Australian Government
Department of Agriculture

Ref: D19/638051

Ms Niki Ford
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Dear Ms Ford

Thank you for the submission from Australian Organic of 19 April 2018 with comments on the *Draft review of import conditions for brassicaceous crop seeds for sowing into Australia*.

Following consideration of your comments and further discussion with the organic industry, we have included other pest management options (e.g. heat treatment and seed testing) in the final report that are suitable for both the organic and non-organic (seed) industries. A summary of our responses to this and other issues raised by stakeholders is enclosed with this letter. If you would like to discuss our responses further, I would be happy to organise a teleconference with your organisation.

The next step in the risk analysis process is to issue the final report. We expect to publish the final report on 13 September 2019. The final report will include our responses to all technical comments received from stakeholders, as well as our consideration of the alternative risk management options proposed by stakeholders.

The publication of the final report is the end of the process for the review of import conditions for brassicaceous vegetable seeds.

We are currently preparing the final report for cucurbitaceous vegetable seeds. The views presented by the organic and non-organic industries on this review will be taken into consideration for the final report for cucurbitaceous vegetable seeds.

Thank you again for your contribution towards finalising this report.

Yours sincerely

G. V-Smith

Dr Gabrielle Vivian-Smith
Assistant Secretary
Plant Sciences and Risk Assessment

5 September 2019

Enc. Response to comments on the *Draft review of import conditions for brassicaceous crop seeds for sowing into Australia*

Australian Government
Department of Agriculture

Response to comments on the *Draft review of import conditions for brassicaceous crop seeds for sowing into Australia*

We received comments from a number of stakeholders including from industry, trading partner countries, and state and territory governments.

The key technical issues raised, and our responses, are provided below. References that are cited below are listed in full in the final report.

Pathway association

Stakeholders suggested that further evidence was required to support the assessments that the fungal pathogens, *Colletotrichum higginsianum* and *Fusarium oxysporum* f. sp. *raphani* (*F. o.* f. sp. *raphani*) are seed-borne in brassicaceous hosts.

Colletotrichum higginsianum—three references (Chinese Vegetable Network 2019; Richardson 1990; Rimmer, Shattuck & Buchwaldt 2007) were cited in the draft report in support of *Colletotrichum higginsianum* being seed-borne. Daly & Tomkins (1997), Damicone (2017), Li (1989) and Scheffer (1950) are also added to the final report as additional evidence that *Colletotrichum higginsianum* is seed-borne in radish and turnip.

The Chinese Vegetable Network (2019) stated that *Colletotrichum higginsianum* overwinters in plant debris and seed, and the pathogen can be spread through infected seeds of *Brassica oleracea, Brassica rapa* and *Raphanus sativus*. The quality of this reference was questioned. A translation of the relevant details can be provided on request.

The *Annotated List of Seed-borne Diseases* provided authority that *Colletotrichum higginsianum* is seed-borne in *Raphanus sativus* (Richardson 1990). This handbook (4th Edition) is published by the International Seed Testing Association. The quality of this reference was challenged on the basis that some primary references are not accessible. It is acknowledged that some older references may not be accessible from the website. However, all information contained in this edition has been placed into a data-bank for improved access and to bring this book up to date.

Rimmer, Shattuck and Buchwaldt (2007) was used to support the seed-borne association for *Colletotrichum higginsianum*. Rimmer, Shattuck and Buchwaldt (2007) stated that '*Colletotrichum higginsianum* has been found in seeds of radish and may be disseminated with seeds of other hosts.' The quality of the original references to support this statement was questioned. We note that this publication is a joint effort of 59 international plant disease experts and has been subject to peer review.

