INTRODUCTION TO PHYTOSANITARY IRRADIATION

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INTERNATIONAL IRRADIATION ASSOCIATION

Earliest suggestion of irradiation as a phytosanitary treatment

Kiyoshi Koidsumi

Quantitative studies on the lethal action of X-rays upon certain insects

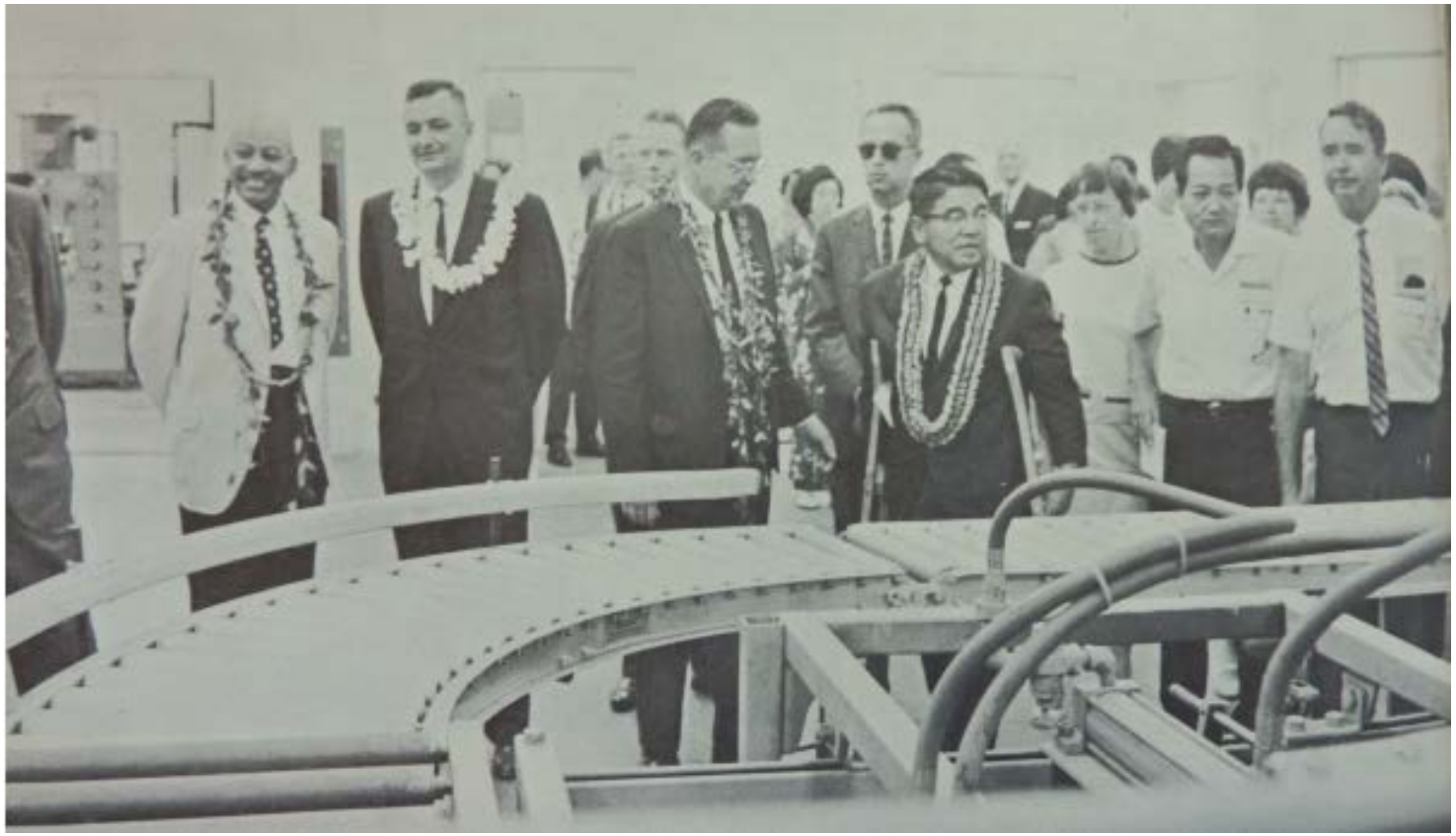
J. Soc. Trop. Agriculture 1930 2: 342-363

In the Island of Formosa, a large number of fruits and vegetables such as Citrus, Mango, Bamboo-shoot, Cucumber, Melon, Luffa etc. are damanged in a considerable degree by many species of fruit fly, *Dacus*. These larvae hatching from eggs laid on these plants damage them very considerably. The killing of any stages of these insects which are parasitic to these plants, as they are contained in plants themselves or in a package to be exported, has a very important significance in the exportation of the plants.

