



Name and Description of Measure	
Name of Measure	Irradiation Treatments for Quarantine Insects Associated with Apple
Measure Type	Irradiation
Active Ingredient	N/A
Schedule	<p>(1) A minimum absorbed radiation dose of 150 Gy to prevent the emergence of adult fruit flies.</p> <p>(2) Minimum absorbed dose of 250 Gy to prevent emergence of viable adults from irradiated eggs, larvae and pupae of tortricid moths and the eggs/larvae of other lepidopterous pests.</p> <p>(3) A minimum absorbed dose of 400 Gy - all other insects.</p>
Target Pest	<p>Eggs, larvae and puparia of tephritid fruit flies (all Schedule 1):</p> <ol style="list-style-type: none"> 1. <i>Anastrepha fraterculus</i> 2. <i>Anastrepha serpentina</i> 3. <i>Bactrocera tryoni</i> 4. <i>Bactrocera dorsalis</i> 5. <i>Ceratitis rosa</i> 6. <i>Rhagoletis pomonella</i> 7. <i>Rhagoletis species</i> <p>Eggs, larvae, pupae and adults of lepidopteran pests (Schedule 2 unless stated otherwise):</p> <ol style="list-style-type: none"> 8. <i>Acleris senescens</i> 9. <i>Carposina sasakii</i> (Sched. 3) 10. <i>Choristoneura rosaceana</i> 11. <i>Grapholita inoptinata</i> 12. <i>Grapholita prunivora</i> 13. <i>Platynota stultana</i> <p>Eggs, larvae and adults of the coleopterous species (Schedule 3):</p> <ol style="list-style-type: none"> 14. <i>Anthonomus quadrigibbus</i> 15. <i>Naupactus xanthographus</i> <p>Scales of the diaspid pests (Schedule 3):</p> <ol style="list-style-type: none"> 16. <i>Lepidosaphes ussuriensis</i> 17. <i>Lopholeucapsis japonica</i>

Included in ISPM 28	<p>Tephritid species 2, 3 and 6 specifically (Annexes 3, 5 and 8).¹⁻³</p> <p>Tephritid species 1, 4, 5 and 7 generically (Annexes 7 and 39).^{4,5}</p> <p>Tortricid species 8, 10-13 generically (Annex 40).⁶</p> <p><i>Carposina sasakii</i> specifically (Annex 38).⁷</p>
Other information (<i>Please complete as many fields as possible</i>)	
Is there quantitative or qualitative evidence to indicate the measure is effective	

Irradiation of food commodities as a phytosanitary measure (PI, Phytosanitary Irradiation) has the advantage (alongside methyl bromide fumigation) of having broad-spectrum activity against almost all regulated arthropod pests of phytosanitary concern.⁸ Its use as a Quarantine Pre-Shipment (QPS) treatment has grown markedly over the last two decades in response to the progressive withdrawal of methyl bromide.

The USA approves a generic minimum absorbed dose of 150 Gy for tephritid fruit flies.^{9,10} Basic research has validated the ISPM 28 minimum dose (150 Gy) against a range of tephritids from the genera *Anastrepha*, *Bactrocera*, *Ceratitis* and *Rhagoletis*.^{9,11–15} Effective doses for *R. pomonella* in apple have been determined and falls within the dose specified by ISPM 28 and values set out in the USDA-APHIS Treatment Manual.^{10,15,16} Effective doses against *B. tryoni* have also been determined to similarly fall within the absorbed dose specified by ISPM 28.^{8,17}

Disinfestation of tortricid larvae and *C. sasakii* (Carposinidae) from fruit using PI is included in two Annexes to ISPM 28 (PT 38 and PT 40).^{6,7} An extensive body of literature indicates that a generic dose of 250 Gy is effective as a means of preventing the adult emergence of tortricids across several fruit commodities.^{11,18–29}