Additional evidence that *Colletotrichum higginsianum* is seed-borne was added in the final report. Scheffer (1950), concluded that *Colletotrichum higginsianum* is seed-borne on *Raphanus sativus.* Scheffer (1950) isolated *Colletotrichum higginsianum* from 16% of infected radish seeds and confirmed its seed to seedling transmission. Furthermore, numerous other peer reviewed references cite *Colletotrichum higginsianum* as a seed-borne pathogen of radish (Agarwal & Sinclair 1996; George 2009; George 2011; Kidane 1993). *Colletotrichum higginsianum* is also seed-borne in *Brassica rapa* (Daly & Tomkins 1997; Damicone 2017; Holliday 1995). Infected seed was considered to be the most important pathway for the long-distance transmission of *Colletotrichum higginsianum* in *Brassica rapa* (Li 1989).

We have concluded that there is sufficient evidence that *Colletotrichum higginsianum* is seed-borne in radish (*Raphanus sativus*) and turnip (*Brassica rapa*) to justify biosecurity measures to prevent it from entering Australia.

Stakeholders suggested that the evidence provided in the draft report for *Colletotrichum higginsianum* being seed-borne in *Brassica oleracea* was not robust. In the preparation of the final report, we further reviewed available evidence to support the seed-borne status of the two identified quarantine pathogens. Consequently, in contrast to the action proposed in the draft report, *Brassica oleracea* has been removed from the final report on the basis that there is insufficient evidence that *Colletotrichum higginsianum* is a seed-borne pathogen in this host.

- *Brassica oleracea* is a well-studied host, but the body of available evidence for seed association with *Colletotrichum higginsianum* is limited to only one reference (Chinese Vegetable Network 2019).
- The single reference presents a statement to support the association of *Colletotrichum higginsianum* with *Brassica oleracea* seeds but does not provide underpinning evidence.

Three other references (Caesar, Lartey & Caesar-TonThat 2010; Farr & Rossman 2019; Zhuang 2005) provide evidence that *Colletotrichum higginsianum* can naturally infect *Armoracia, Brassica* and *Raphanus* species. Reference to work by Takeuchi, Horie and Shimada (2007) has been added to the final report that supports *Eruca vesicaria* (cultivated rocket) being a natural host. These references were not used to support a seed pathway association in the review.

***Fusarium oxysporum* f. sp. *raphani* (*F. o.* f. sp. *raphani*)**—*Fusarium oxysporum* forms a complex of cosmopolitan fungi (the *Fusarium oxysporum* species complex, FOSC) (Edel-Hermann & Lecomte 2018). Collectively, members of the complex can infect a broad range of hosts, but each *Fusarium oxysporum forma specialis* (f. sp.) usually has one or a few closely related hosts (Edel-Hermann & Lecomte 2018).

Of the more than 200 ff. spp. of *Fusarium oxysporum* described so far, *F. o.* f. sp. *raphani* has been described as the causal agent of fusarium wilt on radish (*Raphanus sativus*) (also known as radish yellows) (du Toit & Pelter 2003; Kim et al. 2017; Toyota, Yamamoto & Kimura 1994) and wilt of wild (*Diplotaxis muralis*) and cultivated (*Eruca vesicaria*) rocket (Catti et al. 2007; Garibaldi, Gilardi & Gullino 2006; Garibaldi et al. 2004; Gullino, Gilardi & Garibaldi 2014b; Srinivasan et al. 2012). Kim et al. (2017) verified *F. o.* f. sp. *raphani* as the causal agent of fusarium wilt on radish by polymerase chain reaction techniques and pathogenicity assays.

Three references (Bomberger 2013; Garibaldi, Gilardi & Gullino 2006; Garibaldi et al. 2004) were cited in the draft review to support *F. o.* f. sp. *raphani* being seed-borne in *Raphanus sativus* and *Eruca sativa*. Rimmer, Shattuck and Buchwaldt (2007) was cited as evidence that *F. o.* f. sp. *raphani* can naturally infect *Brassica* species causing Fusarium wilt, not to prove seed pathway association.

Bomberger (2013) recovered *Fusarium oxysporum* from samples of commercial stock seed of radish and daughter seed collected from wilted parent plants. Bomberger (2013) also reported the association of *Fusarium oxysporum* with red radish (*Raphanus sativus*) in the field, and confirmed that *Fusarium oxysporum* isolates obtained from affected radish plants were pathogenic on radish, consistent with the causative agent being *F. o.* f. sp. *raphani*. However, extended host range tests of these isolates were not undertaken, meaning that the possible involvement of other f. sp. of *Fusarium oxysporum* could not be technically excluded.