It was the purpose of the author to destroy them within fruits or vegetables or packages which contained insects by means of X-ray radiation, and it was developed that a certain intensity of rays killed such naked insects as were not covered with any objects during any stages of development. I first determined the purely scientific relation of the rays to the death of the naked insects. This article will deal with the obtained results of interest from a scientific point of

Hawaii: the birthplace of phytosanitary irradiation

Pionereering research (USDA-ARS)
1967: First pilot scale irradiator for a fresh commodity (cobalt-60)



Early support of the Joint IAEA-FAO Division

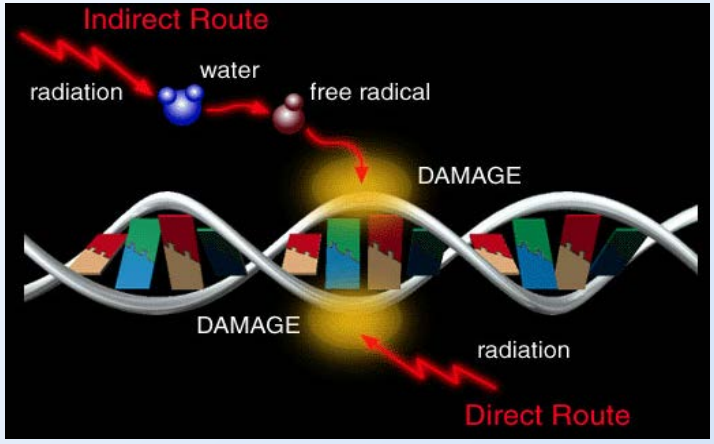
Irradiation

Definition: Exposure to ionizing radiation

Amount of energy absorbed per mass = Dose

Unit: Gray 1 Gy = 1 Joule/kg

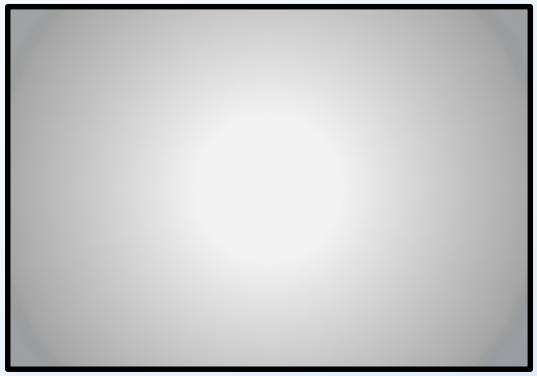
Chemical effects → **Biological effects on living organisms**



Death of pests

DoseS

Energy not evenly deposited within products
Not one dose but a gradient of doses

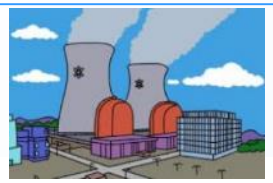


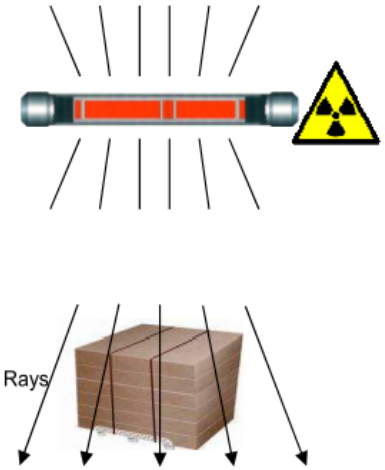
Two critical dose values:

- Minimum dose (**Dmin**):
  dose at which the desired effect is obtained
- Maximum dose (**Dmax**)**:**
  dose at which an undesirable effect takes place