The USDA-APHIS recommends a dose of 250 Gy for the eggs and larvae (not pupae and adults) of lepidopterous insects other than tortricids.^{30,31} As such, non-tortricid moth species are similarly likely to be disinfested by the 250 Gy absorbed dose indicated for tortricids (although, see below). The USA mandates higher doses for certain specified country/commodity combinations up to 400 Gy (see Treatment Manual schedules¹⁰). There is also the provision for a 400 Gy dose for all other insects, such as coleopterous pests. This higher dose has been proposed to be used as a generic treatment for all moths (and mites) which would, in effect, render this dose useful for all insects of phytosanitary concern associated with apple.²⁶ Such an approach has already been adopted in Australia where a minimum absorbed dose of 400 Gy effectively serves as a “catch-all” that can be used to disinfest all insects potentially associated with imported fresh fruit consignments.⁸

The curculionid beetles of phytosanitary concern listed above (*A. quadrigibbus* and *N. xanthographus*) have received little specific attention with respect to PI treatments. However, as members of the Coleoptera, they derive from an insect order where a number of economically important commodity-infesting species have been examined.^{32,33} Data indicates that the 400 Gy would be effective against any curculionids present within a consignment and, hence, such a dose would be efficacious as a QPS treatment for *A. quadrigibbus* and *N. xanthographus*.³⁴ Limited investigations into the response of scale insects to irradiation indicate that lower absorbed dose of 250 Gy will likely be effective against diaspid scale insects listed here (*L. ussuriensis* and *L. japonica*).³⁵

Does experience from use in international trade indicate that the measure is effective?

The geographic distributions of the insect pests listed above means that the irradiation schedules detailed here are applicable to apples originating from a large proportion of major apple producing countries, covering *circa*. 3 million tonnes of exports (e.g China, Chile, New Zealand, Argentina).

Australia, New Zealand (Food Standards Australia and New Zealand (FSANZ)) and the USA (USDA-APHIS) allow or mandate the use of ionizing radiation for quarantine/non-quarantine purposes for a range of insect pests associated with fresh fruit including the fruit flies *A. fraterculus*, *B. dorsalis* and *B. tryoni*.^{8,36–38.}

Data from 2015-16 indicates that the Australian State of Queensland exported almost 1500 tonnes of irradiated fruit to New Zealand and just over 1000 tonnes to other countries.³⁹ Overall, in 2017-18, Australia irradiated >4000 tonnes of produce for all purposes (QPS, food hygiene etc.).⁴⁰ Australia commenced exports of irradiated foodstuffs to New Zealand in 2004.⁸ Currently it has been estimated that between 0.3 and 8% of fruit and vegetables consumed in Australia and New Zealand are irradiated, depending on commodity.⁴¹

In 2015 the USA imported of over 15,000 tonnes of irradiated fruit and treated approximately 450 tonnes of consignments on arrival.³⁹

India first started phytosanitary irradiation in 2007 in response to the USA permitting the import of irradiated mangoes, of which around 600 tonnes are currently exported from the subcontinent to the USA annually.⁴²

Vietnam irradiates a number of fruit types for export to Australia, USA and New Zealand, amounting to >7,700 tonnes.⁴³

Other countries that currently irradiate fresh fruit for export include China and Thailand. China is currently the largest producer of irradiated food although the majority of the volume treated is for domestic (non-QPS) purposes.⁴⁴ Thailand has been exporting several types of irradiated fruit to the USA for since 2007 with volumes approaching 2000 tonnes in some years.⁴⁵

The International Atomic Energy Agency (IAEA) continues to support PI for the treatment of food as a means of overcoming current trade restrictions on fresh food commodities and supports research into refining and growing the technology worldwide.⁴⁶ Given that PI is effective against all insects of phytosanitary importance to apple, the above measures could be applied to a significant proportion of apple exports globally to manage the risk of one or more insect pests of phytosanitary concern.

Has the measure been successfully used to manage non-compliant consignments?