Nevertheless, and despite elements of inconsistency in the scientific literature (Bosland, Williams & Morrison 1988; du Toit & Pelter 2003), it is considered reasonable to conclude that *Fusarium oxysporum* isolated from red radish seeds by Bomberger (2013) was *F. o.* f. sp. *raphani*. Consequently, it is also considered that there is sufficient evidence to conclude that radish seeds are a potential source of inoculum for *F. o.* f. sp. *raphani.*

Garibaldi et al. (2004) and Garibaldi, Gilardi and Gullino (2006) were cited to support the seed pathway association of *F. o.* f. sp. *raphani* on cultivated rocket seeds. Garibaldi et al. (2004) and Garibaldi, Gilardi and Gullino (2006) claimed that seed transmission on wild and cultivated rocket seeds contributed to the sudden appearance and rapid spread of the disease in Italy. Garibaldi et al. (2004) isolated the *F. o.* from commercial rocket seeds, carried out pathogenicity tests of the isolates, and confirmed some of the isolates were pathogenic on wild and cultivated rocket. Garibaldi, Gilardi and Gullino (2006) later used isolates from infected stem tissue of rocket to conduct pathogenicity studies and concluded *F. o.* f. sp. *raphani* to be the causal agent of fusarium wilt on both cultivated and wild rocket in Italy as reported in 2004. Before the publication of this paper, it was not clear which f. sp. caused wilt on rocket.

Catti et al. (2007) and Srinivasan Srinivasan et al. (2012) also concluded *F. o.* f. sp. *raphani* as the causal agent of fusarium wilt on rocket. Movement of the pathogen via seed appears to be the only credible explanation for the sudden appearance and rapid spread of the disease in Italy (Catti et al. 2007; Garibaldi, Gilardi & Gullino 2006; Garibaldi et al. 2004). Srinivasan et al. (2012) reported that low levels of genetic variations among highly virulent strains of *F. o.* f. sp. *raphani* infecting cultivated rocket in Italy is due to a recent introduction of the pathogen into Italy, probably with a contaminated seed lot. Gullino, Gilardi and Garibaldi (2014b) in their review, reiterate that seed transmission contributed to the spread of the fusarium wilt on rocket in Italy. Consequently, it is considered that there is sufficient evidence to conclude that cultivated rocket seeds are a potential source of inoculum for *F. o.* f. sp. *raphani*.

Stakeholders suggested that although contaminated seed might introduce *F. o.* f. sp. *raphani* into the soil, it may not establish and spread in Australia, as there is no information demonstrating survival of the pathogen in soil and subsequent potential infection of a host. It is known that *F. o.* f. sp. *raphani* can colonize plant debris, persist in soil as chlamydospores, is wind disseminated and likely to survive dispersal and spread into new areas (du Toit & Pelter 2003; Toyota, Yamamoto & Kimura 1994). In many locations, the pathogen has established as a soil inhabitant and caused significant losses (du Toit & Pelter 2003).

Recent outbreaks of several seed-borne diseases have highlighted the risk of seed as a potential pathway for pathogens and the need for appropriate phytosanitary regulation. For example, by the time it was recognised that basil seeds provided a pathway for *F. o.* f. sp. *basilici*, the fungus had spread to many countries, including Australia (Martini & Gullino 1991; Vannacci et al. 1999). Demand for basil production in North America led to seed imports and in the 1990s the disease emerged in the USA (Wick & Haviland 1992). Similarities exist between *F. o.* f. sp. *basilici* and *F. o.* f. sp. *raphani* in their mode of transmission, and both pathogens infest the seed coat with no visual symptoms.

Based on the weight of evidence, it is concluded that *F. o.* f. sp. *raphani* is seed-borne and could enter Australia through infected radish and rocket seeds.

