silage, maize grain, domestic distillers' grain, and kibbled maize
Non forage Seeds	All non-forage seed grown or imported into New Zealand	Vegetable seeds, cereal seeds for sowing, industrials and pharmaceuticals, hemp, oil seed rape, sunflower, borage, Asian brassicas, beet/chard, cabbage, carrot, corn salad, radish, and spinach
Forage and Turf Seed	All grass species, legumes, brassicas, plantain, beet, lucerne and chicory grown or imported into New Zealand.	Forage brassicas, plantain, rape, lucerne, red clover, and white clover, grass seeds

Source: Biosecurity Profile for Seed and Grain Readiness and Response Inc. Arable Crops. Prepared by Biosecurity New Zealand and Seed and Grain Readiness and Response Inc.

Appendix 3.
Crop economic value

2021 (economic impacts excluded)	Total value/$m	Tonnes sold
Total grain and pulses production	740	2,216,423
Total seed production	267	81,470
Total	**1,007**	**2,297,893**

Cereals and Pulses - Cereals	Value of sales $M	Tonnes sold
Wheat (feed, milling)	185	463,124
Barley (feed, brewing)	116	291,066
Oats	11	24,216
Other cereal grains	5	12,609
Total	**317**	**791,015**

Cereals and Pulses - Pulses	Value of sales $M	Tonnes sold
Pulses	26	32,712
Total	**26**	**32,712**

Maize	Value of sales $M	Tonnes sold
Maize silage	296	1,180,000
Maize grain	93	202,861
Total	**389**	**1,382,861**

Non-forage seeds/oil seed	Value of sales $M	Tonnes sold
Rape	7	9,835
Brassica seed	60	12,641
Non-brassica seed	18	1,616
Total	**85**	**24,092**

Forage and Turf seed	Value of sales $M	Tonnes sold
Grasses	127	57,481
Legumes	49	5,791
Total	**176**	**63,272**

Other crops (unspecified)	Value of sales $M	Tonnes sold
Total	**11**	**3,941**

Crop groups also include the following crops for which no values were listed	
Cereals	milling rye, corn, cereal silage, triticale, quinoa, spelt, buckwheat, sorghum
Maize	maize seed
Non-forage seed	vegetable seeds, cereal seeds for sowing, industrials and pharmaceuticals, hemp, sunflower, borage, corn salad, spinach
Forage and turf seed	forage brassicas

Source of economic information from Arable production 2021 Economic impact assessment https://www.afic.co.nz/research-strategy/industry-statistics/