Irradiation treatments are typically conducted prior to shipping (or immediately on arrival)⁴⁷ and are, as a consequence, more structured towards delivering compliance as opposed to dealing with a non-compliant consignment. However, post-import irradiation is conducted in some jurisdictions (e.g. the USA) which, in essence, provides a means to achieve the necessary compliance. Hence, PI treatments applied to non-compliant consignments are appropriate should suitable facilities (with required NPPO approval and oversight) be available at, or close to, points of entry.⁴⁸

Has the measure been successfully used to effectively manage pest risk domestically?

There are only limited domestic applications for PI treatments for use against quarantine pests in most jurisdictions and the procedure is primarily used by source countries to ensure compliance of commodities destined for export into specific markets. However, examples exist where domestic PI treatments are indicated. Exports of some fresh fruit types from Hawaii to the mainland USA provides one such example where consignments are required to be irradiated.⁴⁹ This example provides the first phytosanitary use of fresh commodity irradiation, commencing in the 1990s.⁵⁰

The USA also approves the use of a 150 Gy dose for fresh fruits, vegetables and cut flowers originating in Puerto Rico and the US Virgin Islands.¹⁰ Other domestic uses within the USA include the state of California mandating that several fresh fruit commodities originating from Florida are subjected to PI treatments according to one of the above dose regimes.⁴⁹ Furthermore, domestic irradiation of consignments is also conducted for imports into the mainland USA, at or close to points of entry, for consignments of non-USA origin.⁴⁸

The interstate movement of fresh fruit in Australia is heavily regulated and irradiation (150 Gy) is used as an alternative phytosanitary measure against tephritids.⁸ All types of fresh fruit and vegetables are approved for irradiation in Australia.⁸

Has the measure been used successfully by the private sector or authorized entities?

ISPM 18⁵¹ indicates that irradiation can be undertaken:

- As part of the packing operation
- For bulk unpackaged commodities
- At centralized locations such as the port of embarkation

Treatments may also be undertaken at the point of entry, a designated location in a third country or a designated place within the destination country. The USA mandates that phytosanitary irradiation treatments are conducted only at approved facilities, both within the country for exports and in foreign countries for imports. Lists of commercial service providers are provided by USDA-APHIS for both USA-based and international irradiation services.^{48,52}

As of 2019 there were 24 approved irradiation facilities within the EU, one of which was in the UK.⁵³ At the same time, ten irradiation facilities were approved in non-EU countries to process products destined for export to the EU (in South Africa, India, Thailand, Switzerland and Turkey).⁵³

Australia has instigated an “Offshore Irradiation Treatment Providers Scheme” in order to provide oversight and determine the suitability of parties undertaking irradiation treatments applied to commodity imports into Australia.⁵⁴

Has the measure has been identified as an effective pest risk management option based on a PRA or comparable technical evaluation?

A large number of technical evaluations have been conducted in support of the efficacy of phytosanitary irradiation treatments for use against tephritid fruit flies.^{9,11,12,14,15,22,44,55–63} Effective doses for some species fall below the indicated schedule value and, as such, 150 Gy represents a value that is universally accepted to control the emergence of all tephritids of quarantine importance associated with apple and other fresh fruit.

An Import Risk Assessment (IRA) report on imports of Chinese apples to Australia indicates irradiation as an accepted measure for the disinfestation of arthropods in apple, including *C. sasakii* and *G. inoptinata*.⁵

Interstate consignments of fruit in Australia are mandated to be exposed to at least one of several phytosanitary measures, one of which comprises PI treatments for use against tortrix moths.⁶⁴ Tasmania similarly requires irradiation of any potential fruit fly host according to Interstate Certification Assurance (ICA) protocol ICA-55.^{65,66}

Irradiation is an accepted disinfestation procedure for some fresh fruit commodities entering, New Zealand, including apple.^{67,68}

Is the measure, relevant to the pest, adopted in an ISPM or regional standard?