Economic consequences

Stakeholders suggested that the economic consequences for *Alternaria malorum* (syn. *Cladosporium malorum*) and *Raphanus sativa virus* (1, 2, and 3) should be considered further in the pest categorisation process.

Alternaria malorum (syn. *Cladosporium malorum*)—Goetz and Dugan (2006) was cited in support of a claim that this pest has potential for economic consequences. The reference stated *A. malorum* has been reported on the seeds of several hosts. However, no information about losses caused by this fungus was provided. The fungus was reported as pathogenic on ripe apple and cherry fruits, but this resulted from artificial inoculation (Goetz & Dugan 2006). Therefore, this reference does not support the claim.

Raphanus sativa virus (1, 2 and 3)—Schmelzer (1976) was cited in support of a claim that these viruses have potential for economic consequences. The reference was about a mosaic disease in garden radish (*Raphanus sativus* L. var. *sativus*) that had spread quickly to cause substantial crop losses. Several viruses were isolated from the diseased plants, including *Cauliflower mosaic, Cabbage black ring, Turnip yellow mosaic, Turnip crinkle, Turnip rosette* and *Radish mosaic viruses* (Schmelzer 1976). However, no isolate was confirmed as *Raphanus sativa virus* 1, 2 or 3. Therefore, this reference does not support the claim.

Genus level regulation

Stakeholders suggested that all pathogens in a genus should be considered to be seed-borne on all hosts if one or more pathogen species within that genus is seed-borne in any of their hosts. These genera include *Alternaria, Cercospora* and *Cladosporium*.

It is acknowledged that some species in the genera *Alternaria, Cercospora* and *Cladosporium* are seed-borne in several hosts. However, for most species in these genera there is no scientific evidence that they are seed-borne in any brassicaceous vegetable species under review.

Additionally, several species in these genera are not of biosecurity concern for Australia as they are present in Australia and are not under official control.

The WTO SPS Agreement (WTO 1995) requires members to set the least trade restrictive phytosanitary measures possible to achieve an appropriate level of protection. ISPM 11 states that the taxonomic unit for a pest is generally the species (FAO 2019c). In addition, the use of a higher or lower taxonomic level (such as a genus listing) should be supported by scientifically sound rationale (FAO 2019c).

These three pathogen genera are well studied; however, there is no evidence indicating that they are seed-borne in the genera of brassicaceous vegetables covered by this review. The body of available evidence for species in these pathogen genera being seed-borne is also limited.

Based on the weight of available evidence, it is considered that regulating the entire genera of *Alternaria, Cercospora* and *Cladosporium* is not technically justified. Consistent with ISPM 11 (FAO 2019c) and the SPS Agreement (WTO 1995), these pathogens were not considered at the genus level.

Regional pest status

Stakeholders suggested that *Alternaria japonica* and *Ditylenchus dipsaci* are present in Australia's eastern states, but not recorded in Western Australia, and that their entry is restricted or prohibited under Western Australia's legislation, the *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2018).

However, *Alternaria japonica* and *Ditylenchus dipsaci* have been recorded in Western Australia (Goss 1964; Nobbs 2003; Plant Health Australia 2019). Therefore, these pathogens must be under 'official control' to justify phytosanitary regulations.

To meet the definition of 'official control', two major requirements need to be satisfied: active enforcement of mandatory phytosanitary regulations (official rules such as state/territory legislation) and the application of mandatory phytosanitary procedures (officially prescribed methods for implementing phytosanitary regulations) with the objective of pest eradication or containment. At a minimum, official control programs must demonstrate program evaluation and pest surveillance to determine the need for, and effect of, control.

The department was not provided with evidence that demonstrates controls are in place to prevent movement of host material of these pathogens, or to prevent the spread of these pathogens from known infested areas to other areas in the state. Consequently, these pathogens are not considered to be under official control in Western Australia.