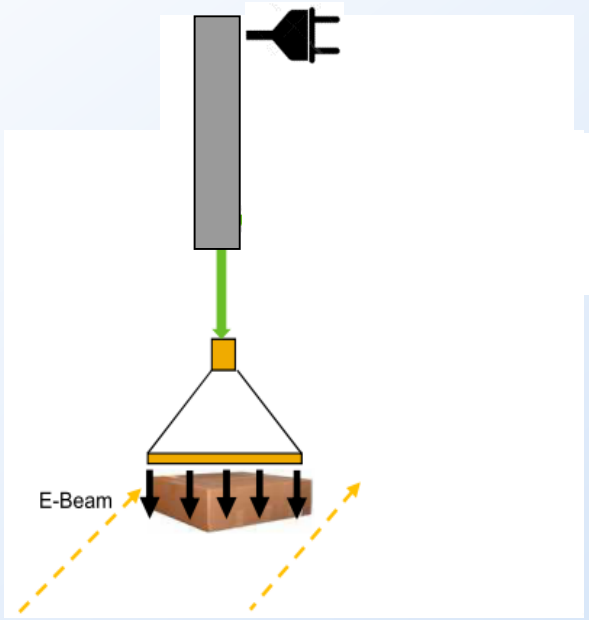
Dmax / Dmin = Dose Uniformity Ratio (**DUR**)

Three ways to produce ionizing radiation

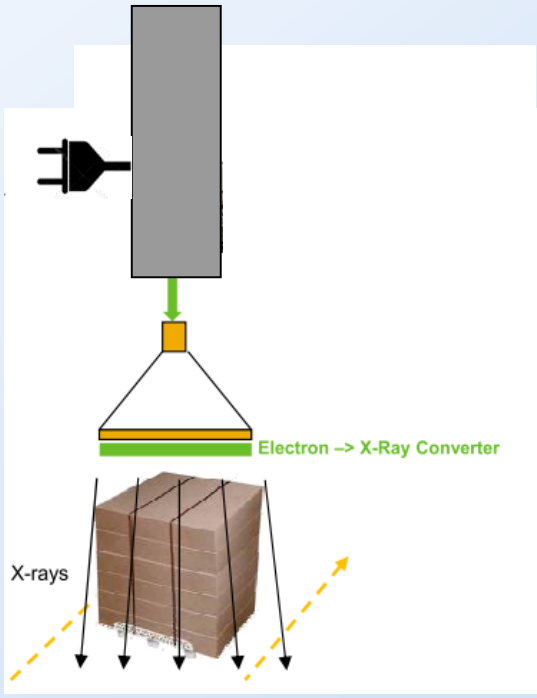




Gamma irradiation



Electron accelerators



X-Ray machines

The three have pros and cons

Users decide which one is best for their products

Milestones

1980: Joint WHO-FAO-IAEA Expert Committee on the Safety of Irradiated Food:
Irradiated food pose no toxicological, microbiological or nutritional hazard

1986: US FDA approves irradiation up to 1 kGy for preservation and disinfestation of fresh fruits and vegetables

1990s: First commercial shipments of irradiated fruit from Hawaii

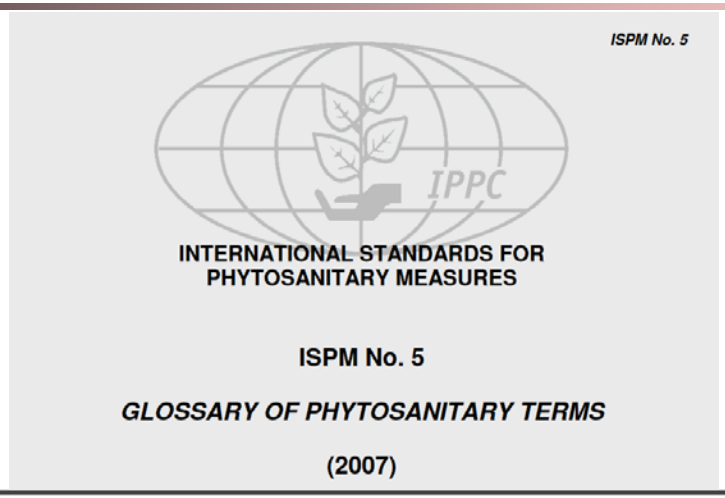
2002: USDA APHIS establishes regulations providing for use of irradiation as a phytosanitary treatment for imported fruit and vegetables

