The Development of Generic Irradiation Doses for Quarantine Treatments

REPORT OF THE 3\textsuperscript{RD} RESEARCH COORDINATION MEETING

Buenos Aires, Argentina, 15 – 19 October 2012

FAO / IAEA Division of Nuclear Techniques in Food and Agriculture
Reproduced by the IAEA
Vienna, Austria, 2012

\textit{NOTE}
The material in this document has been agreed by the participants and has not been edited by the IAEA. The views expressed remain the responsibility of the participants and do not necessarily reflect those of the government(s) of the designating Member State(s). In particular, neither the IAEA nor any other organization or body sponsoring this meeting can be held responsible for any material reproduced in the document.
Report of the 3rd Research Coordination Meeting

On

The Development of Generic Irradiation Doses for Quarantine Treatments

Buenos Aires, Argentina
15 – 19 October 2012

CRP D62008
Meeting Code: RC-1143.2

Produced by the IAEA
Vienna, Austria, 2012
1. Introduction

The third Research Coordination Meeting (RCM) of the Coordinated Research Project (CRP) on the Development of Generic Irradiation Doses for Quarantine Treatments was held in Buenos Aires, Argentina from 15 to 19 October 2012.

This CRP is advancing work to establish validated irradiation dose treatments to control insect species of quarantine significance and considerable progress has been made since the project commenced in 2009. The results will strengthen existing irradiation standards developed under the International Plant Protection Convention (IPPC), thereby enabling international trade for various fruits and vegetables through the use of generic irradiation doses for a wide range of quarantined pests.

The Meeting was chaired by G Hallman, with C Horak as co-chair. The list of participants (Annex A) and adopted Agenda (Annex B) are attached.

2. Background

Regulatory authorities and scientists from many internationally recognised institutions have generated research data on the effectiveness of irradiation as a quarantine treatment against specific insect pests that can infest various commodities such as fruits and vegetables. These authorities have concluded that the development of generic irradiation dose treatments suitable to control a broad range of pests is both feasible and desirable and in many cases generic dose treatments could negate the need to develop or validate specific irradiation dose treatments tailored to individual arthropod species.

The application of ionizing radiation (gamma, electron beam or X-ray irradiation) as a plant health (phytosanitary) treatment has expanded rapidly in recent years with several countries irradiating fruit in order to meet quarantine requirements for exports (Table 1). This application of irradiation technology is important for both developed and developing countries due to uncertainties on the future availability and increasing price of methyl bromide, a fumigant facing increasing restrictions under the Montreal Protocol, but still widely used as a quarantine and pre-shipment treatment for pests of quarantine significance. There is a need for validated alternative post-harvest pest control methods, and ionizing radiation is a viable and effective alternative as demonstrated by applied research leading to the development of additional irradiation treatments.

Since 1981, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture has supported research, education and cooperation in the use of ionising radiation as a post-harvest treatment. In this regard, the Food and Environmental Protection Sub-programme has implemented four coordinated research projects in the area of phytosanitary applications of irradiation. These projects established the basis for developing national and international standards on the use of irradiation as a phytosanitary treatment. Specifically, in 2003 the IPPC approved the International Standard for Phytosanitary Measures Guidelines for the Use of Irradiation as a Phytosanitary Measure (ISPM 18), and subsequently established irradiation treatments under the IPPC Standard on Phytosanitary Treatments for Regulated Pests (ISPM 28).
Table 1: Countries Using Irradiation as a Quarantine Treatment

<table>
<thead>
<tr>
<th>Country of Origin</th>
<th>Destination Country</th>
<th>Commodity</th>
<th>Date trade started</th>
<th>Volumes (tonnes)</th>
<th>Radiation used</th>
<th>Minimum Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA (Florida)</td>
<td>USA (Texas and California)</td>
<td>Guava</td>
<td>1999</td>
<td>750 t (2011), 201 t (2011)</td>
<td>Gamma.</td>
<td>70 Gy,</td>
</tr>
<tr>
<td>USA (Hawaii)</td>
<td>USA (mainland)</td>
<td>Sweet potato, rambutan, longan, apple, banana, curry leaf, dragonfruit, mangosteen,</td>
<td>2000</td>
<td>4,000 t (Mainly sweet potato)</td>
<td>X-ray</td>
<td>400 Gy</td>
</tr>
<tr>
<td>Australia</td>
<td>New Zealand</td>
<td>Litchiis, mango, papaya</td>
<td>2004</td>
<td>580 t (2010) 1262 t of mango (2011/12)</td>
<td>Gamma</td>
<td>-</td>
</tr>
<tr>
<td>USA</td>
<td>USA</td>
<td>Mango</td>
<td>2007</td>
<td>275 t (2008)</td>
<td>Gamma (E-Beam facility authorized in 2012)</td>
<td>400 Gy</td>
</tr>
<tr>
<td>India</td>
<td>USA</td>
<td>Mango</td>
<td>2007</td>
<td>79 t (2011)</td>
<td>Gamma</td>
<td>400 Gy</td>
</tr>
<tr>
<td>Thailand</td>
<td>USA</td>
<td>Mango, longhan, mangosteen, rambutan</td>
<td>2007</td>
<td>4,080 t (by late 2007)</td>
<td>Gamma</td>
<td>400 Gy</td>
</tr>
<tr>
<td>Vietnam</td>
<td>USA</td>
<td>Dragon fruit, rambutan;</td>
<td>2008</td>
<td>&gt; 1,500 t (2011)</td>
<td>Gamma</td>
<td>400 Gy</td>
</tr>
<tr>
<td>Mexico</td>
<td>USA</td>
<td>Mango, guavas, citrus fruit, Manzano, Mangosteen, chilli,</td>
<td>2008</td>
<td>10,318 t (2010)</td>
<td>Gamma</td>
<td>150 or 400 Gy</td>
</tr>
<tr>
<td>Pakistan</td>
<td>USA*</td>
<td>Mango*</td>
<td>2010</td>
<td>5.8 t (2011)</td>
<td>X-ray (USA)*</td>
<td>400 Gy</td>
</tr>
<tr>
<td>Malaysia</td>
<td>USA</td>
<td>fruits</td>
<td>-</td>
<td>-</td>
<td>Gamma / E-Beam?</td>
<td>Proposed</td>
</tr>
<tr>
<td>Philippines</td>
<td>USA</td>
<td>Mango</td>
<td>-</td>
<td>-</td>
<td>Gamma / E-Beam?</td>
<td>Proposed</td>
</tr>
<tr>
<td>Australia</td>
<td>Malaysia</td>
<td>Mango</td>
<td>-</td>
<td>-</td>
<td>Gamma?</td>
<td>Proposed</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Chile</td>
<td>Dragon fruit</td>
<td>-</td>
<td>-</td>
<td>Gamma / E-Beam?</td>
<td>Proposed</td>
</tr>
</tbody>
</table>

* Irradiated on arrival in the USA, all others are irradiated at country of origin
In 2009, eight irradiation treatments were adopted, a year later a further three irradiation treatments were included, and an additional three treatments were adopted at the March 2011 meeting of the Commission on Phytosanitary Measures (CPM) of the International Plant Protection Convention (IPPC), making a total of fourteen internationally adopted post-harvest phytosanitary treatments. All fourteen irradiation treatments are included in the annexes to the standard ISPM No. 28 Phytosanitary Treatments for Regulated Pests, as follows:

Adopted by the Commission on Phytosanitary Measures in 2009

- Annex 1: Irradiation treatment for Anastrepha ludens
- Annex 2: Irradiation treatment for Anastrepha obliqua
- Annex 3: Irradiation treatment for Anastrepha serpentina
- Annex 4: Irradiation treatment for Bactrocera jarvisi
- Annex 5: Irradiation treatment for Bactrocera tryoni
- Annex 6: Irradiation treatment for Cydia pomonella
- Annex 7: Irradiation treatment for fruit flies of the family Tephritidae (generic)
- Annex 8: Irradiation treatment for Rhagoletis pomonella

Adopted by the Commission on Phytosanitary Measures in 2010

- Annex 9: Irradiation Treatment for Conotrachelus nenuphar
- Annex 10: Irradiation Treatment for Grapholita molesta
- Annex 11: Irradiation Treatment for Grapholita molesta under hypoxia

Adopted by the Commission on Phytosanitary Measures in 2011

- Annex 12: Irradiation treatment for Cylas formicarius elegantulus
- Annex 13: Irradiation treatment for Eusceps postfasciatus
- Annex 14: Irradiation treatment for Ceratitis capitata

Despite these successes, important gaps in knowledge still remain, and there are a number of other critical non-fruit fly pests of quarantine significance where comparatively little research on their susceptibility to irradiation has been performed. Such pests include mites, thrips, mealybugs, weevils, leaf miners, aphids and scale insects.

A Consultants Meeting held at the IAEA Headquarters from 3 - 7 November 2008 considered these gaps in knowledge. The purpose of the Consultants Meeting was to advise the Food and Environmental Protection and the Insect Pest Control Subprogrammes of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture (NAFA) on the proposed Coordinated Research Project (CRP) on the Development of Generic Irradiation Doses for Quarantine Treatments. The Meeting recommended that:

i. A set of guidelines should be developed during the first RCM on the application and reporting of dosimetry to ensure consistency.

ii. Research protocols should be developed during the first RCM that include, among other things, definitions of the measure of efficacy for irradiation as a phytosanitary option, for all the arthropod groups that will be studied under the CRP.

iii. The CRP outcomes should facilitate the finalisation of IPPC treatments and standards that deal with phytosanitary applications of irradiation.

iv. A high priority should be given to develop a generic dose for all phytophagous mites.

v. A generic dose for all weevils should also be developed.

vi. Reducing the generic dose of 400 Gy for all Insecta (except pupae and adults of Lepidoptera) should be investigated.

vii. The CRP framework should consider the outputs of previous CRP and synergies with related TC country and regional irradiation projects.

viii. Large scale testing up to 30 000 insects should be considered in confirming that the selected dose is efficacious.
The first Research Coordination Meeting, held in Vienna, Austria, 5 – 9 October 2009, noted that three of the recommendations could not be fully addressed, namely:

- Recommendation (iv): Although the research will start to establish a body of work that could eventually result in a generic dose for the quarantine treatment of all mites, the CRP includes work on four species of phytophagous mites, and it is unlikely that a generic dose could be agreed based on four species.
- Recommendation (v) cannot be addressed as none of the CRP participants are studying weevils.
- Recommendation (vi): In making this recommendation, it was assumed that the 400 Gy generic dose for all Insecta (excluding pupae and adults of Lepidoptera) would be accepted by the IPPC.