It was also suggested that *Alternaria cheiranthi, Arabis mosaic virus, Broad bean wilt virus, Cercospora brassicicola, Fusarium poae, F. o.* f. sp. *conglutinans, Peronospora lepidii, Pseudomonas syringae pv. alisalensis, Pyrenopeziza brassicae, Rhodococcus fascians, Tobacco streak virus, Xanthomonas campestris* pv. *aberrans, Xanthomonas campestris* pv. *armoraciae* and *Xanthomonas campestris* pv. *raphani,* are not recorded in Western Australia, are associated with seeds, and require further risk assessment.

We adhere to the internationally accepted guidelines for a 'pest free area' (PFA). For recognition of a PFA, a submission demonstrating area freedom is required, as outlined in ISPM 4 (FAO 2017b).

In accordance with ISPM 11(FAO 2019c), to assess the probability of entry, an association of the pest with the import pathway is required. In this case, the pathogens must be recorded as seed-borne in one or more of the brassicaceous vegetables under review. However, the references provided by the stakeholder do not provide evidence to support the pathway association of these pathogens with seeds of brassicaceous vegetable species under review. Therefore, these pathogens are not considered further in the pest categorisation process.

Organic status of fungicide treated seeds

Stakeholders suggested that a mandatory fungicidal treatment proposed in the draft report would impact the organic status of imported seeds. Several potential alternative options to the mandatory fungicidal treatment were proposed for consideration.

As advised by the Australian organics sector, the majority of seeds used by organic growers are conventionally produced and follow the same import process as for conventional seeds. Therefore, the majority of imported seeds used by the Australian organic growers may not be strictly organic because seed produced conventionally is unlikely to meet Australia's National Standard for Organic and Bio-Dynamic Produce (NSOBP) (DAWR 2016). It is also likely that these seeds may have been exposed to fungicides.

This review has identified two fungal pathogens (*Colletotrichum higginsianum* and *F. o.* f. sp. *raphani*) of biosecurity concern that are associated with brassicaceous vegetable seeds for sowing. The economic consequences that would result from the introduction of these pathogens to Australia would impact both the organic and non-organic production sectors.

Alternative options are provided for both organic and non-organic production sectors to achieve the appropriate level of protection for Australia (Section 4.4). Supplementary details of the potential range of options raised by stakeholders and their consideration are provided in Appendix 3 of the final report.

Fungicidal seed treatment

Stakeholders suggested that more details of the recommended fungicidal treatment, including specific details of the required fungicide, be provided in the report.

ISPM 38 '*International movement of seeds*' recommends that phytosanitary import requirements do not specify chemical products, active ingredients or exact protocols (FAO 2017a). Therefore, consistent with ISPM 38, we did not prescribe the names of fungicides for seed treatment. Fungicidal seed treatment is an integral part of the modern seed production system. Fungicidal seed treatments protect seedlings from both seed-borne and soil-borne pathogens. Vegetable seeds are generally treated with a broad spectrum fungicide such as Thiram, Carboxin plus Thiram or another product with equivalent chemical ingredients.

Thiram is registered as a seed treatment fungicide worldwide on a variety of crops including brassicaceous vegetables such as broccoli, Brussels sprouts, cabbage, cauliflower, kale, radish, rape seed, swede and turnip (Anon 2018). It has been used to control a broad range of seed-borne pathogens, including *Colletotrichum* spp. (Thomas & Sweetingham 2003) and *Fusarium oxysporum* (Falloon 1982, 1987). Soaking seeds in 0.2 % suspension of thiram has been shown to eradicate 11 out of 13 tested seed-borne fungal pathogens (Maude, Vizor & Shuring 1969).

Historically, Australia has been importing brassicaceous vegetable seeds treated with a broad spectrum fungicide such as Thiram, and neither *Colletotrichum higginsianum* nor *Fusarium oxysporum* f. sp. *raphani* is reported in Australian brassicaceous vegetables. This empirical evidence supports an assessment that fungicidal treatment is effective in managing the risk posed by these fungal pathogens.

Polymerase Chain Reaction (PCR) testing of seeds

It was suggested that seed testing by PCR to verify freedom from the identified pathogens may be an appropriate measure.

Seed testing by PCR to verify freedom from identified seed-borne pathogens is regularly used as an effective and least trade restrictive measures against other pathogens.

