USDA
United States Department of Agriculture

Phytosanitary Irradiation: Technology and Efficacy

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Animal and Plant Health Inspection Services
United States Department of Agriculture

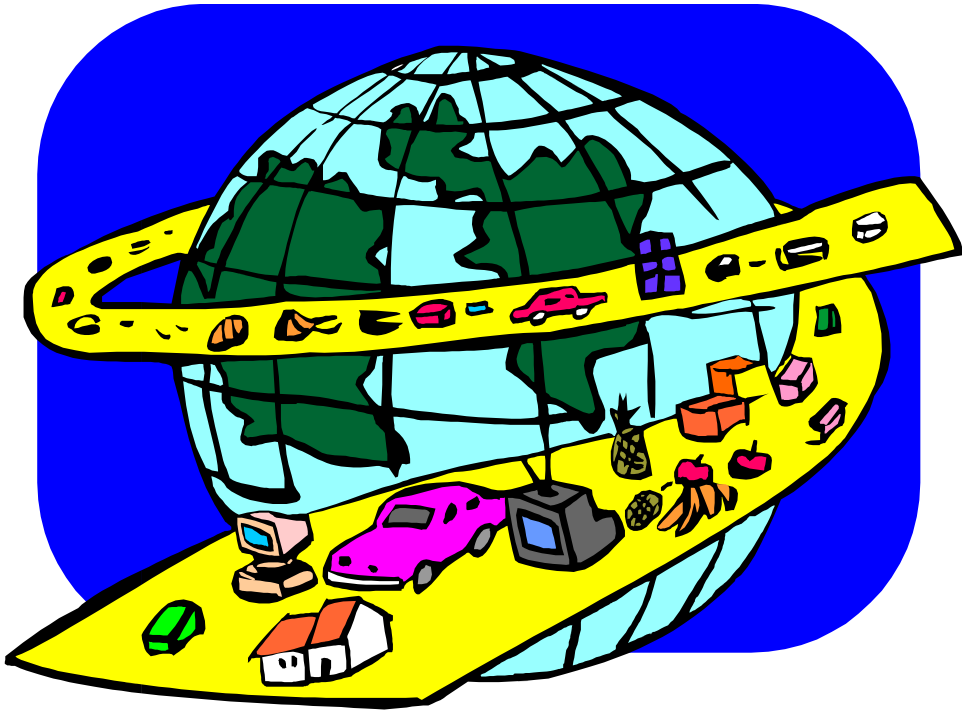
Outline

- Irradiation Technology
- Insect Efficacy
- Phytosanitary Irradiation History
- Mite Generic Dose Development

Background

Global trade of commodities

- New products for US consumers
- New export markets for US producers
- Exotic pests



PPQ Mission

Plant Protection and Quarantine (PPQ)
Animal and Plant Health Inspection Services
United States Department of Agriculture

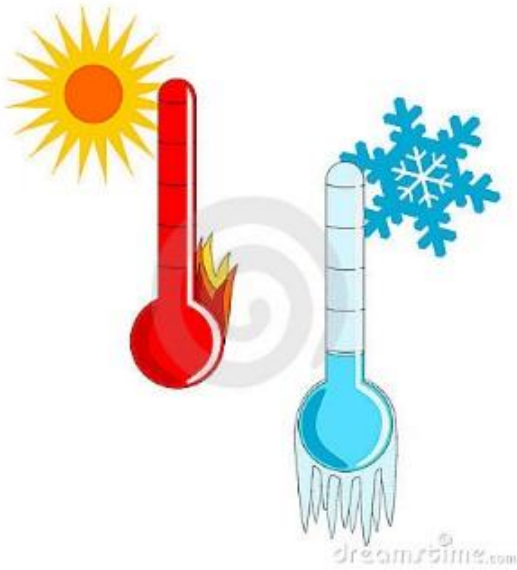
APHIS

Safeguard U.S. agriculture and natural resources against the entry, establishment, and spread of economically and environmentally significant pests, and facilitate the safe trade of agricultural products.

Definitions & Concepts

Phytosanitary Treatment- Regulatory measure intended to prevent the introduction or spread of quarantine pests by killing or sterilizing pests with high efficacy

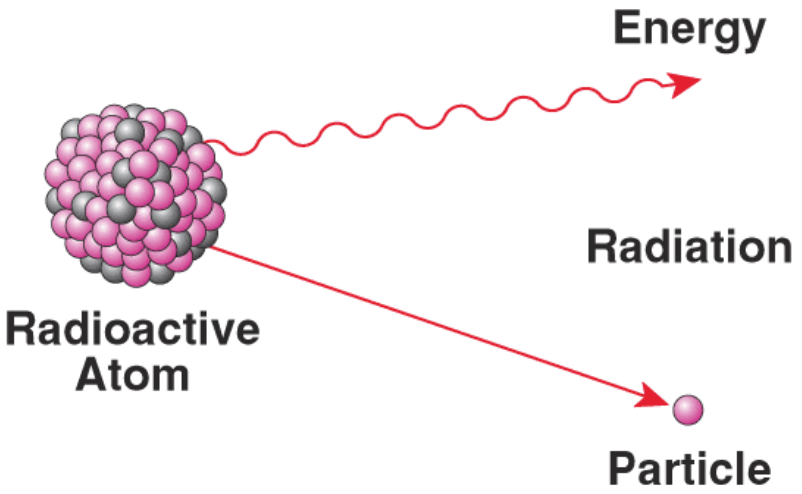
Examples of Treatments:
Irradiation
Heat (44-48 °C)
Cold (0-2 °C)
Fumigation