The second Research Coordination Meeting (RCM) of the Research Coordination Project met at the National Center for Electron Beam Research, Texas A&M University, College Station, Texas USA from 11 – 15 April 2011. The meeting reviewed the results and proposed research of individual participants, evaluated the extent to which generic doses for specified groups of arthropods could be established and discussed research to fill any gaps in the data need for setting generic doses.

The meeting recalled that one of the considerations that differentiate irradiation from other phytosanitary treatments is the fact that quarantine irradiation treatments may not lead to acute mortality. Phytosanitary security can be assured by the prevention of further development and/or reproduction of pests and, following irradiation treatment it is possible that quarantine inspectors could find live (though non-viable) insects in properly irradiated commodities. As a result, there is no independent confirmation of efficacy, such as the presence of dead insects treated by other phytosanitary methods. Therefore, the efficacy of irradiation treatments must be assured through appropriate research to confirm the process. Precise definitions of post-irradiation responses are therefore required for the benefit of government inspectors and commercial users.

The conclusions and recommendations of the Second RCM were as follows;

**Conclusions of the Second RCM**

1. The following participants, Mohammed Mansour, Valter Arthur, Yeudiel Gomez Simuta, Hu Meiying and Zhan Guoping (from Syria, Brazil, Mexico and China) were unable to attend this meeting as a result of visa problems.
2. The presentations demonstrated considerable progress in achieving the objectives of the CRP and some specific generic treatment doses should be proposed by the end of the project.
3. It was noted that the dosimetry carried out by the different researchers appeared to be highly consistent: the measured doses closely correlated with target doses within the tolerance of the dosimetry dose comparison system.
4. The meeting recognized the usefulness of an on-line Internet forum, with appropriate resources, which will enable participants to readily communicate effectively on issues of mutual concern.
5. Working Groups were established to address specific issues and improve collaboration and achieve synergies on common research topics.
6. The presence of observers to the meeting substantially enriched the discussions.

**Recommendations of the Second RCM**

1. The On-line discussion forum was recognized as being a very valuable resource and programing support should be continued.
2. The meeting recommends continued liaison and cooperation with both the IPPC secretariat and the TPPT in order to facilitate the adoption of generic irradiation treatments stemming from this Project.
3. The meeting continued to encourage further funding and implementation of training courses related to the application of international standards, the operation of irradiation facilities and quarantine inspection and regulatory control by international organizations as per RAS5050. The group thought that there was a particular need for training of NPPO inspectors with regard to the inspection of irradiated consignments.
4. In order to increase the number of species tested within the selected insect groups, participants are encouraged to generate dose-response data for any additional species which are readily available. These doses-responses curves should be compared, and confirmatory testing carried out, on only the most radio-tolerant species.

5. Participants who were unable to attend should use the On-line forum to update the CRP on their progress, and any other concerns.

6. Future meetings should be arranged to take best advantage of local observers who can contribute to the discussions.

The participants proposed that the 3rd RCM be held in Argentina in the 4th quarter of 2012 as the new regional TC project will start in 2012 and one of the TPPT members is based there. In addition, the region is proposing using irradiation for export commodities.

3. Objectives

3.1 Objectives of the Coordinated Research Project

The overall objective of the CRP is to validate generic treatment doses for groups of arthropod pests of quarantine significance in international trade. Secondary objectives include an examination of the effects of low oxygen commodity storage and dose rate on the efficacy of treatments against insect pests and the tolerance of food commodities to the treatment doses.

Research will assist in the development of a generic dose treatments against Insecta and the work will also assist in setting doses for the quarantine treatment of phylum Arthropoda (and a few subgroups within that phylum) as well as directly establish minimum doses that will provide quarantine security against specific pests in various commodities.

Research on specific non-fruit fly pest species or groups will be conducted at different locations by researchers using practices that are adequate for phytosanitary applications of irradiation, such as accurate, traceable dosimetry, acceptable pest-rearing methods and precise determinations of efficacy. Efficacy under commercial conditions of oxygen stress, whether intentional or passive, will be tested for certain applications. Tolerances of specific commodities under various commercial conditions will also be studied.

Expected Research Outputs

- Data on applications of irradiation on pests of quarantine significance.
- Validation of irradiation doses for the quarantine treatment of specific insect species.
- Determination of the effect of low oxygen gas content (i.e. modified atmosphere storage) and dose rates on irradiation efficacy.
- The tolerance of specific products to irradiation.
- Communication of research findings to the wider scientific community.

Expected Research Outcomes

- Consideration of the project findings by the IPPC and national plant protection organisations.
- Additions to International Standards for Phytosanitary Measures, including ISPM 28 on Phytosanitary Treatments for Regulated Pests.
- Beneficial outcomes to developed and developing countries by increasing international trade in high value crops and fruits that are subjected to irradiation treatments.
- An increase in international trade and a lowering of trade barriers by addressing quarantine requirements for insect pests.

### 3.2 Objectives of the Third Research Coordination Meeting

The objectives of this third RCM were to follow on from previous coordination meetings and to review and appraise research activities and outputs produced so far and to agree a programme of work for the final phase of the project. The logical framework used in formulating the CRP was used as the basis for its evaluation, which included an examination of what had been achieved by each participating organisation and how this is contributing to the objectives of the project as a whole.

### 4. Third Research Coordination Meeting

Ms María Julia Palacín, Vegetal Quarantine Director in SENASA (National Food Safety and Quality-Phytosanitary Regulatory Authority) and Ms Eulogia Kairiyama, Radiations Technology and Application Manager, welcomed the participants and each provided an opening address. Opening remarks were presented on behalf of the FAO and IAEA by Carl Blackburn and Andrew Parker of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture, based in Vienna, Austria. They thanked the hosts and in particular Ms Celina Horak and her team, for the excellent arrangements in place for hosting the meeting.

The participants (Annex A) introduced themselves and reviewed the meeting arrangements. Mr Guy Hallman was appointed chair and Ms Celina Horak was appointed co-chair of the meeting. Mr Ray Cannon volunteered to be rapporteur. The provisional agenda (Annex B) was adopted as proposed.

#### 4.1 Introductory Presentations

Update on The IPPC Technical Panel on Phytosanitary Treatments (TPPT) and forward look to the TPPT meeting in December 2012.

Mr Ray CANNON [Agreement Holder 15837]

A total of 14 irradiation treatments are currently adopted in Annex of ISPM 28. The first eight were adopted by the Commission on Phytosanitary Measures (CPM) of the IPPC in 2009. An additional six treatments were adopted at the fifth and sixth sessions of the CPM in 2010 and 2011.

Additionally, four new irradiation treatments have been submitted to the Technical Panel on Phytosanitary Treatments (TPPT) in response to the “2012 call for treatments” and all four were submitted by participants of this CRP:

1. 2012-009 - Irradiation as a Treatment for *Ostrinia nubilalis*
2. 2012-011 - Irradiation as a Treatment for *Dysminococcus neobrevipes* Beardsley, *Planococcus lilacinus* (Cockerell), and *Planococcus minor* (Maskell) (Hemiptera: Pseudococcidae)
3. 2012-008 - Generic Irradiation Treatment for Eggs and Larvae of Lepidoptera
4. 2012-012 - Generic Irradiation Treatment for pupae of Lepidoptera

Mr Cannon summarized comments that were received during the adoption process on the above recommended irradiation treatments for ISPM 28. These included concerns about the following:

1. whether there were any potential non-target effects on the quality of the irradiated produce.
2. the applicability of irradiation treatments to all fruits and vegetables (is the extension safe?)
3. Dosimetry methods should be described.
4. Concerns about the extrapolation from the results of researched species to all species within a group (e.g. Family) covered by a generic dose (i.e. the validity of an effective dose for all species of quarantine significance which were not tested in regard to irradiation).
Some of the TPPT concerns regarding a submission for a broad generic 400 Gy treatment against all Insecta except pupal and adult Lepidoptera were also discussed. This treatment is currently used commercially on imports to the USA by the authorities in that country under bilateral agreements with the producer countries. However, this treatment has yet to be adopted by the CPM. The concerns raised against this generic treatment include:

- The assumptions and reasoning in support of the extrapolation and a need to explore them more fully.
- Arguments in support of this extrapolation could be made more explicit in the submission.
- More details on the scientific rationale for the extrapolation to all fruits and vegetables should be included.
- Providing assurance that there is no evidence which conflicts with or contradicts proposed treatment dose.
- Issues related to understanding and setting an Effective Dose (ED) for the generic treatment (based on a number of different studies).
- Statistical issues concerning outliers.

A number of comments were made concerning the confidence and reliability of setting generic dose levels. Submissions based on a large number of different studies, taken from the literature, deal with a range of data for irradiation doses. The aim in setting effective dose treatments is to strive to set generic treatment level(s) that inspire confidence in the treatment (“provide a liberal margin of security”). To achieve this involves identifying genuine outliers (i.e. any exceptions where a specific insect species needs high irradiation doses than would be expected) from false outliers (i.e. unnecessarily high dose treatments). By definition, a generic dose should be higher than the doses needed for most (if not all) species – at least those species identified as being of quarantine concern (for example by “Pest Risk Analysis”, PRA). From a statistical perspective, there will be an overall level of confidence, based on the (different) numbers of insects used in the different studies.

In summary, it was thought that when considering any submission for a generic dose treatment, the TPPT will need to be informed of the basis (or logic) for excluding some of the literature and/or selecting only some of the evidence. For example, reasoning might include the following:

- highlighting where a single study is contradicted by a number of other consistent studies.
- an extrapolation made from evidence for a congeneric (related, belonging to the same genus) species.
- a study may have been chosen in preference to another because a higher number of insects were used in the experiments.
- a dose study may have been preferred if it is regarded as being in some way the more scientifically sound of similar studies.
- an extrapolation may have been made to a less onerous (i.e. easier to achieve) developmental end point or measure of efficacy.

Recent Developments in Generic Dose Phytosanitary Treatments and expectations for the CRP Outputs and Outcomes.