2003: International Plant Protection Commission (IPPC) publishes ISPM 18

2004: First bilateral agreement for irradiated produce between Australia and New Zealand for Australian mangoes entering New Zealand

Irradiation must be indicated on irradiated food products

Phytosanitary measures



phytosanitary measure (agreed interpretation)

Any **legislation**, **regulation** or **official** procedure having the purpose to prevent the **introduction** and/or **spread** of **quarantine pests**, or to limit the economic impact of **regulated non-quarantine pests** [FAO, 1995; revised IPPC, 1997; ISPM, 2002]

Irradiation is one of the options **not a panacea**

- Methyl bromide fumigation
- Cold treatment
- Hot water dipping
- Vapor Heat Treatment…

The world needs more and better phytosanitary treatments

Massive yet grossly underestimated global costs of invasive insects

Corey J. A. Bradshaw ✉, Boris Leroy, Céline Bellard, David Roiz, Céline Albert, Alice Fournier, Morgane Barbet-Massin, Jean-Michel Salles, Frédéric Simard & Franck Courchamp ✉

Nature Communications **7**, Article number: 12986 (2016) | Download Citation

*…**invasive insects cost a minimum of 70 billion USD per year globally**, while associated health costs exceed 6.9 billion USD per year…*

*…two main phenomena leading to an increased frequency of introductions and potentially expanding distributions of the costliest insect invaders: **international trade and global warming**.*

Advantages of phytosanitary irradiation

- A non-chemical process, quick and effective
- Applicable to a broad range of products with no or marginal loss of
  - sensory qualities
  - nutritional qualities
- Tolerance (maximum dose applicable) of produce depends on
  - Species
  - Variety
  - Maturity at time of irradiation
  - Storage and handling conditions…
- Possibility to use *one fits all* minimum dose (g
- Extends shelf-life in some cases only
- Simultaneous inactivation of the most radiation sensitive pathogens ?

Responses to irradiation as a phytosanitary measure

1. **Mortality**
   Target pest is killed, immediately or after a delay

2. **Prevention of successful development**
   Examples of disruptions: non-emergence of adults, target pest alive but unable to develop to full maturity, develop to maturity but unable to fly

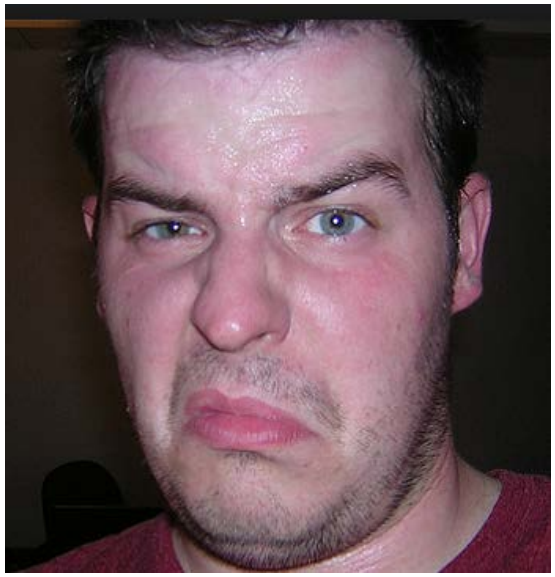
3. **Inability to reproduce**
   Examples: complete sterility, sterility of F1 generation, egg laying and / or hatching without further development

4. **Inactivation or devitalization**
   Plant products incapable of germination, seeds germinate but seedlings do not grow, bulbs or tubers do not sprouts

Specifics of irradiation vs. other phytosanitary treatments

THE MEASURE OF EFFICACY IS NOT ACUTE MORTALITY BUT PREVENTION OF FURTHER DEVELOPMENT OR REPRODUCTION

A REGULATED PEST PRESENT AT THE TIME OF IRRADIATION MAY STILL BE ALIVE WHEN ENTERING THE IMPORTING COUNTRY



YES !