Definitions & Concepts

Irradiation- The exposure of a substance to ionizing energy (radiation) for the purpose of achieving some desired technical benefit

- Food and agricultural products
  - phytosanitary treatment, shelf life extension, sprout inhibition, pathogen reduction
- Sterilization of medical products
- Materials modification
  - semiconducters, gemstone coloration, polymers



Irradiation (gamma, e-beam, X-ray) at typical energies for radiation processing WILL NOT cause any of the irradiated products to become radioactive or leave any radioactive residue.

Definitions & Concepts

Dose vs Absorbed Dose- Dose refers to the amount of ionizing radiation delivered; Absorbed dose refers to the quantity of radiating energy (in *Gray*) absorbed per unit of mass of a specified target

Gray (Gy)- a unit of absorbed dose where 1 Gy is equivalent to the absorption of 1 joule per kilogram of the specified material (1 Gy = 1 J/kg)

Typical Absorbed Dose Requirements

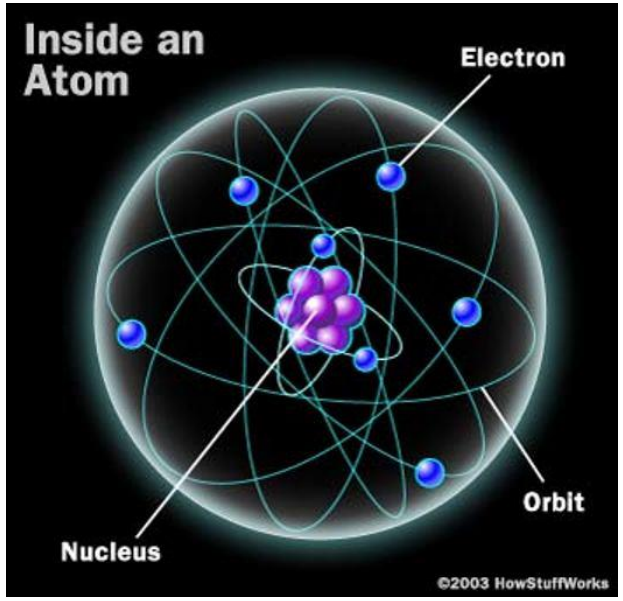
Purpose	Dose (Gray)
Inhibit Sprouting	50
Phytosanitary Irradiation	60-400
Pathogen Reduction (Meat and Poultry)	1,500
Spice Sanitation	6,500
Medical Device Sterilization	25,000
Food Sterilization (NASA)	46,000