Mr Guy HALLMAN

Mr Hallman commented on the August 2012 IPPC TPPT call for irradiation treatments and reviewed reasons for the Panels rejection of earlier PI proposals. These included:

1) Insufficient number of insects treated.
2) Poor performance of controls.
3) Most resistant life-stages were not tested.
4) Research was carried out using only one artificial diet.
5) Uncertainty about the fate of the F₁ generation (e.g. adults will be present, so the radiation dose will also need to prevent reproduction of this generation).
6) The need to be highly specific about the treatment end point: e.g. at what particular life-stage was development arrested.
It was suggested that expectations for the remainder of the CRP are to focus on key groups where additional data would have a large impact on developing a treatment. For example a generic dose for scale insects, mealybugs and lepidopteran larvae. In addition, generic treatment doses against weevils and mites would also be very useful. It may also be possible to propose a generic dose for all insects (except outlier groups such as lepidopteran pupae). Research data generated by this CRP would also assist and possibly help reduce the dose for the current 400 Gy phytosanitary treatment against all insects (except lepidopteran pupae) in use by the USA authorities but which remains as an active submission at the TPPT.

Several discussion points were raised:
- How to guide research toward approval of generic doses?
- Can we take up other organisms to work on (e.g. not only insects, but other pests such as slugs)?
- In 2014, could the CRP confidently propose a generic dose treatment or a number of generic treatments?

It was noted that the TPPT has a precedent in adopting a generic dose (for tephritids) and this contained many ‘outliers’, in one case a dose of approximately 1 kGy; but these were dealt with successfully, in that there was an adequate explanation for the high dose values and in support of a lower effective treatment dose.


Mr Carl BLACKBURN

Currently the international standard ISPM 28 has one generic dose treatment out of fourteen phytosanitary irradiation (PI) treatments (the generic dose treatment of 150 Gy for all fruit flies in the Family Tephritidae). This paper proposes a new generic PI dose treatment of 250 Gy for lepidoptera eggs and larvae, and is the basis of a new submission to the IPPC in response to the 2012 TPPT call for new phytosanitary treatments.

The proposed Generic Phytosanitary Irradiation Dose of 250 Gy for Lepidoptera Eggs and Larvae uses the endpoint (measure of efficacy) of the prevention of emergence of normal-looking adults. It defines “normal looking adults” as insets that can fly and therefore mate; it is the same approach as for Generic PI treatment against tephritids. The proposal as drafted is supported by published research involving 29 species and data on late instar larvae were considered (larvae are more radio-tolerant than eggs).

Mr Blackburn also used this opportunity to outline why there was, in practice, a liberal margin of security provided when setting a generic dose treatment. When the treatment is applied commercially, the generic dose for the treatment is the minimum acceptable dose that must be applied (for example equal to 250 Gy treatment for lepidoptera eggs and larvae), which means that an irradiation facility will need to aim to deliver a dose slightly greater than 250 Gy i.e. most of the irradiated food will receive a dose much greater than 250 Gy.

The presentation outlined the process of characterising the dose distribution in a product using an example of a simple ‘two side’ irradiator, where a box of product makes two passes of a radiation source and is irradiated on one side and then on the opposite side. It was explained that radiation processing involves dose mapping i.e. measuring the dose distribution with dosimeters to characterise the distribution in a typical process load, and determining the location and magnitude of both the maximum dose and the minimum dose in the process load.

An optimal dose range for irradiation processing can be calculated using statistics to give “target dose” parameters. The irradiation facility can then set up the process to dose within the “minimum target dose” and “maximum target dose” range when it is treating the commodities, i.e. to schedule an exposure time by setting the conveyor speed so that the radiation facility delivers a “minimum target dose” that is greater than the minimum acceptable level for the desired benefit with an acceptable confidence limit (e.g. of 97.5%
confidence that the minimum dose actually delivered is always greater than the minimum acceptable dose).
A full explanation of the Target Dose approach can be found from pages 68 – 72 in the publication “Dosimetry for Food Irradiation”, Technical Reports Series No. 409 of the International Atomic Energy Agency (2002), which is available online1.

For example for an irradiation treatment where no part of the product must receive a dose less than 250 Gy, statistical analysis of validation studies could suggest setting the irradiation plant to deliver a minimum target dose of at least 350 Gy because the statistics show that when a dose of 350 Gy is delivered to the food, the facility can be 97.5 percent confident that no part of the irradiated product will receive a dose less than 250 Gy. Note that using this target dose parameter will result in the vast majority of the irradiated product receiving a radiation dose much greater than the specified treatment dose of 250 Gy. Also, a similar approach can be used for maximum dose, where a statistical approach can be used to calculate a maximum target dose which is less than the maximum dose allowed by regulations or that would cause some unacceptable detrimental effect.

In discussions following the presentation it was mentioned that an operator of a commercial facility works to a “minimum target dose” of 620 Gy and a maximum target dose of 920 Gy in order to ensure that they deliver dose of at least 400 Gy with a maximum dose that does not exceed 1000 Gy for all products processed.


Mr Andrew PARKER

Mr Parker gave an outline of the draft journal paper. It is also the basis of a proposal for an additional generic PI treatment and was submitted to the IPPC in response to the 2012 TPPT call for new phytosanitary treatments.

There is a 400 Gy generic dose PI treatment that is used by the USA authorities and is still being considered for adoption by the IPPC as an international standard treatment against all Insecta but specifically excluding Lepidoptera pupae and adults. A dose much higher than 400 Gy would be necessary for treatments against Lepidoptera adults and pupae. Adults, however, rarely infest commodities and so are not important for PI. A treatment dose for pupae would be very useful as these could be present on commodities and such a PI treatment would “fill the gap” while the 400 Gy generic dose is being discussed by IPPC member countries.

Prevention of adult Lepidoptera emergence would require a high dose and is not necessarily the ideal end-point for a PI treatment. The draft journal paper proposes using prevention of reproduction as an alternative measure of efficacy (an accepted end-point by the IPPC). A PI treatment could be based on one of several life-stages, including prevention of oviposition, F1 egg hatch, development past a particular instar (2\textsuperscript{nd}, 3\textsuperscript{rd}, 4\textsuperscript{th}, etc.), pupation, etc. In general, the PI treatment dose required reduces, the more mature the life stage. Hence a generic dose of 350 Gy is proposed as a PT against Lepidoptera that Infest Shipped Commodities as Pupae as 350 Gy would also be adequate against earlier life-stages. This paper has been submitted to the Journal of Economic Entomology and is the basis of a new generic treatment that has been submitted to the IPPC in response to their 2012 call for new phytosanitary treatments.

Many papers have been published in this area and although most are for the Sterile Insect Technique (SIT) much of these data are also applicable to PI. However, SIT publications often have a different emphasis, e.g. prevention of male reproduction. The dose for the prevention of male reproduction is higher than needed for female sterility (which is important for PI). Also, a PI treatment dose determined from studies of irradiated male mated with normal female insects (as with SIT) would lead to a higher treatment dose than considering the more usual PI treatment scenario of irradiated male mated with irradiated female [“irradiated male mated

with irradiated female” requires a substantially lower treatment dose, as the dose required to prevent reproduction in general decreases from “Irradiated male mated with normal female” > “normal male mated with irradiated female” > “irradiated male mated with irradiated female”). For these reasons, it is possible to make use of data generated from SIT studies to determine a generic PI treatment dose.

The draft journal paper could have adopted a liberal position in terms of considering adequate methodologies in the scientific reports reviewed, for example including research studies reporting experiments where females or both sexes were irradiated or where the completeness of reporting and the adequacy of the interpretation of results could have indicated a reasonable irradiation treatment dose. A more conservative position could also have been used, only taking into consideration research where late pupae were irradiated, a series of doses were used in the studies, with at least dose producing sterility, and very detailed reporting of dosimetry and information relating to adults emerging from pupae within 1-2 days after irradiation. However, the draft paper uses a practical approach which aims to be somewhere in-between these two extremes. An initial screening of the potential literature comprising 80 studies of 54 species in 14 families reduced the available literature to 41 studies of 34 species in 9 families, of these five studies reported doses to ensure sterility which were greater than 350 Gy:

1. Cogburn et al reported 1 kGy did not prevent the production of “progeny” (not defined) in Sitotroga cerealella, but Hallman & Phillips found that 443-505 Gy applied to adults prevented egg eclosion.

2. Cogburn et al reported 450 Gy did not prevent the production of “progeny” (not defined) in Plodia interpunctella, but Hallman & Phillips found that 336-388 Gy applied to adults prevented egg eclosion and Johnson & Vail achieved sterilization with 269 Gy.

3. Flint & Cressin reported 450 Gy was required to prevent emergence in Heliothis virescens but El Sayed & Graves reported only 300 Gy

4. Etman et al. reported 500 Gy to sterilize Corcyra cephalonica but Sehgal & Chand found no hatch at 205 Gy

5. Suckling et al. found at 450 Gy was required to prevent egg hatch in Teia anartoides, but a previous study by Suckling et al found no eggs were produced by females mated to F1 males where the parents were treated with only 140 Gy.

Therefore it is proposed that a generic dose of 350 Gy is justified and provides a significant margin of security for a treatment. A dose of 350 Gy is greater than required for most species, and the actual dose applied commercially will in practice always be higher than 350 Gy (previous presentation). Radiation induced F1 sterility ensures that any individuals surviving the treatment will not be able to reproduce.

Discussion on the Publication of CRP Research in a Scientific Journal (e.g. Special issue of Radiation Physics and Chemistry).

Discussion led by Mr Andrew PARKER

One of the conditions under a CRP contract is that the work supported by the IAEA shall be published. Whilst results and reports could be published as an IAEA Technical Document, CRP participants would prefer to publish in a format that is more commonly accessed by those involved in this type of entomological technical work. It was proposed therefore that the research is published as a special issue of a journal (for example Radiation Physics and Chemistry). The details will need to be agreed but it would be relatively straight forward to publish in an open access journal that does not charge publication fees. Copyright will be held by the IAEA, in order to ensure the information is accessible and can be made available.