A PARADIGM SHIFT INDEED FOR PHYTOSANITARY REGULATIONS

NPPOs must not reject shipments containing products with live regulated pests (if they were properly irradiated and satisfy quarantine requirements)

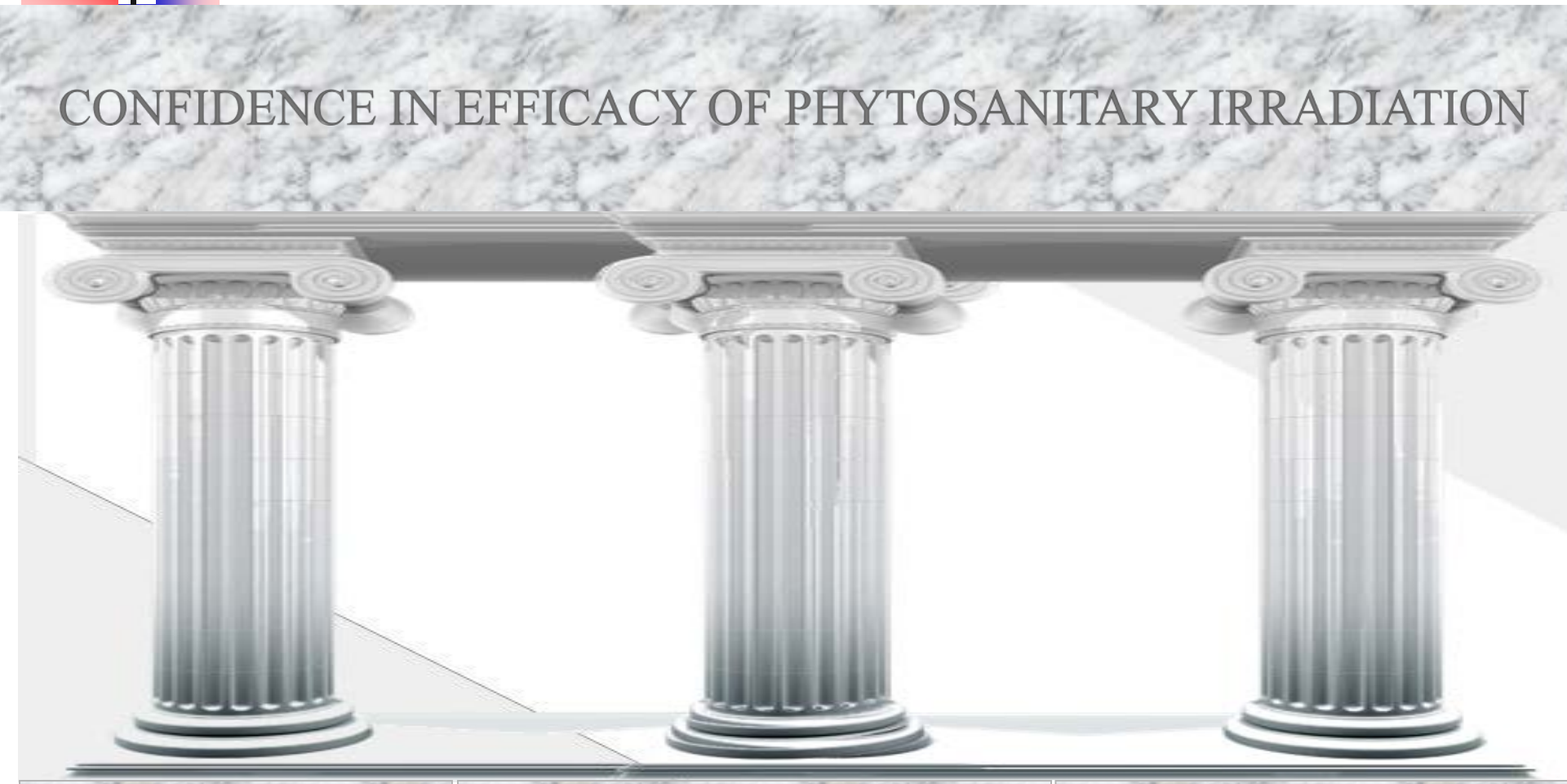
Specifics of irradiation vs. other phytosanitary treatments

- Absence of live insects is the yardstick of fumigation, heat, and cold treatments

In fact, rejection of lots when live insects are found shows that these treatments fail at one time or another.