Photo: Sunflower

Appendix 4.
Information used to assess pest-specific risk

Photo: Maize

Appendix 4

	PEST INFORMATION			DESCRIPTION OF RISK		DESCRIPTION OF RISK		QUALITATIVE ASSESSMENT						REFERENCES
Ranking	Risk Organism	Scientific Name Family:Order	Arable Hosts • CABI (main/ other hosts)	Entry Potential • pathways • distribution	Establishment Potential • host range • climate • NZ conditions	Spread Potential • dispersal • movements	Impact • damage, yield loss • economic impact	Entry Potential	Establishment Potential	Spread Potential	Likelihood Sum (refer Table 5)	Impact	Overall Risk (refer Table 5)	
1	**Black grass**	***Alopecurus myosuroides*** Poaceae: Cyperales	**Cereals and other crops** Main hosts (CABI): oats, beet, rape, barley, rye, wheat, maize. Other hosts (CABI): carrot, lucerne, bean, pea, clover. 12 host species.	Highly likely to be transported internationally by accident (contaminant). Native and widely distributed in Europe, found in Central/South Asia and has been introduced to North and South America, and Australasia. Incursions in NZ in 2013, 2016, 2021. Potential for entry on a pathway is HIGH.	Mainly affects cereal crops. Species restricted by climate. Found in oceanic/ sub-oceanic climates (maritime, cool/mild winters, summers not dry or hot). NZ has temperate/ maritime climate. Grows in climates similar to NZ. Potential to establish is HIGH.	Spreads as a contaminant of crop seed in local and long distance spread. Has extremely high seed production capacity. Sheds seed early and before cereal harvest so high possibility of long distance spread in baled straw, etc. Also spread on harvesters and cultivation equipment, and by movement of soil on equipment/equipment tyres. Potential for spread is HIGH.	Significant weed species in temperate cereal crops. Serious pest weed in Europe and UK where it is resistant to many herbicides making it difficult to control. Can seriously reduce crop yield. Difficult/ costly to control. Important in cereal-based rotations: high impact in winter cereals and oilseed rape; medium in spring cereals and beet; low in maize (CABI). Up to 71% of NZ arable sector value affected - $708m/$993m calculated for main hosts listed in CABI. Impact is HIGH.	H	H	H	**H**	H	**E**	https://www.cabi.org/cpc/datasheet/4360 https://www.far.org.nz/articles/1606/black-grass-detection
2	**Brown marmorated stink bug**	***Halyomorpha halys*** Pentatomidae: Hemiptera	**Polyphagous** Main hosts (CABI): pea Other hosts (CABI): Brassica (cabbage), sunflower, bean, maize Reported hosts (PRA): rapeseed, clover, rye, sorghum, wheat. 10 host species.	Hitchhiker species transported on imported inanimate objects, particularly vehicles, equipment, containers. Higher risk of entry on objects, lower risk on fresh commodities and nursery stock (PRA). High risk of entry for adults, lower risk for larvae/eggs. Regularly detected at the border and in surveillance traps. National surveillance programme and detection tools available. High season requirements specified for consignments from high-risk countries. Native to temperate/ subtropical parts of Asia (China, Korea, Japan, Taiwan) but has rapidly invaded North America and Europe, and reported in Chile in 2017. Potential for entry is HIGH.	Wide host range available in NZ. Is considered an arboreal species but also feeds on tree fruits, vegetables, field crops, ornamentals and native vegetation. Aggregated populations more likely to establish than individual adults. Seeks shelter to overwinter. Climate and environmental conditions in most of NZ are highly favourable for establishment. Potential to establish is HIGH.	Strong ability to disperse, strong fliers over short distances, active at night, attracted to artificial light. Long distance spread by hitchhiking on inanimate objects. Potential to spread is HIGH.	Major crop losses for maize/ corn, soyabean reported in USA since invasion, and disrupts seed development. Damages crops making them unsaleable, particularly fruit crops. Impacts crop production and lifestyle, as a nuisance pest. Chemical controls have limited effectiveness and require repeat applications, often at high doses. Pheromone traps available but have limited effectiveness. Exclusion netting an option but expensive. Biological control (Samurai wasp) approved for release if BMSB arrives. Detection tools available. Potential economic consequences can be high (PRA). Overall, 42% of arable sector value affected - $415m/$993m calculated for maize and pulses. Impact is HIGH.	H	H	H	**H**	H	**E**	https://www.cabi.org/cpc/datasheet/27377 EPPO minidatasheet: https://gd.eppo.int/taxon/HALYHA/documents MWLR: https://www.landcareresearch.co.nz/tools-and-resources/identification/pentatomidae/pentatomidae-factsheets/brown-marmorated-stink-bug-halyomorpha-halys-stal-1855/ MPI PRA: Brown marmorated stink bug, BNZ Technical paper no. 2019/43 https://www.mpi.govt.nz/dmsdocument/38075-Pest-risk-assessment-Halyomorpha-halys-Brown-marmorated-stink-bug-Technical-Paper