Approved Irradiation Sources

Gamma: Cobalt 60 or Cesium 137 emits photons during decay

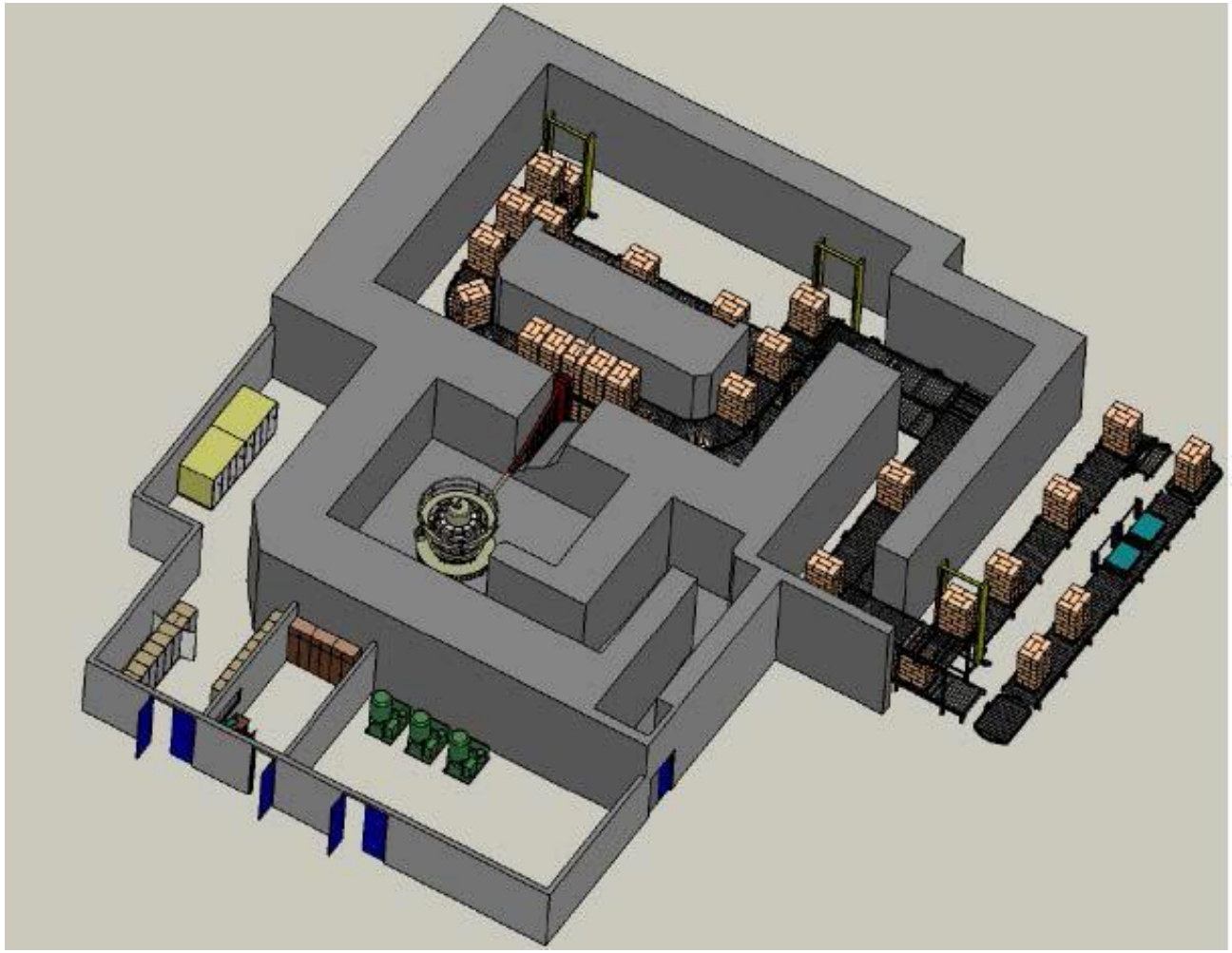
E-beam: High energy electrons propelled (particle beam) from an electron gun

X-ray: High energy electrons are converted to X-rays (photons)



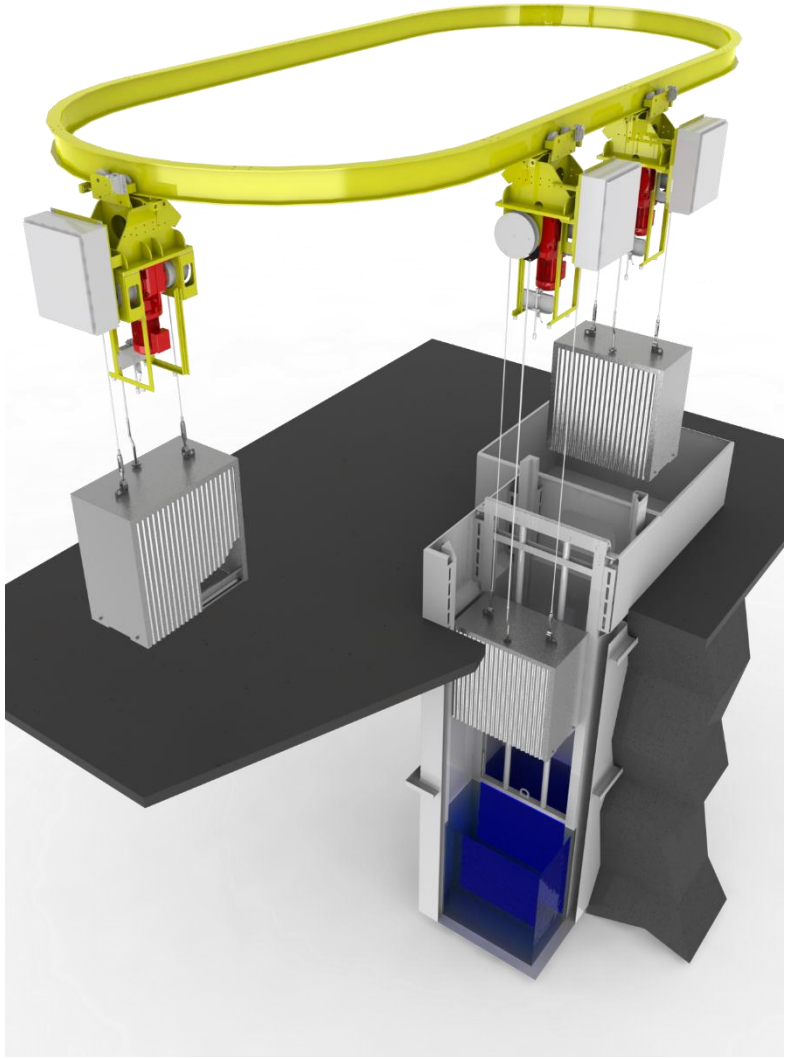
Components of Irradiation Facilities

- Radiation source
  (gamma, x-ray, e-beam)
- Biological shield
- Product transport system
- Control and safety equipment