Phytosanitary irradiation introduces an approach resting on three pillars and akin to HACCP

The three pillars



SOUNDNESS OF RESEARCH SUPPORTING MINIMUM DOSE	CONFIDENCE THAT THE IRRADIATION PROCESS WILL ACHIEVE THAT MINIMUM DOSE	PHYTOSANITARY SAFEGUARDING OF PRODUCT AFTER IRRADIATION

Generic dose

Single minimum dose that controls a group of pests on a variety of commodities

Why Generic Doses?

Approx. one million different species of insects have been identified and there may be many millions of insect species yet to be discovered.

How long will it take to develop quarantine treatments one pest and one commodity at a time?

Other advantages:

- Possibility of emergency treatment *e.g.* in case of invasion by a new tephritid fruit fly species or other quarantine pest.
- Exports using irradiation as a phytosanitary treatment would not be interrupted because the generic doses would also apply to the new species.

Generic doses

In 2003, P. Follett and G. Hallman (USDA-ARS) recommended:

- 150 Gy for all tephritid fruit flies and
- 400 Gy for all insects (except pupae and adults of Lepidoptera)

based on a critical examination of the literature and work done.

In 2006, publication by USDA APHIS of a landmark rule accepting these two generic doses.

IPPC has approved one generic dose: 150 Gy for all tephritid fruit flies on all commodities.

International standards

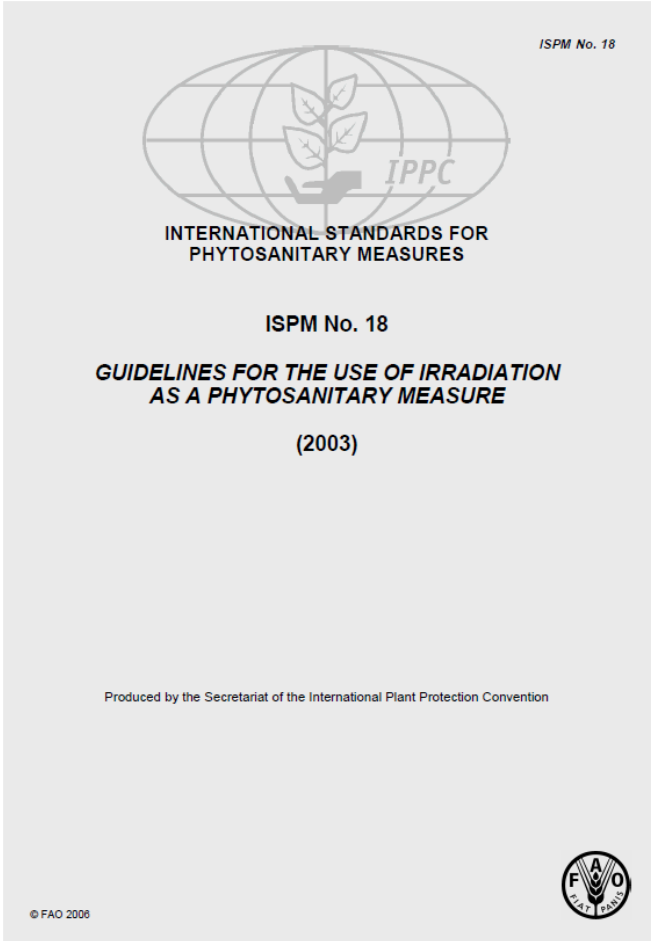
International Plant Protection Convention
Protecting the world's plant resources from pests