The meeting participants agreed that each would provide original papers (approximately 15 papers in total) for submission to a special issue of a scientific journal. In addition, a small number of introductory and review articles would also be produced. Guy Hallman agreed to be a technical editor; Ray Cannon and Carl Blackburn agreed to act as editors of the English language of the papers. It is envisaged that the draft manuscripts should be completed in readiness for review at the fourth and final RCM (in 2014).
4.2 Participants Reports


Brazil; Mr Vinicius BARROS

Small, self-contained irradiators are used in many radiation processing applications, including food irradiation research, quarantine irradiation research, sterile insect technique (SIT) and plant breeding applications. For many years the principal source of ionizing radiation has been cobalt-60 with caesium-137 less common. Over the past few years the procurement, transportation and security of installed sources has become increasingly difficult. For research and self-contained irradiators the difficulties and delays inherent in procuring cobalt are disproportionate to the value of the service and the cost of electron-beam systems can be prohibitive. As a result there is a growing interest in using X-ray systems in research and for applications that use small, self-contained irradiators. However, the principal problem remaining with new X-ray irradiators is calibration. Currently calibration can only be made with an ion chamber and electrometer, but the process is difficult and the ion chamber and electrometer system need to be calibrated by a certified laboratory on a regular basis. High energy X-ray systems can be calibrated using transfer standard dosimeters provided by a primary or secondary standards laboratory, but no transfer dosimeter is currently calibrated for use with low-energy X-ray systems (150 keV X-rays).

Mr Barros discussed alanine / EPR dosimetry systems and explained that the research has involved producing cylindrical alanine pellets and determining the calibration curve for alanine irradiated by a 150 keV X-ray. Work to date has included the production and testing of alanine pellets using various concentrations of alanine in PTFE binder. The dose response of these pellets is being tested. Work will continue to study the performance of the alanine system and in particular will need to evaluate the energy dependence of the response and optimize EPR spectrometry for dosimeter read out. The development of a reference dosimeter will include investigating and calculating uncertainties associated with the system. The prototype alanine dosimeters will be tested in canisters used for the X-ray of pupae (e.g. for the Sterile Insect Technique).

Advantages of using an alanine/EPR dosimetry system for low energy X-ray irradiation
- Dosimetric signal is stable for a considerable time after irradiation (years)
- Offers a wide range of applicability (1Gy - 100 kGy)
- Gives a linear signal-to-dose dependence (≤ 10 kGy)
- Dosimetric signal is energy and dose rate independent (gamma and electron beams)
- Accuracy
- Non-destructive read-out and fast detection
- Low temperature coefficient of irradiation
- Can be made into pellets (different shapes) and also produced as a strip
- Dosimeters are inexpensive
- Easy to handle
- Non-toxic
- Chemical composition is similar to the chemical composition of organic matter

Disadvantages
- Signal can be sensitive to light (when illuminated for a long time)
- Signal is sensitive to water (humidity)
- Electron Paramagnetic Resonance (EPR) spectrometer is expensive (but an EPR spectrometer is need to read the dosimetric signal)
Gamma Radiation Quarantine Treatments for Different Groups of Arthropods

Argentina; Ms Celina HORAK and Mr Guido Van Nieuwenhove (Research Contract 15641)

The main objective of the research is to determine and validate minimum irradiation doses necessary to secure quarantine security at 99.99 % and 95 % confidence limits in the following species: Trialeurodes vaporariorum (Hemiptera), Hemiberlesia lataniae (Hemiptera), Spodoptera frugiperda (Lepidoptera) and Tetranichus urticae (Acari).

The most radio-tolerant developmental life stage of S. frugiperda was determined. An analysis of variance of the dose response was conducted on eggs, L1/L2, L3/L4, and L5/L6 life stages using a single dose (60 Gy) applied to three replicates of 300 individuals per life stage (n=300 per life stage in 3 trials). It was confirmed that the most radio-tolerant stage occurring in the commodity is the L5/L6 stage. Also the radio susceptibility of a population reared on corn leaves (natural host) vs. artificial diet was tested, and these studies are continuing. Dose-response irradiation tests were performed with S. frugiperda in order to determine the minimum dose to achieve control efficacy: non emergence of normal adults. The minimum dose required to prevent normal adult emergence to achieve a minimum efficacy of 99.99% and a confidence limits of 95 %, was 84.35Gy (PROC PROBIT, SAS Institute 8.01)

The insect pest greenhouse whiteflies, Trialeurodes vaporariorum (Westwood) are one of the two main pest species affecting fruit and vegetable crops in Argentina. The most radio-tolerant developmental stage and minimum effective dose to prevent normal adult emergence were determined using two methods; an ANOVA [dose (30, 60, 90 and 120 Gy) and life-stage (egg, nymph and pupa) with Probit analyses [at the 99.99% of efficacy at 95% of confidence level (CL)]. Three trials were performed using at least 200 individuals of each stage per dose with “emergence of normal adults from pupae” as the treatment end point (measure of efficacy).

The two ways ANOVA analyses followed by Tukey HSD (p=0.05) showed that pupae were significantly the most radio-tolerant stage. Mean minimum effective dose irradiation to prevent 99.99% of normal adult emergence was estimated as 101 Gy. The time taken for adult emergence increased as dose increased. Emerged adults from 90 Gy treatments only survived a few hours while those from 0 (control), 30 and 60 Gy survived up to 6, 5 and 2 days respectively. Only adult females that emerged following 30 Gy treatments were able to produce viable eggs to generate an F1 population.

Future work
Further tests will be conducted using large numbers of individual insects in order to validate the minimum effective dose that prevents normal adult development on H. lataniae (Signoret) and T. vaporariorum, using a cumulative approach in experiments involving at least 29,956 individuals (to achieve 99.99% of efficacy at the 95% CL).

In addition, studies to determine the most radio-tolerant life-stage of Tetranychus urticae (Koch) will be taken forward using four doses (270, 300, 330 and 360 Gy) for each developmental stage (egg, nymph and adult). The minimum effective dose (to prevent normal adult development) for the most radio-tolerant stage will be determined. Large scale testing will be performed to confirm the minimum effective dose to prevent normal adult development.

An analysis of variance of response will be carried out on sixth-instars larvae of each rearing condition of Spodoptera frugiperda using a single dose in the upper level of control (possibly 60 Gy). Tests will be done using approximately 100 individuals per rearing condition and per trial. A minimum of three trials will be performed.

The Argentine Regulatory authority has been asked to grant permission to rear Lobesia botrana to perform dose-response irradiation studies on this insect. If this authorization is obtained, further work will be carried out to research and determine the minimum dose to achieve effective control (prevent emergence of normal adults) from fifth-instars larvae and studies involving irradiating pupae will also be taken forward. Susceptibility tests to evaluate the radio-tolerance of insects reared on natural host compared with those reared on artificial diet will be also carried out.
Development of Generic Dose Quarantine treatments

Australia; Mr Peter LEACH (Agreement Holder 15708)

Australia now has approval for the phytosanitary use of irradiation for exports to both domestic and international markets. For domestic trade, treatments are conducted using the procedure outlined in Interstate Certification Assurance (ICA) Procedure No. 55. There are two generic doses approved in ICA 55: A minimum of 150 Gy for Tephritidae (ISPM 18) and 400 Gy for all insect pests except lepidopteron that pupate internally (APHIS).

International exports of irradiated produce to New Zealand and Malaysia are continuing and Biosecurity Australia is negotiating with several countries including Thailand and the US to expand the use of irradiation. Domestically the use of irradiation has been limited due to the availability of cheaper chemical treatments. However these treatments (dimethoate and fenthion) are currently under review and some uses have already been restricted. An example is the use of dimethoate on tomatoes. This use is now restricted and as a result access to the New Zealand market has been lost until alternative treatments can be developed. Interim market access protocols are currently being negotiated (methyl bromide) but the use of irradiation cannot be negotiated until irradiation is approved for use on tomato (approval expected in March 2013).

In response to the reviews on the use of dimethoate and fenthion a national communication plan was initiated. Irradiation and the use of systems approaches were promoted as alternative fruit fly treatments and a nationwide tour was undertaken in April 2012 to promote both technologies.

Australia has nominated 2 new draft regional standards (RSPM) under the Asia Pacific Plant Protection Commission (APPPC). Regional standards were developed for methyl bromide fumigation and accreditation of irradiation facilities. The draft RSPM for irradiation facilities was based on guidelines developed in IAEA project RAS 05/050 “Guidelines for the Audit and Accreditation of Irradiation Facilities used for Sanitary and Phytosanitary Treatment of Food and Agricultural Products”.

Research is also being undertaken in several international collaboration projects funded by the Australian Centre for International Agricultural Research (ACIAR). Research in Indonesia is focusing on the use of irradiation for local mango varieties and mangosteen. Research in Australia is looking at irradiation of newly developed mango and papaya varieties. Research in collaboration with universities is also being undertaken on mango fruit quality with emphasis on lenticel spotting which is emerging as a serious defect in several Australian mango varieties after irradiation.

Use of Gamma Radiation to Control Insects and Mites

Brazil; Mr Valter ARTHUR (Research Contract 15201)

In 2011 data were obtained from experiments researching irradiation to control two insect and four mite species. Eggs, second and last instar larvae of Ecdytolopha aurantiana (Lima, 1927) (Lep.: Tortricidae), and of Tuta absoluta (Meyrick, 1917) (Lep.: Gelechiidae) were irradiated with the following gamma radiation doses: 0 (control), 25, 50, 75, 100, 125, 150, 200, 300, 400 Gy, at a dose rate of 0.511kGy per hour. After irradiation, the insects were maintained under controlled conditions of 25±3° Centigrade and 65% to 75% relative humidity. The conclusion was that the dose of 400 Gy was sufficient to induce lethality to all phases (eggs, second and last instar larvae).

In experiments involving the irradiation of Aceria litchii (Keifer, 1943) (Acari: Eriophyidae) samples of small pieces of the litchi leaf (with adult mites) were collected and irradiated with doses of 0 (control), 100, 200, 300, 400 and 500 Gy, at a dose rate of 0.486 kGy/hour. The others mites studies (Tetranychus urticae, Tetranychus desertorum and Tetranychus oligonichus) were placed in petri dishes on an alternative host (the bean plant Canavalia ensiformis). Leaves with mites were irradiated (dose rate of (0.486 kGy/hour) to doses of 0 (control), 100, 200, 300, and 400 Gy. The results show that sterilize dose for T. urticae and T. desertorum were 300 Gy, for T. oligonichus this dose was 200 Gy. For A. litchi, the data show that a dose of 400 Gy was sufficient to prevent reproduction and a 500 Gy dose resulted 100% adult mortality for adults.
was, after 15 days. A. litchi is the more radiation tolerant mite of the four mite species studied and therefore an irradiation treatment suitable to control this mite will be more than sufficient to control all four of these mites. All experiments that involved irradiation used Harwell Gammachromic YR, dosimeters with a dose range of 0.1 – 3 kGy.