X-Ray Facility Image Credit: IAEA

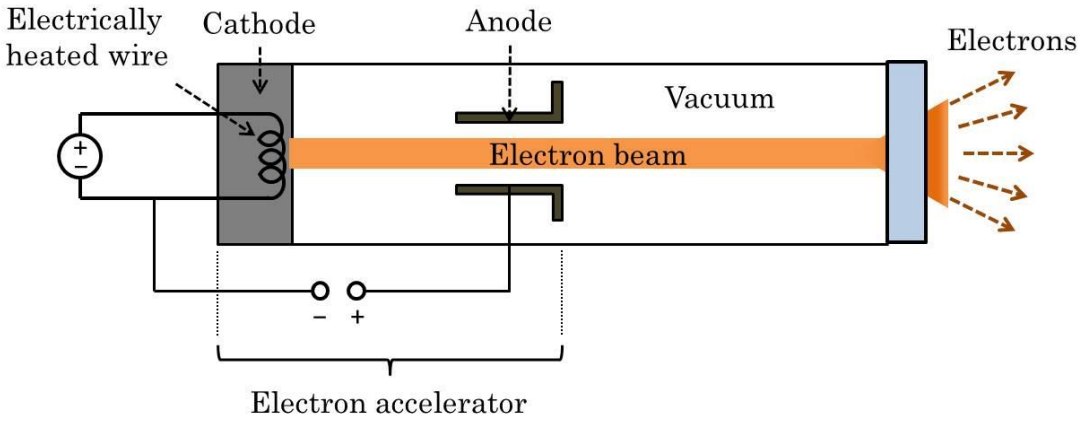
Gamma Irradiator (Cobalt 60)