Colletotrichum higginsianum—currently, there is no PCR test protocol suitable for the detection of *Colletotrichum higginsianum* on commercially traded seeds. However, if one were to become available, it is likely that this could provide an alternative measure.

Fusarium oxysporum* f. sp. *raphani—the PCR test protocol described by (Kim et al. 2017) is reported to be effective for the detection of *F. o.* f. sp. *raphani.* This PCR testing protocol is in the process of validation. When validated, the department's Biosecurity Import Conditions (BICON) database will be amended and testing (on-shore or off-shore) can commence.

Heat treatment of seeds

It was suggested that heat treatment could provide an alternative measure to the proposed fungicidal treatment.

Dry heat treatment—dry heat treatment (DHT) has been applied to various vegetable seeds to mitigate the risk of seed-borne pathogens (Bang et al. 2011; Kubota, Hagiwara & Shirakawa 2012; Schmitt et al. 2009). Nakamura (1982) stated that DHT of vegetable seeds was routinely used by seed companies on watermelon, bottle gourd and tomato in Japan. Lecoq and Desbiez (2012) also noted that many of the commercial cucurbit seeds produced in the Mediterranean region are heat treated.

Specifically, DHT has been successfully used to eradicate *Colletotrichum* species from seeds.

- *Colletotrichum orbiculare* was eradicated from four vegetable crop seeds by DHT at 70°C for 90 minutes (Meng 2014).
- DHT at 70°C for 90 minutes was optimal for the eradication of *Colletotrichum orbiculare* from cucumber seeds (Shi et al. 2016).

Consequently, DHT at 70°C for 90 minutes is recommended for control of *Colletotrichum higginsianum.*

There is no known scientific evidence that DHT is efficacious for the eradication of any *Fusarium oxysporum* species from seeds. For example, Bennett and Colyer (2010) incubated cotton seeds infected with *Fusarium oxysporum* f. sp. *vasinfectum* in dry heat at 60, 70, and 80°C for 2 to 14 days. None of these treatments were efficacious at eliminating this pathogen from cotton seeds.

Consequently, DHT is not recommended for control of *F. o.* f. sp. *raphani*.

Hot water treatment—Nega et al. (2003) demonstrated that hot water treatment (HWT) is an efficacious treatment to control seed-borne pathogens.

Zhou et al. (2002) investigated the effects of HWT on the growth, sporulation and conidial germination of *Colletotrichum higginsianum.* Their results showed that the lethal temperatures for conidia were 53°C for 10 min or 55°C for 5 min. HWT has also been shown to be efficacious in eradicating other *Colletotrichum* species from seeds of other hosts.

- Babadoost (1992) recommended HWT of seeds of cabbage, broccoli, Brussels sprouts, cauliflower, collards, kale, kohlrabi, mustard, radish and turnip at 50°C for 20 – 25 minutes as efficacious against several pathogens including anthracnose (*Colletotrichum* spp.).

- Siang et al. (1956) demonstrated that complete control of anthracnose of kenaf (*Colletotrichum hibisci*) could be achieved by treating the seed at 50°C for 15 – 20 minutes after presoaking at 20°C for 24 hours.

Consequently, HWT at 53°C for 10 minutes or 50°C for 20 minutes is recommended for the treatment of *Colletotrichum higginsianum.*

However, there is no scientific evidence that HWT can eradicate any *F. o. formae speciales* from seeds without a significant reduction of seed germination.

- Doan and Davis (2015) tested a series of seed treatments using hot water at various temperatures (55 to 90°C) for various lengths of time (105s to 20 min) on cotton seed infected by *Fusarium oxysporum* f. sp. *vasinfectum*. The pathogen was completely eliminated by treating the seed at 80°C for 20 min. However, seed germination was reduced by 95% and vigour was reduced by 98%.

Consequently, HWT is not recommended for *F. o.* f. sp. *raphani*.

Organic treatments described by Meena et al. (2013)

It was suggested that further consideration be given to non-fungicidal treatments as considered by Meena et al. (2013) to minimise potential impacts to the organic sector.