- ISPM 18: Guidelines for the use of irradiation as a phytosanitary measure, 2003.⁵¹
- ISPM 28 Annex 3 (*A. serpentina*) and Annex 39 (*Anastrepha* sp.)¹
- ISPM 28 Annex 5 (*B. tryoni*)²
- ISPM 28 Annex 7 (generic)⁴
- ISPM 28 Annex 8 (*R. pomonella*)³
- ISPM 28 Annex 33 (*B. dorsalis*)⁶⁹
- ISPM 28: Annex 38 (*C. sasakii*)⁷
- ISPM 28 Annex 40 (tortrix moths)⁶
- The USDA-APHIS Treatment Manual lists irradiation schedules appropriate for fresh fruit imports into the USA from specific countries as well as inter-state movements.¹⁰
- Standard 1.5.3 Irradiation of food, produced by FSANZ, describes procedures employed by Australia and New Zealand for the irradiation of fruit and vegetables, amongst other commodities.⁷⁰
- Australia: Interstate Certification Assurance (ICA) protocol ICA-55.⁶⁶

References

1. FAO / IPPC. ISPM 28 Phytosanitary treatments for regulated pests PT 3: Irradiation treatment for *Anastrepha serpentina*. (2009).
2. FAO / IPPC. ISPM 28 Phytosanitary treatments for regulated pests PT 5: Irradiation treatment for *Bactrocera tryoni*. (2009).
3. FAO / IPPC. ISPM 28 Phytosanitary treatments for regulated pests PT 8: Irradiation treatment for *Rhagoletis pomonella*. (2009).
4. FAO / IPPC. ISPM 28 Phytosanitary treatments for regulated pests PT 7: Irradiation treatment for fruit flies of the family Tephritidae (generic). (2009).
5. FAO / IPPC. ISPM 28 Phytosanitary treatments for regulated pests PT 39: Irradiation treatment for the genus *Anastrepha*. (2021).
6. FAO / IPPC. ISPM 28 Phytosanitary treatments for regulated pests PT 40: Irradiation treatment for Tortricidae on fruits. (2022).
7. FAO / IPPC. ISPM 28 Phytosanitary treatments for regulated pests PT 38: Irradiation treatment for *Carposina sasakii*. (2021).
8. Akter, H. *et al.* An Overview of phytosanitary irradiation requirements for Australian pests of quarantine concern. *Agriculture* 13, 771 (2023).
9. Follett, P. A. *et al.* Irradiation as an alternative quarantine treatment to control fruit flies in exported blueberries. *Revista industrial y agrícola de Tucumán* 85, 43–45 (2008).
10. United States Department of Agriculture. Animal and Plant Health inspection Service Treatment Manual. *United States Government*. 940 pp. (2016)
11. Hallman, G. J. Ionizing Irradiation quarantine treatment against oriental fruit moth (Lepidoptera: Tortricidae) in ambient and hypoxic atmospheres. *Journal of Economic Entomology* 97, 824–827 (2004).
12. Bustos, M. E., Enkerlin, W., Reyes, J. & Toledo, J. Irradiation of mangoes as a postharvest quarantine treatment for fruit flies (Diptera: Tephritidae). *Journal of Economic Entomology* 97, 286–292 (2004).
13. Sommer, N. F. & Mitchell, F. G. Gamma Irradiation—A quarantine treatment for fresh fruits and vegetables? *HortScience* 21, 356–360 (1986).
14. Zhao, J. *et al.* Gamma radiation as a phytosanitary treatment against larvae and pupae of *Bactrocera dorsalis* (Diptera: Tephritidae) in guava fruits. *Food Control* 72, 360–366 (2017).
15. Hallman, G. J. & Thomas, D. B. Gamma Irradiation quarantine treatment against blueberry maggot and apple maggot (Diptera: Tephritidae). *Journal of Economic Entomology* 92, 1373–1376 (1999).