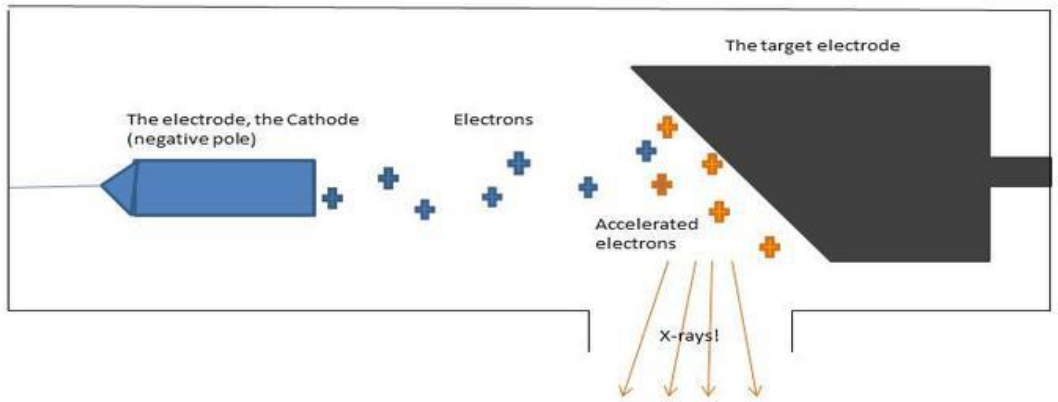
Cherenkov radiation

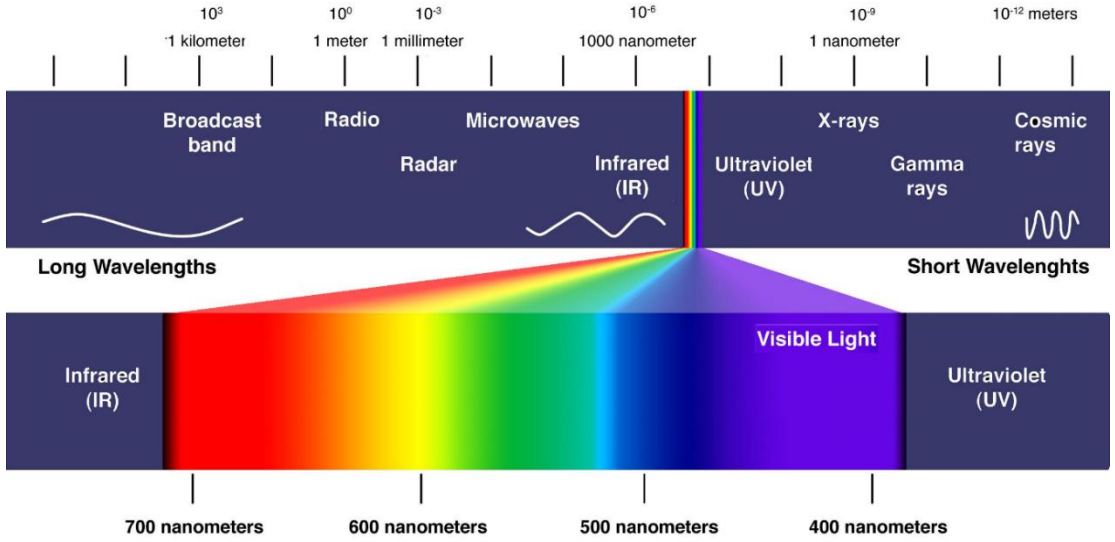
E-beam Irradiator

Image Credit: IAEA



X-Ray Irradiator

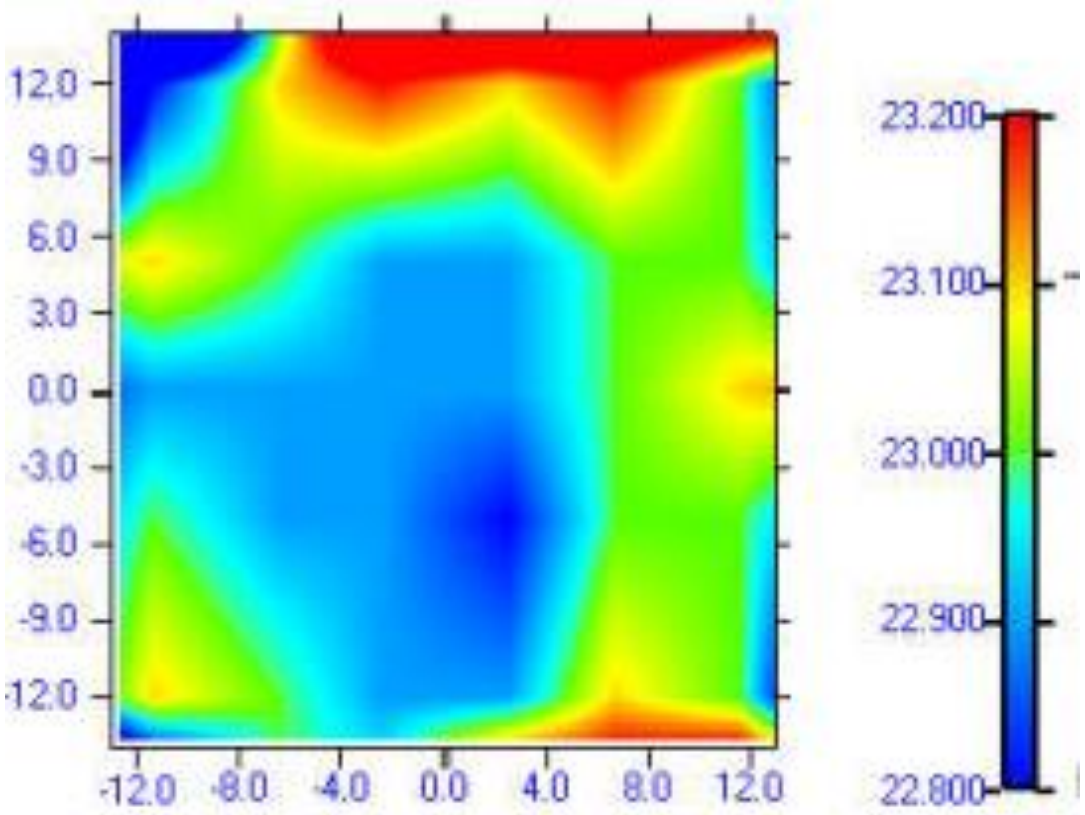




Definitions & Concepts

Dose Distribution- The spatial variation of absorbed dose throughout the process load, the dose having the extreme values *D*max and *D*min.

Note: FDA limits fresh fruit and vegetable treatments to 1000 Gy



From www.teasystems.com/WhitePapers/WeirPW_DoseUniformity.htm

Insect Efficacy

The objective of using irradiation as a phytosanitary measure is to prevent the introduction and spread of plant pests

This can be realized by achieving certain responses in the target pest(s) such as:

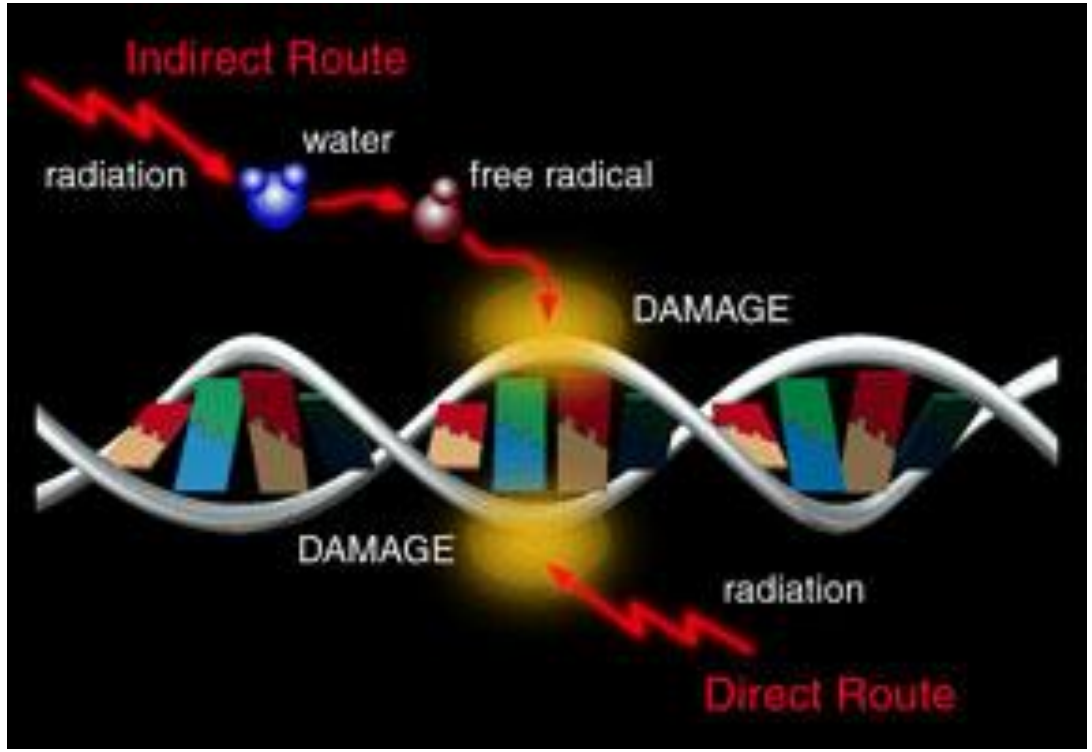
- mortality
- preventing development
- sterility
- inactivation