In 2012 data were obtained from experiments involving four insects and one mite species. Pupae of Ecdytolopha aurantiana (Lima, 1927) (Lep.: Tortricidae), were irradiated under a high oxygen atmosphere and the experiment was replicated but with irradiation in normal (ambient) air to doses of: 0 (control), 100, 200 and 300 Gy, at a dose rate of 0.511 kGy/hour. Irradiation under oxygen was found to be approximately 20% more effective at controlling Ecdytolopha aurantiana than irradiation at the same dose under a normal air atmosphere. The sterilizing dose in atmosphere of oxygen was found to be 300 Gy, which is too low a dose to prevent reproduction when the Ecdytolopha aurantiana is irradiated in air.

Pupae of the oriental fruit moth, Grapholita molesta (Busck) (Lepidoptera: Tortricidae), were exposed to 0 (control), 25, 50, 75, 100, 125, 150, 175, 200, 250, 300 and 350 Gy, of gamma radiation (dose rate of 0.508 kGy/hour). The lethal dose to pupae was 350 Gy (100% mortality), and a dose of 250 Gy prevented the emergency of adults.

Larvae of 15-20 days age of Spodoptera frugiperda and Agrotis ipsilon were irradiated with doses of 0 (control), 50, 100, 200 and 300 Gy. A dose of 300 Gy applied to larvae was sufficient to prevent the emergence of both Spodoptera frugiperda and Agrotis ipsilon (note next lowest dose used was 200 Gy). Pupae of Spodoptera frugiperda were subsequently irradiated to doses of 0 (control), 25, 50, 75, 100, 125, 150, 175, 200, 250, 300 and 350 Gy and a dose of 250 Gy was found to be sufficient to prevent larvae hatching.

The irradiation of Aceria litchii (Keifer, 1943) (Acari: Eriophyidae) involved using samples of small pieces of the litchii leaf that had adult mites which were irradiated to doses of 0 (control), 100, 200, 300, 400 and 500 Gy, (dose rate 0.486 kGy/hour). After irradiation the pieces of irradiated leaf with the irradiated mites were placed on fresh leaves in petri dishes. The experiment was repeated but with the adult mites maintained on fresh lichii leaves placed in vases of water post irradiation (to ensure good quality leaf). The results of the two experiments were in agreement, the data show that a dose of 200 Gy was sufficient to prevent egg hatch and a dose of 500 Gy resulted in mortality of all adult mites, after 21 days.

Proposed future work: Research with Aceria litchii will include finding an alternative host because the leaves of litchii are very sensitive and tend to dry out in the laboratory making it difficult for rearing and maintaining these mites under laboratory conditions. It may be possible to work with other species of mites, and to do further experiments with different life stages and with a greater number of individuals per experiment. Future research with E. aurantiana will involve verification tests using greater numbers of individuals in order to statistically validate the treatment doses found. Future research with Tuta absoluta will include looking at methods of rearing the insect in artificial diet and experiments irradiating a larger number of individuals in order to statistically validate the treatment dose. Tests using irradiation in combination with low and high atmospheres of oxygen will be also be continued with mites and others insects.

Irradiation as Quarantine Treatment of Orange against Citrus Mites

China; Ms Mei Ying HU (Research Contract 15630)

The effects of gamma irradiation against Citrus red mite, Panonychus citri (McGregor) and effects of irradiation coupled with cold storage on the citrus rust mite, Phyllocoptura oleivora, were investigated over the past 18 months. The results show that citrus red mite mortality increased with increasing radiation dose and a dose of 200 Gy was found to prevent egg hatch. Only 4% of mite larvae irradiated to 400 Gy developed into adults and only 12% of protonymphs irradiated to 400 Gy developed into adults, the adults from these larvae and protonymphs did not produce eggs. Therefore, a dose of 400 Gy can prevent citrus red mite from reproducing. An irradiation dose of 400 Gy and 600 Gy resulted in 100% mortality by the 15th day after irradiation.
The effect of irradiation in combination with cold storage after irradiation as a treatment against citrus rust mites was found to be significant: storage at low temperatures following irradiation treatment was found to increase mortality and inhibited oviposition (egg laying). An irradiation dose of 400Gy in combination with cold storage at the temperature of 5°C resulted in 97% mortality at day 7 after irradiation (approximately half the time for 100% mortality when irradiated at 400 Gy and stored at ambient temperatures) and could be used to fully control citrus rust mites.

Fruit quality was also tested (ascorbic acid content, total sugar content and weight loss following irradiation). There was little effect on sugar content or change in weight of oranges irradiated at doses below 500Gy. However, there was a significant difference in the content of ascorbic acid between the irradiated and the control samples after 15 days storage, the ascorbic acid content in irradiated samples was almost half that of non-irradiated samples, however, after 30 days storage the ascorbic acid content in irradiated samples was two thirds that of non-irradiated samples. This suggests that irradiation at doses of 400-500Gy could be recommended as an effective control against citrus red mites and citrus rust mite without significant adverse effects on the fruit.

Experiments to investigate the application of 400Gy and 450Gy doses on citrus red mites and citrus rust mites in citrus fruits that were packed in different package materials were carried out during last 18 months, respectively. The results showed that the highest mortality (and the lowest fecundity) was for citrus red mites, irradiated at 400Gy on the Shatang mandarin packed by EPP foam packaging box, were 100% mortality was observed on the 5th day after irradiation, while citrus red mites on fruits packed by other material boxes took at least 11 days to reach 100% mortality and kept laying eggs until the 11th day. 100% mortality of citrus rust mites was observed when the mites on oranges packed by the same packaging material were irradiated at 450Gy, which also caused the lowest fecundity; while those on oranges packed by other three packaging materials took 9 days to reach the same results.

In line with this research, other Citrus mites such as six-spotted mite and citrus yellow mite will be investigated using the treatment doses against different life stages of Citrus red mite and Citrus rust mite. Extended experiments of irradiation will be investigated in export and import orange trade. Large scale application of irradiation as a quarantine treatment is feasible and would help establish export trade of Shatang mandarin orange, reducing quarantine technical barriers and enabling market access.

**Discussion**

The meeting discussed different possible end-points (measures of efficacy) for a generic irradiation treatment against mites. It was thought that mortality might not be the most appropriate measure of efficacy in terms of using a low but effective dose against mites. It was thought that a treatment to prevent mite reproduction but leaving the treated insects live would require a lower dose than the dose necessary to ensure 100% mortality, therefore a generic irradiation treatment based on a minimum dose to prevent mite reproduction would be a good end point / measure of efficacy.

Dosimetry was also discussed. It can be difficult for researchers who are working with commercial irradiation facilities to have access to full dosimetric data. It was recognized that it is necessary to do dose mapping whenever anything changes in the experimental set-up. Experiments should retain information on the actual doses received in each experiment (not just the intended “target” doses). Dose mapping is carried out in commercial situations to ensure that the correct dose is delivered when the loading configuration is altered so that the dosimetry is reliable for the different conditions (packet size, orientation, different materials and densities). Target doses under commercial conditions are greater than the treatment dose to ensure that all of the fruit in a consignment receives at least the minimum dose of irradiation necessary for the treatment to be effective (the absorbed dose > minimum dose for the irradiation quarantine treatment). In practice, some parts of the consignment will therefore receive considerably more than the minimum treatment dose that has been calculated by research and is set as a standard for example. Ideally the minimum dose, the maximum dose and the dose range should be recorded. However, many researchers rely on others to irradiate their samples for example, they hand the material over to an irradiation facility where the practitioners have their own system for achieving the required dose. It is important to clarify the actual
doses received by the samples when they were treated and to have full documentation on the dosimetry so that the research findings can be supported fully.

**Irradiation as a Phytosanitary Treatment for Controlling Carposina Sasakii Matsumura (Peach Fruit Moth, PFM)**

China; Mr Guoping ZHAN (Research Contract 15633)

Peach fruit moths (*Carposina sasakii* Matsumura), collected from the infested fruits (apple and hawthorn) in Beijing, Hebei, and Shandong Province, were successfully reared to establish a laboratory population for conducting phytosanitary irradiation tests. Research has included testing and comparing the radio-sensitivity of egg, larvae and pupae (Table A) and the biological effect of gamma-ray and X-ray radiation on mature larvae had been studied.

In radio-sensitivity tests the, 1\*\textsuperscript{st}, 2\*\textsuperscript{nd}, 3\*\textsuperscript{rd}, 4\*\textsuperscript{th}, and 5\*\textsuperscript{th} instars larvae developed in apple fruits (irradiated with 40, 60, 80, 100, 120, and 140Gy, respectively). The results showed that:

1) the number of mature larvae emerged increased significantly from 1\*\textsuperscript{st} to 5\*\textsuperscript{th} instars larvae when irradiated at the same dose of 100, 120, and 140Gy;

2) The mortality of mature larvae during pupation and eclosion significantly decreased from 1\*\textsuperscript{st} to 5\*\textsuperscript{th} larvae when irradiated at the same dose; and

3) The calculated dose for 100% non-emergence of adult increased from 1\*\textsuperscript{st} to 5\*\textsuperscript{th} instars. Therefore, mature larva (5\*\textsuperscript{th} instars larvae) are the most resistance stage infested in fresh fruit.

Mature larvae (hawthorn population) were irradiated (60, 80, 100, 120, 140 and 160 Gy) with gamma-ray, 5MeV and 6MeV X-rays, respectively. The results showed that:

1) there was no significant differences observed in terms of pupation and eclosion of moths between the different types of ionizing radiation treatments;

2) the doses calculated to result in 99% and 99.9968% prevention of adult emergence were similar in each case, and they are also similar to the dose calculated to prevent adult emergence from 5\*\textsuperscript{th} instars larvae in apple fruits (Apple and hawthorn moth populations were found to have a similar radiation tolerance when irradiated with gamma rays).

Eggs (3 day old and 5 day old) was also treated with gamma radiation, the difference in time observed for the emergence of mature larva and adults indicated that 5-day old eggs are more radiation resistant than 3-day old eggs. The dose calculated for 99% and 99.9968% prevention of adult emergence for comparing 5-day old eggs is similar to the dose calculated for 1\*\textsuperscript{st} and 2\*\textsuperscript{nd} instars larvae. In addition, the results on gamma radiation of pupae indicated that 9-day pupae were more tolerant than 6-day pupae.