Meena et al. (2013) reported the use of various treatments to reduce overall pest incidence in field trials in India. However, the targeted pests and treatments were not explicitly defined in the paper. In addition, neither individual treatments nor the combinations of seed treatments were demonstrated to be efficacious to manage seed-borne pathogens. Therefore, this review does not provide sufficient information to inform the selection of appropriate measures.

Other potential organic treatments for seeds

It was suggested that other organic seed treatments may be appropriate as measures to mitigate the risk of *Colletotrichum higginsianum* and *F. o.* sp. *raphani*. These included biocontrol agents, biopesticides, essential oils/thyme oil, or chitosan.

These organic seed treatments were carefully considered as potential alternative options. The details of potential options and their consideration are provided in Appendix 3 of the final report.

Limitations of alternative measures (e.g. hot water treatment)

It was indicated that the organic sector was concerned that commercial practicalities and excessive costs will rule out many potential alternatives (e.g. hot water treatment) to mandatory fungicidal treatment.

It is acknowledged that not all risk management options will be suitable for, or acceptable to all members of the vegetable seed industry. Therefore, all potential alternative options proposed by stakeholders were considered (see Appendix 3 in the final report). Based on available scientific evidence, very few alternatives to fungicidal treatment are considered suitable as risk management measures, with the exceptions of PCR testing and heat treatment.

The limitations of hot water treatment, both practically and scientifically, are also acknowledged. Therefore, it is recommended that stakeholders undertake pilot heat tolerance studies on seeds prior to using the recommended temperature and time combinations on large batches. Miller and Lewis Ivey (2018) provided a range of recommended hot water temperature and exposure times required for various brassicaceous vegetable seeds to eradicate bacterial pathogens in organic production systems. These included treatment at 50°C for 20 minutes for broccoli, cauliflower, collard, kale, kohlrabi, rutabaga and turnip seed, and for 15 minutes for mustard, cress and radish seed.

Nega et al. (2003) also demonstrated that HWT can be an alternative treatment method to control seed-borne pathogens in organic farming. According to Nega et al. (2003), seed-borne pathogens could be reduced without significant losses of germination by using HWT at 50°C for 20 to 30 minutes, and up to 53°C for 10 to 30 minutes. At higher temperature, however, treatment time needed to be lowered to avoid reduced germination of sensitive seeds.

Underpinning supporting evidence and references

It was suggested that there was over-reliance on citing the fungal database of Farr and Rossman (2019) rather than the underpinning supporting references.

In principle, it is acknowledged that primary references should be cited in preference throughout risk assessments. However, Farr and Rossman (2019) was cited in the pest categorisation process only to support the association of a pest with the genera under review, or the geographic distribution of that pest. Original references were cited in support of specific pathway associations (i.e. seed-borne associations) and economic consequences. This ensured that all potential pests associated with brassicaceous vegetables were included in the initial step of the risk analysis.

Farr and Rossman (2019) is a reputable USA national fungus-host database, which is managed by the USA Department of Agriculture. It is one of the most comprehensive collections of fungal pathogen data in the world, and a respected source of evidence to initiate the pest categorisation process. However, references cited by the database often cannot not be accessed easily. For reasons of transparency, the database is cited as it is easily publically accessible.

Most importantly, primary references were always used for the later steps of risk analysis, such as the assessments of risk and economic consequences, and for supporting the determination of the risk ratings.

Sprouting and micro-greens for human consumption

It was noted that sprouting and micro-greens producers are also reliant on imported seeds, and suggested that an exemption should be considered where seeds are imported for human consumption. It was also stated that sprouts produced for therapeutic use may not be able to meet required residue limits.

Under existing import conditions, brassicaceous vegetable seeds imported for sprouting or micro-greens are subject to standard seeds for sowing conditions. Therefore, any changes of import requirements for brassicaceous vegetable seeds for sowing will have potential to affect seeds imported for sprouting and micro-greens.