Mortality is usually not the target response for APHIS irradiation treatments and live insects may remain after treatment

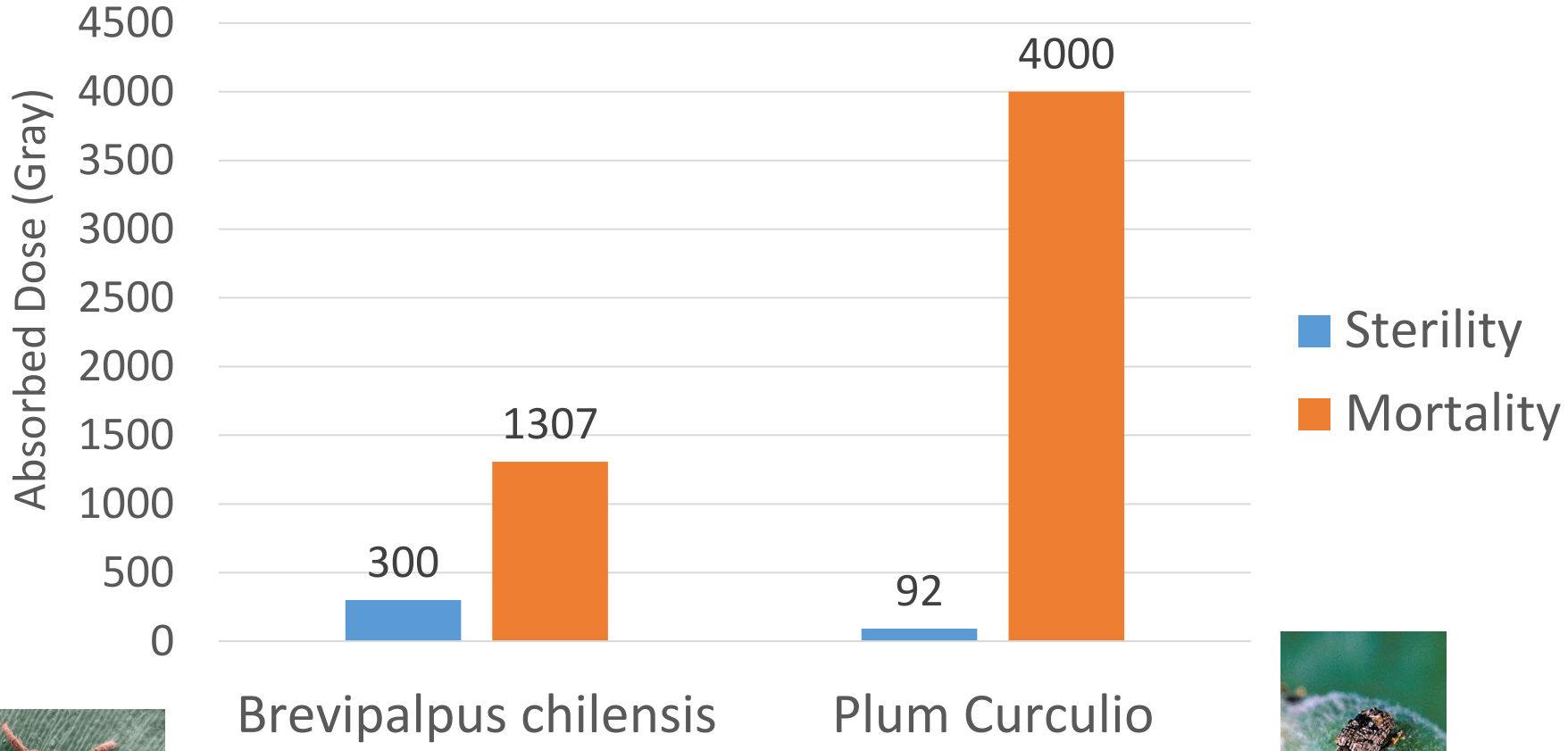
Insect Efficacy

Effects of ionizing radiation on insect pests:

- Free radicals cause tissue damage
- Broken chemical bonds
- DNA damage can be fatal or prevent reproduction



Absorbed Doses Required for Sterility vs. Mortality



From Castro et al., 2004 and Hallman, 2003.