**Conclusion:** No significant differences were found between gamma and X-ray irradiation in preventing emergence of adults from mature larvae of Carposina Sasakii Matsumura (Peach Fruit Moth). A disinfestation dose of **200 Gy** (gamma radiation) is suggested for prevention of emergence of adults, developing from irradiated larvae.
Future plans include large scale testing (>30,000) of Peach Fruit Moth, using non-diapausing larvae in apple fruit. Also, it is planned to compare diapausing and non-diapausing mature larvae.

Table A. The effective dose for phytosanitary irradiation of Peach Fruit Moth

<table>
<thead>
<tr>
<th>Instars</th>
<th>Effective Dose (Gy)</th>
<th>Objective of Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Egg:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-day</td>
<td>156.0 [124.0 ~ 235.3]</td>
<td>Prevention of adult emergence</td>
</tr>
<tr>
<td>5-day</td>
<td>161.4 [135.5 ~ 216.3]</td>
<td></td>
</tr>
<tr>
<td><strong>Larvae:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L₁ (3-day)</td>
<td>154.4 [134.4 ~ 191.6]</td>
<td>Prevention of adult emergence</td>
</tr>
<tr>
<td>L₂ (6-day)</td>
<td>156.4 [135.8 ~ 196.6]</td>
<td></td>
</tr>
<tr>
<td>L₃ (9-day)</td>
<td>165.2 [142.7 ~ 217.4]</td>
<td></td>
</tr>
<tr>
<td>L₄ (12-day)</td>
<td>177.9 [154.4 ~ 223.8]</td>
<td></td>
</tr>
<tr>
<td>L₅ (15-day)</td>
<td>208.6 [195.0 ~ 226.5]</td>
<td></td>
</tr>
<tr>
<td><strong>Pupae:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-day</td>
<td>246.6 (222.9~277.6)</td>
<td>Prevention of F₁ egg hatch</td>
</tr>
<tr>
<td>9-day</td>
<td>344.1 (297.9 ~ 414.7)</td>
<td></td>
</tr>
</tbody>
</table>

Development of Generic Irradiation Doses for Phytosanitary Treatment of Mealy Bug Spp. Infesting Agricultural Commodities

India; Ms Ranjana SETH (Research Contract 15852)

Mealy bugs (Sternorrhyncha: Coccoidea: Pseudococcidae) are small sap-sucking insects, and some pest species of this group cause severe economic damage to a wide range of vegetable, horticultural and field crops in India. Mealy bug species, Solenopsis mealybug, Phenacoccus solenopsis, the Pink hibiscus mealy bug, Maconellicoccus hirsutus and papaya mealy bug, Paracoccus marginatus have gained status of serious quarantine pests in India. Ionizing radiation could be considered a potential alternative for treating agricultural products to overcome quarantine barriers in trade for the spread of these pests. Bioefficacy of gamma radiation as a phytosanitary treatment was evaluated against the various ontogenetic stages of Phenacoccus solenopsis and Maconellicoccus hirsutus in this study.

Solenopsis mealybug, Phenacoccus solenopsis: The efficacy of ionizing radiation was ascertained on pre-imaginal stages and imaginal stages of Solenopsis mealy bug, Phenacoccus solenopsis, using a range of doses (5-500Gy), in order to obtain age related insect’s response towards radiation. Radio-biological investigations of mealy bugs were conducted in terms of (i) % metamorphic inhibition and % inhibition of adult formation for each pre-imaginal stage irradiated, (ii) reproductive inhibition (sterility) in parent (P₁) and F₁ generation in response to irradiation of pre-imaginal stages and imaginal stages. The ontogenetic stages of the Solenopsis mealy bug exhibited increase in radio-resistance with age. Radiation exhibited an inverse relationship with successful metamorphic development and adult formation, hence affected the growth index (GI) markedly. For instance, complete metamorphic inhibition was observed for the stage-N₁(to check its moult into N₂) at 174Gy, whereas the effective dose to N₃-♀ (determined as most radio-resistant pre-imaginal stage) for metamorphic inhibition (that would be equivalent to check in female adult formation in view of N₃-♀ being the last female pre-imaginal stage) was determined to be 340Gy. The gamma dose to N₄-♂ (most resistant among male nymphs) for metamorphic inhibition was observed to be 270Gy. The effective dose inducing ~ complete sterility (ED₉₀) was determined as 25.7Gy for N₁; 27.3Gy for N₂ and 35.5Gy for N₃ female; whereas ED₉₀ dose for inducing ~ complete sterility was 52Gy, 138Gy and 374Gy for 0-1d, 5-6d & 11-12d old (gravid) parthenogenetic females, respectively.

Pink hibiscus mealy bug, Maconellicoccus hirsutus: The efficacy of gamma radiation was also ascertained on the pink hibiscus mealy bug (Maconellicoccus hirsutus) treated in various pre-imaginal stages in a similar manner to P. solenopsis. Gamma dose to 0-1 day old eggs inducing disruption in embryogenesis and hatch (to N₁) was 57Gy. Complete metamorphic inhibition was observed for the stage-N₁ at 228Gy,
whereas the effective dose to N3-♀ (most radio-resistant pre-imaginal stage) for metamorphic inhibition was determined to be 371Gy. The gamma dose to N4-♂ (most resistant among male nymphs) for metamorphic inhibition was observed to be 357Gy.

**Work in Progress and Future research:** Further, the effective gamma doses (ED$_{50}$, ED$_{90}$ & ED$_{99.9}$) as phytosanitary irradiation will be determined for inducing parent and F$_1$ sterility in *Maconellicoccus hirsutus* treated in different pre-imaginal stages and imaginal age groups. It is also proposed to conduct the radiobiological investigations on the papaya mealy bug, *Paracoccus marginatus* in order to determine the gamma doses causing metamorphic inhibition and inducing sterility/inviability. In the last phase, the influence of temperature on radiation efficacy will be ascertained on *Phenacoccus solenopsis*, *Maconellicococcus hirsutus* and *Paracoccus marginatus*. These findings would help in deciding the quarantine irradiation doses for a complex of mealy bug species.

**Generic Dose of Gamma Irradiation for Quarantine Treatment of Mangosteen Insect Pests**

**Indonesia; Mr Achmad Nasroh KUSWADI (Research Contract 15808)**

*Exallomochlus hispidus* (Morris), a mealybug pest of mangosteen (*Garsinia mangostana*) in Indonesia, feeds on a wide variety of plants including fruit. Economic losses happen mostly due to the indirect effects of the mealybug pest infestation which, for example black sooty molds grow on deposits of honeydew produced by feeding mealybugs and deposited on leaves and fruit surfaces. This affects photosynthesis and reduces fruit quality. At present, the distribution of this mealybug species is restricted to South East Asian countries, and may be a quarantine pest hindering export of fruits, vegetables, and ornamental plants from the region. For these reasons, research is being undertaken to determine the dose of gamma irradiation required for a phytosanitary (quarantine) treatment against this pest, which seems to be limited to Asia i.e. Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam.

*Exallomochlus hispidus* was successfully collected, isolated and reared on a host medium of pumpkin / squash (*Cucurbita moschata*) in the laboratory. Investigations on biology of this mealybug, and the efficacy of gamma irradiation were undertaken in order to identify the most radio-tolerance life stage of the mealy bug, and to find out the minimum dose of gamma irradiation that could be used as a phytosanitary treatment. Pumpkin / squash were used as the host commodity in all steps of the experiments. On this host medium, the life cycle of *Exallomochlus hispidus* was found to be 27 days: with 6 days as 1$^{st}$ nymph, 7 days as 2nd nymph, 4 days as 3$^{rd}$ nymph and 10 days as pre-oviposition adult. Efficacy tests for gamma irradiation treatments (dose of 100, 200, 300 and 400 Gy) on 2$^{nd}$ nymph and pre-oviposition adults, involved approximately 50 treated individuals per experiment with 4 replicates. The results showed that the adult was more radio-tolerance than the nymph. LD50 (50% mortality) of the nymph was 200 Gy and that of the adult was 450 Gy.

Besides mortality, irradiation also affected the development of the immature life stages and induced adult sterility. With 2$^{nd}$ nymphs, irradiated with 100 to 400 Gy, experiments showed that by 26 days after irradiation a large percentage of the survivors were still in the 2$^{nd}$ and 3$^{rd}$ nymph stage, and no progeny were found to be produced by low percentage of adults that did form. Also, progeny were not produced by survivors of irradiated adults. Experiments to investigate using “the ability to produce progeny” as a measure of efficacy were carried out using irradiation doses of 50, 75, 100, and 125 Gy on pre-oviposition adults (50 individuals per experiment with 4 replicates). These experiments showed that adults irradiated with doses above75 Gy did not produce progeny. Furthermore, of the four replicate experiments where adults were irradiated to 50 Gy it was only in one replicate that adults produced progeny. Therefore 75 Gy could be the minimum dose recommended to be used in Phytosanitary Irradiation for the *E. hispidus* mealybug. It is planned to repeat this efficacy test with irradiation doses of 40, 60, 80 and 100 Gy, and dose response of individual sterility/fertility will be observed to see if a minimum dose for a treatment can established with more precision. Tests will be applied to different ages of pre-oviposition and early oviposition period of adults, to see the different degree of response between ages. Future work will undertake similar research but focusing on the mealybug *Pseudococcus cryptus*. 

---

21
Quality of Gamma Irradiated Mango “Ataulfo” - Part of the Implementation of a Generic Dose Irradiation Treatment to Control of Insect Pests Other Than Fruit Flies in Mango.

Mexico; Mr Yeudiel GOMEZ SIMUTA (Research Contract 16037)

The imminent restrictions on the use of ethylene dibromide (EDB) for quarantine disinfestation purposes has provided new impetus for research into the application of ionizing irradiation as an alternative phytosanitary treatment. In 1986, an International Consultative Group on Food Irradiation Task Force Meeting on Irradiation as a Quarantine Treatment was held at Chiang Mai, Thailand. The Task Force Group considered that tephritid fruit flies had been researched so well that a dose of 150 Gy could be recommended for any species in the absence of specific data to support a lower dose. The Group also considered insects other than fruit flies, recommending for further consideration a generic disinfestation dose of 300 Gy, which could be appropriate for all insects, in the absence of specific data to support a lower dose.