It is acknowledged that fungicidal treatment may not be a viable option for sprouting and micro-greens for human consumption. After consultation with stakeholders, alternative options have been recommended in this final report, such as PCR testing or heat treatment that do not involve use of any chemicals. In addition, seeds for sprouting and micro-greens production will be exempt from the additional measures if imported directly to be germinated at a production facility operated under an approved arrangement.

Potential impacts of fungicide on the environment

It was suggested that the draft review did not fully consider the environmental impacts of imported seeds being treated with a broad spectrum fungicide.

It is acknowledged that it has been suggested (White & Hoppin 2004) that farmers may be exposed to residual fungicide treatments on seeds during seed handling practices.

Fungicidal seed treatment is routinely applied in Australian primary industries. The consideration and approval of agricultural chemicals are the responsibility of the Australian Pesticides and Veterinary Medicines Authority (APVMA). All safety directions concerning the use of fungicides authorised by the APVMA should be followed.

Potential impacts of some plant pests on human health

It was suggested that the potential impacts of some plant pests on human health are not adequately considered in the pest risk assessments, as illustrated by the genus *Chaetomium*.

We are aware of the potential for impacts of some plant pathogens on human health, and where this may occur it is considered in the pest risk analysis under 'Indirect pest effects' (Chapter 2). One of the most common ways in which plant pathogens can affect humans is through the secretion of toxic metabolites, such as of 'mycotoxins' by fungi infecting plant products (Al-Sadi 2017). Additionally, airborne fungi have been reported to play a role in causing allergy and infections in susceptible people (Hung et al. 2011).

ISPM 11 provides guidelines for determination of quarantine pest status, and for conducting a pest risk analysis. According to ISPM 11, in the case of pest effects (direct and indirect effects), specific evidence is needed (FAO 2019c). It is acknowledged that *Chaetomium*-like fungi can cause opportunistic infections in humans. However, there is no evidence that any of the *Chaetomium* species listed in the pest categorisation (Appendix 1 of the final report) cause infections in humans. Therefore, human impacts were not addressed in the pest categorisation for the identified *Chaetomium* species.

Acknowledging the potential for some plant pathogens to cause human health issues, such as toxicity or allergenicity, we will continue to review the literature in the future and address any human impacts where specific evidence becomes available.

Potential long term impacts of fungicide

Stakeholders suggested that the draft review did not fully consider the long-term efficiency of the proposed seed treatment with a broad spectrum fungicide. Stakeholders suggested that over time the effectiveness of fungicides may decline due to resistance development.

Fungicidal seed treatments are an integral part of the modern seed production system, and they have been used in Australia over many decades. Potential long term impacts from fungicides such as Thiram, which has multiple modes of action, is low (Hahn 2014; Wyenandt et al. 2016). In addition, of all brassicaceous vegetable species, only three are recommended for additional measures, of which fungicidal treatment is one option. According to CropLife Australia (2018), there is no indication that *Fusarium* or *Colletotrichum* spp. has developed resistance to fungicides.

Permissibility of removing fungicides prior to planting

Stakeholders requested clarification of whether treated seeds could be washed to remove the fungicide, and advised that this may be a common practice in the organics sector.

A broad spectrum fungicidal treatment is recommended as an option to mitigate the risks posed by the identified quarantine pests (*Colletotrichum higginsianum* and *Fusarium oxysporum* f. sp. *raphani*) to a level that achieves the ALOP for Australia. As removing the fungicide from the seed prior to planting interferes with the treatment efficacy, we do not permit this. However, other options, such as heat treatment or PCR testing that do not involve use of any fungicides have also been recommended in the final report. Therefore, if the organic status of seeds is a concern, stakeholders can source seeds imported under heat treatment or PCR testing, or source seeds produced domestically.

Establishment of an Australian seed bank

Stakeholders suggested that establishing an Australian seed bank is a potential alternative to heavy reliance on imported vegetable seeds and organic derogations.

Australian vegetable growers (organic or conventional) have the choice to import seed, use their own, or purchase locally produced seeds. Establishment of a seed bank is beyond the scope of this review.