Phytosanitary Irradiation History

- 1986. US FDA approves irradiation of fruits and vegetables for insect disinfestation
- 1989. Approval of Hawaii papaya
- 1995. Hawaii produce exported with special permit
- 1996. USDA APHIS approves phytosanitary irradiation against fruit flies on any commodity

Phytosanitary Irradiation History

2002. Irradiation approved for all admissible fruits and vegetables from all countries to US

2004. Australian mangos to New Zealand

2006. USDA APHIS approves generic doses

2007. Thai mango to United States

2011. First Upon Arrival Irradiation Treatment

2015. First US exports of irradiated fruit

Generic vs. Specific Treatment

Generic

- Treatment covers multiple pests and commodities
- Subset of insects from group are tested

Specific

- Treatment applies to a single pest
- Often commodity-specific
- Single pest tested

APHIS Approved Irradiation Treatments

Pest	Dose (Gy)
All fruit flies of the family Tephritidae	150
All insects except adults and pupae of the order Lepidoptera	400
Eggs and larvae of the family Tortricidae	290

Pest	Dose (Gy)
Rhagoletis pomonella	60
Anastrepha ludens, Anastrepha obliqua, Anastrepha suspensa	70
Conotrachelus nenuphar	92
Anastrepha serpentina, Bactrocera jarvisi, Bactrocera tryoni, Ceratitis capitata, Copitarsia declora	100
Aspidiotus destructor, Cylas formicarius, Euscepes postfasciatus, Omphisa anastomosalis, Pseudaulacaspis pentagona, Bactrocera cucurbitae, Bactrocera dorsalis	150
Sternochetus frigidus	165
Cydia pomonella, Grapholita molesta, Epiphyas postvittana	200
Cryptophlebia ombrodelta, Cryptophlebia illepida	250
Brevipalpus chilensis, Sternochetus mangiferae	300

Generic Treatments in Use

Trading Partners	Commodity	Dose
Mexico to US	Citrus, manzano pepper, mango	150 Gy
India & Pakistan to US	Mango	400 Gy
Mexico to US	Guava	400 Gy
Vietnam to US	Dragonfruit	400 Gy
Australia to New Zealand	Mango, papaya	250 Gy
Australia to New Zealand	Lychee	350 Gy

Hallman, G., 2012. Generic phytosanitary irradiation treatments. Radiation Physics and Chemistry. 81:861–866.

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Dose Development - Mites

- Mites
  - Quarantine pests for many fresh commodities
  - Vectors for plant diseases
- Limited phytosanitary treatment options
  - Not covered by generic 400 Gy insect dose
- Australia and New Zealand
  - 400 Gy for Tetranychidae
  - 500 Gy for all other mites

Joseph Berger, Bugwood.org

USDA United States Department of Agriculture

Dose Development - Mites

Objective

- Determine irradiation dose that prevents reproduction of *Brevipalpus yothersi*
  - Endpoint = prevent F1 egg hatch

- Contribute to the body of literature required to establish a generic dose for mites