16. Hallman, G. J. Irradiation disinfestation of apple maggot (Diptera: Tephritidae) in hypoxic and low-temperature storage. *Journal of Economic Entomology* 97, 1245–1248 (2004).
17. Haynes, F. E. M & Dominiak, B. C. Irradiation for phytosanitary treatment of the Queensland fruit fly *Bactrocera tryoni* Froggatt benefits international trade. *Crop protection* 112, 125–132 (2018).
18. Hallman, G. J., *et al.* The case for a generic phytosanitary irradiation dose of 250 Gy for Lepidoptera eggs and larvae. *Radiation Physics and Chemistry* 89, 70–75 (2013).
19. Burditt, A. K., Jr. γ Irradiation as a quarantine treatment for walnuts infested with codling moths (Lepidoptera: Tortricidae). *Journal of Economic Entomology* 79, 1577–1579 (1986).
20. Burditt, A. K., Jr. & Hungate, F. P. Gamma irradiation as a quarantine treatment for apples infested by codling moth (Lepidoptera: Tortricidae). *Journal of Economic Entomology* 82, 1386–1390 (1989).
21. Hallman, G. J. Phytosanitary Applications of irradiation. *Comprehensive Reviews in Food Science and Food Safety* 10, 143–151 (2011).
22. Hallman, G. J., *et al.* Factors affecting ionizing radiation phytosanitary treatments, and implications for research and generic treatments. *Journal of Economic Entomology* 103, 1950–1963 (2010).
23. Hofmeyr, H. *et al.* Postharvest phytosanitary disinfestation of *Thaumatotibia leucotreta* (Lepidoptera: Tortricidae) in citrus fruit: Validation of an ionizing radiation treatment. *Florida Entomologist* 54–58 (2016).
24. Hofmeyr, H. *et al.* Postharvest phytosanitary disinfestation of *Thaumatotibia leucotreta* (Lepidoptera: Tortricidae) in citrus fruit: Comparative tolerance of larvae reared in synthetic diet and oranges to ionizing radiation. *Florida Entomologist* 43–47 (2016).
25. Hofmeyr, H., Hofmeyr, M. & Slabbert, K. Postharvest phytosanitary disinfestation of *Thaumatotibia leucotreta* (Lepidoptera: Tortricidae) in citrus fruit: Tolerance of eggs and larvae to ionizing radiation. *Florida Entomologist* 48–53 (2016).
26. Nadel, H. *et al.* Postharvest Irradiation Treatment for Quarantine Control of the Invasive *Lobesia botrana* (Lepidoptera: Tortricidae). *Journal of Economic Entomology* 111, 127–134 (2018).
27. Lester, P. J. & Barrington, A. M. Gamma irradiation for postharvest disinfestation of *Ctenopseustis obliquana* (Walker) (Lep., Tortricidae). *Journal of Applied Entomology* 121, 107–110 (1997).
28. Mansour, M. & Al-Attar, J. Effects of gamma irradiation on the grape vine moth, *Lobesia botrana*, mature larvae. *Radiation Physics and Chemistry* 97, 370–373 (2014).