Acarid mites (Acarina: Acaridae) are common pest of stored agricultural products. These mites not only cause economic loss in storage but, through quarantine, their presence restricts the export marketing of grains, dried fruits and vegetables, onions and other agricultural products. Such restrictions may be eased by application of a suitable disinfestation treatments: fumigation with chemicals (such as methyl bromide or phosphine), heat treatments, cold treatments, or ionizing radiation. Irradiation has been proposed as a quarantine treatment for various fruit flies, the mango weevil, Sternochaetus mangifera (F), and the codling moth, Cydia pomonella (L), but until this CRP, little attention was been given to the possible use of radiation as a potential quarantine treatment for mites infesting stored products. Literature from the 1990’s suggests an irradiation treatment for immediate mortality of mites could require doses higher than 2000 Gy, but lower doses (1300 to 1500 Gy) could be sufficient for mortality within a few weeks. Research indicates that treatment and doses of 250 to 300 Gy could be effective by inducing sterility and preventing the reproduction of mites.

In Mexico the hot water treatment has been used as quarantine treatment for the Mexican mango (Ataulfo variety), however, the number of packers that use this treatment method is insufficient to meet the demand of mango producing areas. In this case, irradiation phytosanitary treatments can be useful but it is necessary to find if the irradiation dose to meet the phytosanitary measure can be applied in a commercial scale irradiation facility, without effecting product (fruit) quality.

Studies were focused on the dose mapping of the irradiators and on the quality of the fruit after treatment. It was found that doses of 150 Gy and 300 Gy (gamma radiation) can be applied because these irradiation treatments had no adverse effect on the weight loss, external and internal color, pH, soluble solids, firmness and acceptance of the fruit for the consumers. In terms of fruit quality, findings suggest fruit treated with 150 Gy - 300 Gy, has the same degree of acceptability as hot water treated fruit and non-treated fruit.

When considering the commercial practicalities and especially regarding dose mapping our findings emphasize that it is very important to select the dose rate of the source according to the required dose treatment in order to minimize the dose distribution (reduce the difference between the minimum and the maximum dose) received by the product during the irradiation process. The next step of the project will be focused on the studies of the effects of dose on nutritional factors of the fruit and to evaluate the impact of radiation treatments on Mamey (Pouterua sapota) and Rambutan (Nephelium lappaceum) fruits.

Use of Irradiation as Phytosanitary Treatment for the Control of Citrus Psyllids Diaphoronia Citri and Scale Insects.

Pakistan; Mr Inamullah KHAN (Research Contract 16894)

The citrus psylla, Diaphoronia citri, and citrus red scales Aonidella aurantii are of quarantine importance in Pakistan, they are key pests on citrus and cause millions of dollars in losses to the citrus industry every year. Exporting to pest free countries is not possible without effective phytosanitary treatment as immature life-stages (particularly eggs and nymphs) could be transported along with fresh fruits to importing countries.
Irradiation as a phytosanitary treatment was explored as a method to prevent adult emergence and/or mortality of citrus psylla nymphs and adults. First and second stage nymphs infested citrus shoots and nursery plants of 6-8 months old were irradiated in two different experiments with target doses of 40, 80, 100, 150, 200, 250, 300 Gy at a dose rate of 0.367 Gy/minute and held for possible mortality and adult emergence. Post irradiation mortality was low for the target dose of 40, and 80 Gy, also the 100 Gy treatment dose did not prevent adult emergence. However emerging adults were short lived and died within 48 hours of emergence. The 150 Gy dose prevented adult emergence and all nymphs died within a 3 day post irradiation period. Doses of 200 resulted in 100% mortality of nymphs within 24 hrs.

Mortality of citrus psylla adults when exposed to various doses of gamma irradiation (40, 80, 100, 150, 200, 250, 300, 400, and 600 Gy) at a dose rate of 0.367 Gy/ mim and to doses of 800, 1000, 1500 at dose rate of 141.66 Gy/minute showed that male citrus psylla were more radiation tolerant than females. Dose of 800 Gy resulted in complete mortality of the males within five days and females within 4 days post treatment. The trend in mortality for females was similar to males except that they were comparatively more susceptible to irradiation than males. Complete mortality of irradiated psylla adults occurred within a 4 hour post irradiation time with a dose of 1000 Gy. None of the females in control samples or treated samples produced eggs and sterility (egg hatch, viable adults) could not be properly evaluated.

Colonization of citrus red scale on oranges and mango scales on mango fruits and plants was undertaken for determination of suitable irradiation dose in preventing eggs hatching and development of mango and citrus scales. Considerable success was made in transferring crawlers on to mango and citrus fruits. Research will continue in order to accomplish large scale studies on D. citri, A. aurantii and mango scales including studies of their radio-sensitivity to gamma irradiation.

Evaluating Gamma Irradiation as a Post-Harvest Treatment for the Control of Citrus Mealybug and False Codling Moth.

South Africa; Mr Hendrik HOFMEYR (Research Contract 15634)


Dosimetry procedures for the initial calibration and sustained correct application of ionizing radiation to ensure treatment reliability are described in detail. Additionally, two dosimetry comparisons conducted by Dr Andrew Parker during 2010 and 2011 confirmed the accuracy of applications.

A review of the initial research conducted in 2010-2011 on butternuts, *Cucurbita moschata*, infested with citrus mealybug, *Planococcus citri*, is submitted:

- The development into productive females of eggs and 1st to 3rd instar nymphs was prevented by treatment with 100 Gy of ionizing radiation.
- Pre-ovipositing and ovipositing females were fully sterilized with a treatment of 150 Gy.

The above results were considered to be sufficient to ratify a probit-8.7 study (30 000 individuals) in order to validate the efficacy of 150 Gy as a potential phytosanitary treatment for citrus mealybug:

- The reproduction and infestation capabilities of 21 800 untreated ovipositing mealybugs were confirmed.
- 70 440 ovipositing females were treated with 150 Gy.
- Fresh butternuts supplied for infestation by treated individuals were examined 45 days after treatment.
- A small number of 1st instar F1 nymphs present on the butternuts at the time of treatment succeeded in migrating to the fresh butternuts, but all died (as 1st instars) without further development.
- Sustained reproduction of the treated population was stopped and development of an F1 progeny was prevented in full.
B. Ionizing Radiation as a Phytosanitary Treatment for False Codling Moth (FCM), *Thaumatotibia leucotreta* (Meyrick) in Citrus.

Dosimetry procedures for the initial calibration and sustained correct application of ionizing radiation to ensure treatment reliability are described in detail.

Studies to determine the sensitivity of various citrus cultivars for ionizing radiation in 2005-7 concluded that citrus would not tolerate treatment doses higher than 160 Gy. A dose uniformity ratio (DUR) of 3.5-4:1 was applicable when using the only available gamma irradiator of commercial specifications. The maximum treatment dose for FCM would consequently have been approximately 40 Gy and all research until 2011 were conducted with this constraint in mind. A review of the initial research conducted in this period on the use of gamma irradiation to disinfest citrus fruit infested with false codling moth, *Thaumatotibia leucotreta*, is submitted:

- 96 h old (fully mature) eggs were the most radio-tolerant of all ages of eggs. A dose of more than 100 Gy would be necessary to prevent egg hatch and suppress the development of pupae from treated eggs. Moth development was prevented at approximately 100 Gy. Moths developing from eggs treated with 70 Gy were unable to fly and fertility was completely suppressed only at 60 Gy. All F1 eggs were sterile at 50 Gy.
- 5th instar larvae were the most radio-tolerant of the 5 larval instars. Respective doses of 350 Gy and 150 Gy were necessary to prevent the development of pupae and moths. Flight was inhibited at approximately 70 Gy; fertility was totally suppressed at 70 Gy.
- The radio-tolerance of artificially reared larvae was compared to that of feral larvae developing in oranges. Infested oranges were collected from three farms and treated with a suboptimal dose of 40 Gy. The fruit was incubated and pupae were collected as they emerged from the fruit. Artificially reared larvae were similarly handled. Eclosed moths from both sources were evaluated for fertility and fecundity.
- The insectary reared larvae outperformed their feral counterparts in terms of both fertility and fecundity, indicating that they were at least as radio-tolerant as the feral insects. It was consequently accepted that continued use of the first-mentioned larvae for research purposes would not present any experimental bias.

Previous information had indicated that ionizing radiation would negatively impact on fruit quality at a dose of 70 Gy (in the range necessary to provide biological efficacy). However, early in 2012 the initial horticultural results were reviewed and it was concluded that this was not correct and that a 500 Gy would, in fact, be applicable to use on oranges. This would allow the safe application of doses up to 125 Gy at a DUR of 4:1. It was therefore decided to conduct a probit-9 evaluation of efficacy at 100 Gy:

- Three replicates, each consisting of 8 untreated control rearing jars with larvae, 8 treated control jars, one jar for instar assessment, and 58 jars treated with 100 Gy, were used.
- **Control treatment**: On average 656 larvae were obtained per rearing jar; 95% of the moths reared from these could fly normally and 200 eggs were deposited per female from which 79% hatched.
- **100 Gy ionizing radiation treatment**: A calculated total of 124 493 of the 5th instar larvae were treated. The numbers of pupae and moths were reduced by respectively 49% and 85% compared to the control. No moths were able to fly, and they were completely sterile – not a single egg was laid.

**Conclusion**: An ionizing radiation treatment for FCM at a dose of 100 Gy is regarded as adequate to maintain phytosanitary security.

**Irradiation as a Phytosanitary Measure for Grapes Infested with the Grape Vine Moth, Lobesia Botrana.**

**Syrian Arab Republic; Mr Mohammed MANSOUR (Research Contract 15574)**

The grape vine moth, *Lobesia botrana*, is a key pest on grape vines in many parts of the world and causes millions of dollars in losses to the grape industry every year. The pest is also of quarantine importance in
Syria and consequently, exports to Lobesia botrana free countries may not be allowed without effective phytosanitary treatment in case this species (e.g. eggs and larvae) accompany fresh products. The chemical fumigant methyl bromide is highly effective against this pest but it is being phased out and its use is to be severely restricted by the year 2015. Ionizing radiation can be used as an alternative to methyl bromide for treating fresh agriculture products and is one of the few alternative treatments that can be applied in order to overcome quarantine controls on trade. The objective of this study is to provide data on the effects of gamma radiation on eggs and mature larvae of the Grave Vine Moth and determine the irradiation doses that will secure phytosanitary (quarantine) control of these insects when irradiation is used to treat fresh produce that could specific retain life-stages of the moth.