ISPM 28 REQUIREMENTS	ISPM 18 GUIDELINES

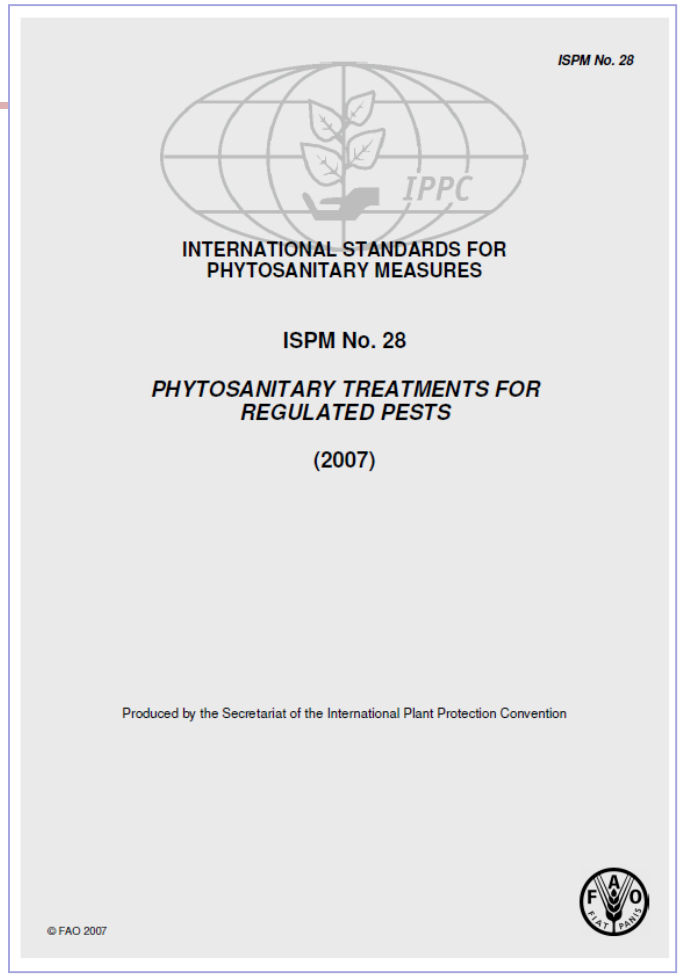
ISPM 18

ISPM 18: Guidelines for the use of irradiation as a phytosanitary measure

Technical guidance on procedures for the application of ionizing radiation as a phytosanitary treatment for regulated pests or articles



ISPM 28



Requirements for submitting research data on treatments

ISPM 28

Phytosanitary Treatments for Regulated Pests

(2007)

ISPM 28

Submissions are reviewed by the Technical Panel on Phytosanitary Treatments which makes recommendations to the Commission on Phytosanitary Measures (CPM)

The CPM either adopts or rejects the treatment as an international standard

If the standard is adopted, it is added as an annex to ISPM 28

ISPM 28 – Approved irradiation treatments

Phytosanitary treatments (PT) based on ionizing radiation approved by the International Plant Protection Convention.

PT No.	Pests covered	Dose (Gy)
1	*Anastrepha ludens* (Mexican fruit fly)	70
2	*Anastrepha obliqua* (West Indian fruit fly)	70
3	*Anastrepha serpentine* (serpentine fruit fly)	100
4	*Bactrocera jarvisi* (Jarvis' fruit fly)	75
5	*Bactrocera tryoni* (Queensland fruit fly)	75
6	*Cydia pomonella* (codling moth)	200
7	Tephritidae (fruit flies)	150
8	*Rhagoletis pomonella* (apple maggot)	50
9	*Conotrachelus nenuphar* (plum curculio)	92
10	*Grapholita molesta* (oriental fruit moth)[a]	232
11	*Grapholita molesta* (oriental fruit moth)[a]	232
12	*Cylas formicarius elegantulus* (sweet potato weevil)	165
13	*Euscepes postfasciatus* (West Indian sweet potato weevil)	150
14	*Ceratitis capitata* (Mediterranean fruit fly)	100
19	*Dysmicoccus neobrevipes*, *Planococcus lilacinus* and *P. minor* (mealybugs)	231
20	*Ostrinia nubilalis* (European corn borer)	289, 343[b]

[a] The two *Grapholita molesta* treatments have different end points and are for irradiation in ambient and low oxygen atmospheres.

[b] The two doses for *Ostrinia nubilalis* have different end points.

Conclusion

Given its advantages, the use of irradiation as a phytosanitary treatment has rapidly grown. This growth should continue.

- More commodities
- More target pests
- More countries

Increased acceptance by regulators (Japan, Korea…) and major retailers will be the key.