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3	**Fall armyworm**	***Spodoptera frugiperda*** Noctuidae: Lepidoptera	**Polyphagus.** Main hosts (CABI): beet, Brassica, lucerne, bean, sorghum, clover, maize. Other hosts (CABI): oats, fescue, sunflower, barley, ryegrass, pea, radish, rye, wheat, 16 host species.	Transported on imported plant material, or via wind dispersal from Australia. Present in North, Central, South America, Africa, India, Asia, Oceania and Australia. Incursion in NZ with detection of egg mass in March 2022, and larvae detections in April 2022. Most likely method of arrival is wind-assisted dispersal from Australia. Low-moderate likelihood of entry on commodities, highest likelihood of entry is via wind dispersal from Australia (PRA). Potential for entry is HIGH.	Has a wide host range but mainly affects Poaceae (maize, sorghum). Present throughout warmer parts of world. Tropical/sub-tropical species adapted to warmer parts of Americas. Optimal temp for larval development is 28°C. Climate matching indicates it could establish in the northern parts of NZ, with southern parts unlikely to be suitable. It is unlikely to survive NZ winters and reach the required number of generations to have the impacts that have occurred in other regions of the world. Potential to establish is MEDIUM.	Adults fly during summer, dispersal occurs during maturation period. Rapid spread in Africa attributed to strong ability to fly. Strong ability for wind-assisted dispersal, enabling long-distance spread. Wider spread potentially due to contaminated trade commodities, and/or stowed on aircraft. It is unlikely to spread widely in NZ as the climate would limit its ability to survive and spread in southern regions of NZ. Strong winds would cause dispersal offshore. Potential for spread is MEDIUM.	Damage results from leaf-eating by larvae which feed together in groups. A large population can cause defoliation and yield losses, then the larvae migrate to adjacent areas in 'armyworm' fashion. Has significant impact where it is present around the world. Has high economic impact in its native range. Larvae feeding has potential to cause 20-50% yield loss in maize. Chemicals available but control can be difficult because larvae can shelter in the plant, and resistance can develop. Lures available Potential for impact in localised areas where pest is present (PRA). Up to 39% of arable sector value affected - $389m/$993m calculated for maize host. Impact is HIGH.	H	M	M	**L**	H	**H**	https://www.cabi.org/cpc/datasheet/29810 MPI PRA: Spodoptera frugiperda, BNZ Technical paper no. 2021/05, April 2021. MPI Biosecurity Intelligence Report, Technical report no. 2021/06. https://www.mpi.govt.nz/dmsdocument/45934-Biosecurity-Intelligence-report-the-threat-of-Fall-Armyworm-natural-dispersal-from-Australia-to-New-Zealand
4	**Turnip moth**	***Agrotis segetum*** Noctuidae: Lepidoptera	**Cereals, polyphagous** Main hosts (CABI); oats, beet, Brassicaceae, carrot, sunflower, barley, lucerne, radish, rye, clover, wheat, maize. 12 host species.	Transported on plant parts (leaves, roots, stems) or soil containing larvae/eggs. Entry via grain or seeds is unlikely. Fresh produce and cut flowers may contain eggs/ larvae. Present in Europe, Africa and Asia. Not present in Americas or Australia (CABI). Potential for entry on a pathway is MEDIUM.	Wide host range, including ornamentals, available in NZ. Geographical distribution primarlly determined by temperature. Larvae prefer upper layers of soil around plants in cooler regions (CABI). Found in climates similar to NZ. Potential to establish in NZ is HIGH.	Adults are strong fliers, can fly against strong winds, wind dispersal. Negligible dispersal in other life stages. Wider spread potentially due to traded commodities (plant parts, soil material) contaminated with larvae/eggs (CABI). Potential for spread is HIGH.	Plant damage dependent on larvae instar stage. Young larvae feeding on leaves create 'window panes'. Mid-stage instar feeding on leaves, stems, stalks causes leaves to fall off and small holes in stalks/stems, feeding on tubers, roots causes small and deep holes. Late instars cause whole plants to fall over, and deep holes in root crops (beet) at/above the soil surface. Small numbers of larvae (cutworms) can cause major crop losses. (CABI). Widespread in Europe, Asia, Africa where it can cause up to 30% of crop loss (medium impact, PHA). Control with insecticides not highly effective, other control approaches needed (PHA). Up to 77% of arable sector value affected - $768m/$993m calculated for main hosts. Impact is MEDIUM.	M	H	H	**M**	M	**H**	https://www.cabi.org/cpc/datasheet/3797 PHA Contingency plan: https://www.planthealthaustralia.com.au/sci_name/agrotis-segetum/