29. Arthur, V., Machi, A. R. & Arthur, P. B. Adult emergence and F1 generation egg and larval production after γ -irradiation of late pupae of *Grapholita molesta* (Lepidoptera: Tortricidae). *Florida Entomologist* 67–68 (2016).
30. FAO / IAEA. Irradiation as a phytosanitary treatment of food and agricultural commodities: Proceedings of a final research coordination meeting organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture 2002. International Atomic Energy Agency (2004).
31. Follett, P. Phytosanitary irradiation tomorrow. Presentation at The Annual Chapman Phytosanitary Irradiation Forum (2018). <https://www.chapman.edu/scst/conferences-and-events/30-follett-future-pi-imagine.pdf>
32. Hallman, G. J. Generic phytosanitary irradiation treatment for “true weevils” (Coleoptera: Curculionidae) infesting fresh commodities. *Florida Entomologist* 197–201 (2016).
33. Hallman, G. J. Generic phytosanitary irradiation dose of 300 Gy proposed for the Insecta excluding pupal and adult Lepidoptera. *Florida Entomologist* 206–210 (2016).
34. Hallman, G. J. & Blackburn, C. M. *Phytosanitary Irradiation*. *Foods* 5, 8; 10 pp (2016).
35. Hallman, G. J. Generic phytosanitary irradiation treatments. *Radiation Physics and Chemistry* 81, 861–866 (2012).
36. Department of Agriculture - Animal and Plant Health Service. 7 CFR Parts 305 and 319. Irradiation Phytosanitary Treatment of Imported Fruits and Vegetables. *Federal Register*, 65, 34113-34125 (2000).
37. Biosecurity Australia. Final Import risk analysis report for fresh apple fruit from the People’s Republic of China. *Australian Government*. 370 pp (2010).
38. Australian Government. Australia New Zealand Food Standards Code – Standard 1.5.3 – Irradiation of food. *Federal Register of Legislation*. <https://www.legislation.gov.au/Details/F2022C00975/Html/Text>, <http://www.legislation.gov.au/Details/F2022C00975>.
39. Roberts, P. B. & Follett, P. A. Food Irradiation for phytosanitary and quarantine treatment. [In] *Food Chemistry, Function and Analysis* (eds. Ferreira, I. C. F. R., Antonio, A. L. & Cabo Verde, S.) 169–182. *Royal Society of Chemistry* (2017).
40. Reilly, B. Australian Update. Presentation at The Annual Chapman Phytosanitary Irradiation Forum (2018). <https://www.chapman.edu/scst/conferences-and-events/15-ben-reilly-steritech-presentation.pdf>
41. Food Standards Australia New Zealand. Irradiation as a phytosanitary measure for all fresh fruit and vegetables. *Australian Government*. 47 pp (2021).

42. Vas, A. Phytosanitary Irradiation: Existing market and new developments in India. Presentation at The Annual Chapman Phytosanitary Irradiation Forum (2018). <https://www.chapman.edu/scst/conferences-and-events/17-arjun-vas.pdf>
43. Nguyen, L. Status of fruit exportation in Vietnam. Presentation at The Annual Chapman Phytosanitary Irradiation Forum (2018). <https://www.chapman.edu/scst/conferences-and-events/18a-ly-nguyen---exported-quantity-of-vietnam.-final.pdf>
44. Wang, K. et al. Research on irradiated food status and consumer acceptance: A Chinese perspective. *Food Science & Nutrition* 11, 4964-4974.
45. Tunlayadechanont, S. Fresh fruits irradiation for phytosanitary purposes in Thailand using a multipurpose irradiation facility. *Acta Horticulturae*. 35–44 (2013) .
46. International Atomic Energy Agency. Novel Irradiation Technology for Phytosanitary Treatment of Food Commodities and Promotion of Trade (2018). <https://www.iaea.org/projects/crp/d61026>.
47. Phytosanitary Treatments Using Irradiation for Fruit Fly Pests Gain Ground. <https://www.iaea.org/newscenter/news/phytosanitary-treatments-using-irradiation-for-fruit-fly-pests-gain-ground> (2020).
48. Jeffers, L. A. Presentation: APHIS PPQ Phytosanitary Irradiation Program (2015). https://www.iaea.org/sites/default/files/documents/tc/Laura_JEFFERS.pdf
49. Mitcham, B. Irradiation as a Quarantine Treatment. *Perishables Handling Quarterly* 99, 19-21 (1999).
50. Follett, P. A. & Weinert. Phytosanitary irradiation of fresh tropical commodities in Hawaii: Generic treatments, commercial adoption, and current issues. *Radiation Physics and Chemistry* 81, 1064–1067 (2012).
51. FAO/ IPPC. ISPM 18 Guidelines for the use of irradiation as a phytosanitary measure. (2003).
52. United States Department of Agriculture – Animal and Plant Health Inspection Services. Agricultural Commodity Import Requirements Facility Search. <https://acir.aphis.usda.gov/s/acir-facility-search>.
53. EU legal framework on food irradiation (Directives 1999/2/EC and 1999/3/EC). *European Commission* <https://data.europa.eu/doi/10.2903/j.efsa.2011.2103> (2021).
54. Department of Agriculture, Fisheries and Forestry. Offshore Irradiation Treatment Scheme V 1.1. Australian Government. 8 pp (2023).
55. Institute of Food Science and Technology. Food Irradiation. <https://www.ifst.org/resources/information-statements/food-irradiation> (2022).