Brevipalpus yothersi

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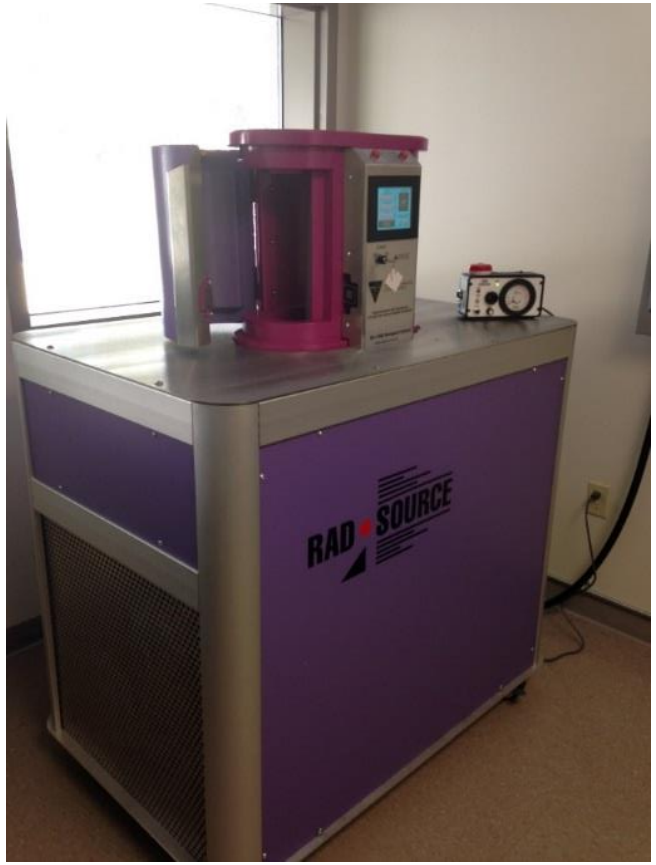
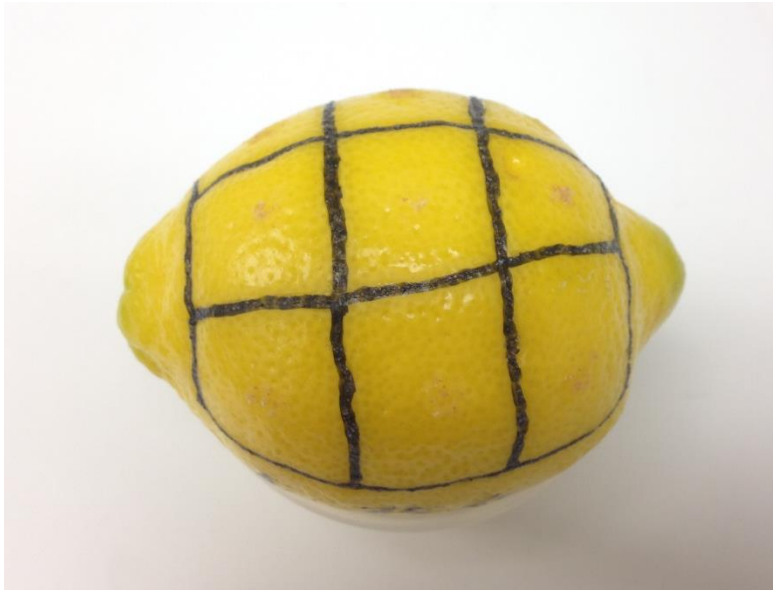
Methods



X-ray irradiator at Miami CPHST lab



Lemon with arenas for individual mites

Brevipalpus mites on lemon

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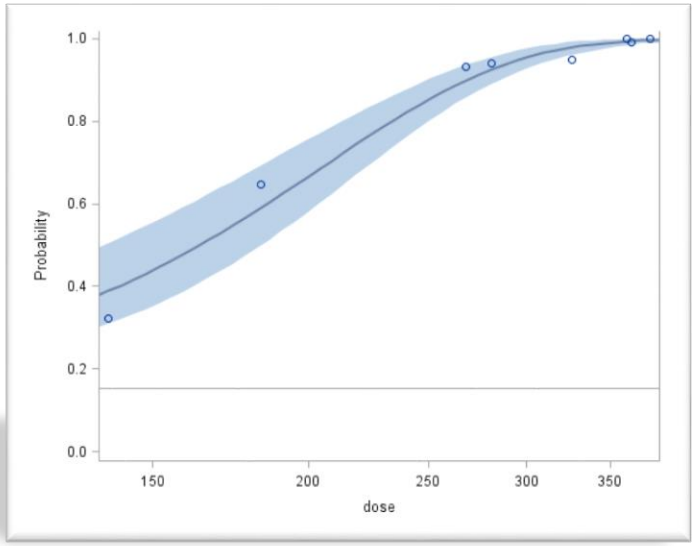
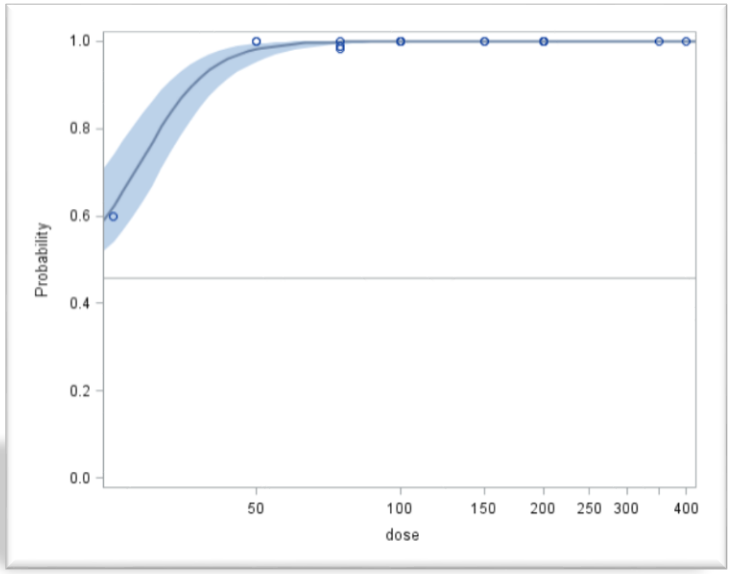
Preliminary Results

Adult (n=577)



Egg (n=1921)

insectimages.org



Life Stage	SD-99	SD-99.9	Model
Adult	352 (327-387)	406 (371-461)	Gompertz
Egg	61 (51-82)	90 (70-140)	Logistic

Concluding Thoughts

Benefits of PI

- Effective for many types of pests
- Minimal impact on commodity quality
- May be applied at diverse points post-harvest

Question for you:

What commodities could be added to the US irradiation program?

Questions?

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