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5	**Wheat stem rust - new races**	***Puccinia graminis* f.sp *tritici*** Pucciniaceae: Pucciniales (Ug99 races: TTKSK, TTKSY, TTTSK, TTKSF, TTKSP, (PHA))	Main hosts (CABI): Wheat, barley, oats, rye, cocksfoot, fescue, perennial ryegrass. 7 host species.	Most likely pathways are international travel and contaminated clothing (PHA). **Ug99:** First identified in Uganda in 1999, has spread to other African and Middle Eastern countries, and Iraq, Turkey, Tunisia in 2021. New strains with increased virulence have also evolved since 2006. Potential for entry on pathway is MEDIUM.	Host range is present in NZ. Stem rust is favoured by hot days (25-30C), mild nights (15-20C) with adequate moisture for night time dew (Rusttracker). Rust fungi have high potential to spread once introduced with examples of dispersal across Australia within 12 months then subsequent dispersal to NZ (PHA). Potential to establish in NZ is MEDIUM.	Rust spores are small, light and can survive for several days away from a host. Can be spread over large distances by wind and easily attach to clothing, machinery and equipment allowing movement and spread between farms and regions. Can also transfer across the world on travellers' clothing (PHA). Potential for spread is HIGH.	Ug99 has overcome stem rust resistance genes. What stem rust can cause severe damage over a large area (50-70%). Up to 60% of Australian cultivars would be susceptible (same in NZ?). Damage is greatest when disease becomes severe before grain is completely formed. Susceptible cultivars can't be grown in areas that favour disease development. Are fungicides registered in NZ effective against wheat stem rust? Wheat stem rusts have potential to cause large economic losses. Up to 32% of arable sector value affected - $317m/$993m calculated on cereal hosts. Impact is HIGH.	M	M	H	**L**	H	**H**	PHA factsheet https://www.planthealthaustralia.com.au/national-programs/grains-farm-biosecurity-program/grains-pest-fact-sheets/ https://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Wheat-stem-rust-Ug99-Business-Continuity-Plan.pdf https://rusttracker.cimmyt.org/?page_id=22
6	**Pea weevil**	***Bruchus pisorum*** Bruchidae: Coleoptera	Monophagous Peas - only known host. 1 host species.	Transported in imported pea seed. Present in North America, parts of South America, Europe, Asia and Australia (CABI). Incursion in 2016, eradicated in 2020. Potential for entry on a pathway is HIGH.	Widely distributed. Host present in NZ. Infestations of pea weevil can only occur if eggs are laid onto green pea pods in the field (CABI). Prefers tropical, subtropical and warmer parts of temperate zones. (CABI). Potential to establish in NZ is HIGH.	Spread by flying adults and infested pea seed. Adults have good flight ability, can fly up to 5km in search of pea flowers. Easily spread from trade in seed/grain because larvae develop inside the pea seed and pupae and adult remain inside. Potential for spread is HIGH.	Reduces overall yield and quality of peas. All life stages occur in the pea seed. Unconsumed part of infested seeds weigh less, taste foul, and have lower germination rates. Economic loss from lower price fetched. Fresh or dried peas can carry pea weevils or their eggs. Weevils don't attack dried or stored seed but can survive up to two years in stored seeds. Live larvae, pupae, adults and the excrement contain the alkaloid cantaridine making peas unfit for human consumption. Reduces overall yield and quality. Can cause significant yield loss (up to 10%, Cesar) (in Australia 25-30%). Approx. 2.6% of arable sector value affected (pulses) - $26m/$993m calculated on value of pea crop. Impact is MEDIUM.	H	H	H	**H**	M	**H**	https://www.cabi.org/cpc/datasheet/9907 https://cesaraustralia.com/pestnotes/beetles/pea-weevil/#:~:text=Pea%20weevil%20is%20a%20major,South%20Australia%20in%20recent%20years.

Notes: [1] Assessment criteria in Appendix 2, [2] where no information was available (establishment, spread), the potential was scored M (medium).

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