56. Heather, N. W., Corcoran, R. J. & Banos, C. Disinfestation of mangoes with gamma irradiation against two Australian fruit flies (Diptera: Tephritidae). *Journal of Economic Entomology* 84, 1304–1307 (1991).
57. Jessup, A. *et al.* Gamma irradiation as a commodity treatment against the Queensland fruit fly in fresh fruit. [In] *Proceedings of the Research Coordination Meeting on Use of Irradiation as a Quarantine Treatment of Food and Agricultural Commodities*, 13–42 (1990).
58. Mansour, M. Gamma irradiation as a quarantine treatment for apples infested by codling moth (Lep., Tortricidae). *Journal of Applied Entomology* 127, 137–141 (2003).
59. Gould, W. P. & von Windeguth, D. L. Gamma irradiation as a quarantine treatment for carambolas infested with Caribbean fruit flies. *The Florida Entomologist* 74, 297–300 (1991).
60. von Windeguth, D. L. Gamma irradiation as a quarantine treatment for Caribbean fruit fly infested mangoes. *Proceedings of the Florida State Horticultural Society* 99, 131–134 (1986).
61. von Windeguth, D. L. & Ismail, M. A. Gamma irradiation as a quarantine treatment for Florida grapefruit infested with Caribbean fruit fly, *Anastrepha suspensa* (Loew). *Proceedings of the Florida State Horticultural Society* 100, 5–7 (1987).
62. Hallman, G. J. & Martinez, L. R. Ionizing irradiation quarantine treatment against Mexican fruit fly (Diptera: Tephritidae) in citrus fruits. *Postharvest Biology and Technology* 23, 71–77 (2001).
63. Follett, P. A. Post-harvest irradiation treatments: Generic dose, high dose, and less-than-probit 9 applications. [In] *FAO/IAEA International Conference on Area-Wide Control of Insect Pests: Integrating the Sterile Insect and Related Nuclear and Other Techniques*. 355- 356 (2005).
64. Department of Agriculture, Fisheries and Forestry. Final report for the review of biosecurity import requirements for fresh apple fruit from the Pacific Northwest states of the United States of America. *Australian Government*. <https://www.agriculture.gov.au/biosecurity-trade/policy/risk-analysis/memos/ba2022-p10.html>
65. Department of Natural Resources and Environment Tasmania. Plant Biosecurity Manual Tasmania 2023 Edition. *Tasmanian Government*. 172 pp (2023).
66. Agriculture Victoria. ICA-55: Irradiation Treatment. *State Government of Victoria*. 24 pp (2022).
67. MAF Biosecurity New Zealand. Standard 152.02 importation and clearance of fresh fruit and vegetables into New Zealand. *New Zealand Government*. 421 pp (2012).
68. Ministry of Primary Industries. Fresh Apple (*Malus sylvestris*, *M. sylvestris* var. *domestica* and *M. x domestica*) for Human Consumption. *New Zealand Government*. 16 pp (undated).
69. FAO / IPPC. ISPM 28 Phytosanitary treatments for regulated pests PT 33: Irradiation treatment for *Bactrocera dorsalis*. (2009).

70. Food Standards Australia New Zealand. Standard 1.5.3 Irradiation of food. *Australian Government*. 4 pp (2016).