The effect of gamma irradiation on the egg and larval stages of Lobesia botrana was studied. Eggs irradiated a few hours before egg-hatch were the most resistant to radiation treatment; at 600 Gy over 33% of the eggs hatched. When pupation and adult emergence were used as criteria for measuring effectiveness, however, the effect of gamma irradiation was very severe, 150 Gy completely prevented pupation and adult emergence. Similarly when mature 5th instar larvae were irradiated, pupation was significantly effective at 150 Gy and adult emergence was completely prevented at 200 Gy.

The Khapra beetle, Trogoderma granarium is also a very destructive pest of stored products and can present a problem for food trade between many parts of the world. The insect can be transmitted from one country to another at any stage of development and consequently quarantine measures are imposed. Research into alternative treatments to methyl bromide has demonstrated that radiation is an effective quarantine treatment to control insect pests associated with stored grain. Therefore, a detailed study on the effect of gamma irradiation on the egg and larval stages of the Khapra beetle were initiated. Results show that 80 Gy is sufficient to prevent egg hatch and 150 Gy radiation dose to mature larvae prevents adult emergence.

Future Plan
1. Study the effect of gamma irradiation on pupae of Lobesia botrana and establish a dose that causes complete sterility of emerged adults
2. Establish large scale confirmatory tests for an irradiation dose that guarantee no reproduction
3. Conduct a similar study with T. granarium

Generic Irradiation Dose to Provide Quarantine Security for Agromyzid Leafminers (L. sativa, L. trifolii and L. huidobrensis)

Turkey; Ms Berna OZYARDIMCI (Research Contract 15644)

This research provides data needed to develop a generic irradiation dose for quarantine treatments for Agromyzid leafminers, using three species in the genus Liriomyza.
- The late stage pupae were treated with Co-60 gamma radiation at 0, 80, 100, 120, 150 and 180 Gy. 
- The measure of efficacy used was the prevention of F₁ mine formation in pea leaves.
- Harwell Gammachrome YR Perspex dosimeters (range: 0.1 - 3 kGy) were used as routine dosimeters on the samples for doses above 100 Gy. Lithium formate monohydrate dosimeters in pellet form were used as the routine dosimeter for irradiation of pupae at 80, 100 Gy and additionally at 120, 150, 180 Gy.

Leafminers (L. sativa, L. trifolii and L. huidobrensis) were found to have very similar responses to irradiation treatments; it was found that the same dose (150 Gy) prevented the formation of F₁ mines in all three species. At lower doses (80, 100 and 120 Gy), offspring developed normally. The F₁ offspring developed into pupae, which subsequently emerged as adults and these went on to produce mines in the F₂ generation. The controls (0 Gy) laid a normal number of eggs and produced offspring that developed normally. The two highest irradiation dose treatments studied (150 and 180 Gy) were found to completely prevent formation leaf mines by the F₁ generation. Although punctures produced by the leaf miners were observed on the leaf surfaces, no mines were produced; nor was there evidence of any offspring following 150 Gy and 180 Gy treatments.

Confirmatory experiments were undertaken using large numbers of leafminers irradiated to a dose of 150 Gy. These confirmatory experiments were carried on all 3 species together, L. sativa, L. trifolii and L. huidobrensis, present in test samples with a total number of leafminers greater than 30,000 insects (10,583
insects for *L. sativa*, 10,280 insects for *L. trifolii* and 10,419 insects for *L. huidobrensis*). This method was used, as the three *Liriomyza* species were previously found to have an equal dose response as, measured by the efficacy of the prevention of F₁ mine formation. In other words, it was not necessary to have 30,000 for each species.

The radio-tolerance of the commodity (pea plants) was studied to ensure that the irradiation treatment does not significantly affect the produce. Three different irradiation doses (250 Gy; 500 Gy and 1000 kGy) were applied to peas. Chemical composition: protein, moisture, ash and total carotene contents of peas were determined. Colour measurement, organoleptic test and vitamin analysis were completed. The pea plants were not significantly affected by irradiation up to and including a dose of 1.00 kGy.

**The future plan**

1. A phytosanitary irradiation meeting will be arranged with quarantine inspectors about generic irradiation treatment in National Plant Protection Office in December 2012.
2. A scientific paper will be produced for publication in a journal.

**Discussion**

Detailed dosimetry information was provided in support of these findings from Turkey and discussions focussed on dose distributions. The variation in the measured doses (mean +/- SD) and how these data could be used to set the dose limit for the minimum treatment dose in a ISPM treatment. For example, the means in measured doses varied from 143.6 – 174.6 Gy, for a target dose of 150 Gy, with approximately 1,000 pupae per treatment. The possibility of taking the highest measured dose (i.e. 175 Gy) was discussed. However, in the past, if no dosimetry data was reported then the target dose was used as the treatment dose in the adopted treatment (as was the case with the fruit fly treatments). However, if the detailed dosimetry data are presented with the treatment submission, then it is possible that a statistical analysis might determine a measured dose, slightly different from that of the target dose and it could be slightly larger or slightly lower. This is an issue which the TPPT of the IPPC needs to be aware of.

**Development of Generic Irradiation Doses for Quarantine Treatments Using E-Beam, x-ray and Gamma Irradiation.**

**USA; Mr Suresh D. PILLAI and Mr Carlos BOGRAN (Agreement Holder 15638)**

After the second RCM efforts to obtain funding to complete the research activities of the agreement holder continued. Two proposals were submitted, one to the Colombian Flower Exporter’s Association (ASOCOLFLORES) and one to the Society of American Florists (SAF), both proposals were not funded. Also since the second RCM the National Center for E-Beam radiation at Texas A&M University has received certification by USDA-APHIS as approved facility for phytosanitary irradiation treatments (May 2012). The Center is now certified to conduct phytosanitary treatments of US commodities for interstate trade within the US, treatments of US commodities for foreign export, and, since approval by APHIS in July 2012 treatment of foreign-origin commodities before market distribution in the U.S. A process for E-Beam treatment of commercial guavas has been developed and is currently under patent application process. The Center is also working on developing E-Beam based businesses in the US and Mexico focused on phytosanitary treatment of fruits and vegetables. The Center is expected to commence commercial phytosanitary treatment of imported guavas from Mexico in spring 2013.

Work on determining the impact of irradiation sources (Gamma, X-rays or E-Beam) continued at the Texas A&M laboratory using bacteria (E. coli) as a model system. When comparing 1.59 MeV Gamma, 10 MeV E-Beam, 5 MeV X-ray and 100 KeV X-ray, results indicated that low irradiation dose-rate has higher kill efficacy compared to high dose rate throughout the dose ranges tested (up to 500 Gy). The highest reduction of bacterial colony forming units was achieved with 1.59 Gamma which delivers the lowest dose rate of the compared irradiation sources. To determine the effects of E-Beam irradiation on the bacterial cell activity after treatment, we used the AlamarBlue® dye Assay. Results indicate that sub-lethal irradiation doses (those
that do not completely kill bacterial colonies) may enhance cell metabolic activity, regardless of irradiation source (Gamma, X-ray or E-Beam). This may be due to a compensatory mechanism by which cells repair themselves after damage by irradiation treatment. This result has practical implications on the development of effective irradiation protocols against bacterial pathogens including foodborne disease causing organisms and plant pathogens transmitted by insect vectors. If lethal irradiation doses are not achieved due to improper treatments bacterial cells could proliferate.

Other activities of our group related to the CRP include a book chapter on irradiation technology for phytosanitary treatment and food safety (Pillai, Blackburn and Bogran). This chapter is expected to be published in a book ‘Global Fresh Produce’ by Jeff Hoorfar from Copenhagen. In addition the Center has been involved in planning E-Beam phytosanitary treatment facilities in Texas and Aguas Calientes (Mexico) and have worked educating the Texas banking industry to understand and exploit irradiation technologies for multiple purposes.

**Exploring the Effects of Controlled Atmospheres on Insect Stress Physiology and the Efficacy of Irradiation Treatments for Insect Control.**

USA; Mr Daniel HAHN (Agreement Holder 15661)

The efficacy of an irradiation dose may be affected by environmental factors experienced by insects prior to or during the irradiation process, including modified and controlled atmospheres. Developing a reliable generic irradiation dose for insects and mites requires understanding how environmental and treatment factors affect the dose needed for successful phytosanitary disinfestation. Numerous studies have shown that irradiation in very low oxygen environments, anoxia or hypoxia below 4 kPa O$_2$, can decrease the efficacy of a phytosanitary irradiation treatment compared to irradiation in normoxic conditions (21 kPa O$_2$). This has led some to suggest that irradiation doses performed on commodities held in modified atmospheres with less than 18 kPa O$_2$ might not be valid. Numerous commodities are stored, shipped, and irradiated in polymeric films that actively modify the atmosphere inside the packaging to decrease commodity respiration and preserve quality. Depending on the commodity in question, values for oxygen in modified atmosphere packaging range from near anoxic hypoxia, 1-4 kPa O$_2$, to moderate hypoxia (~10 kPa O$_2$).

Review of the literature suggests that insects can compensate well for moderate hypoxia because when challenged with low O$_2$, the fly *Drosophila melanogaster* and the grasshopper *Schistocerca americana* can both maintain normal patterns of respiratory metabolism until extreme hypoxia (< 6 kPa O$_2$). However, there is also clear evidence for the ability of *D. melanogaster* to sense moderate hypoxia well above 6 kPa O$_2$ and alter cellular physiology and respiratory behaviour to compensate. Irradiation damages DNA and other cellular components through two routes, direct transfer of energy and secondary damage due to free radicals and other pro-oxidants. The prevailing gaseous atmosphere should have little to no effect on direct energy transfer and damage during irradiation, but might affect the accumulation of secondary damage from free radicals and other pro-oxidants. The prevailing gaseous atmosphere should have little to no effect on direct energy transfer and damage during irradiation, but might affect the accumulation of secondary damage from free radicals and other pro-oxidants produced during irradiation. Most literature to date assumes that the reduced efficacy of irradiation in low-oxygen atmospheres is due to less oxidative radicals being formed from gaseous oxygen in the irradiation chamber. However, an alternative explanation is that low-oxygen environments induce changes in cellular physiology that reduce the effects of pro-oxidants without greatly altering the pro-oxidant load produced during and just after irradiation. Thus, although many studies have revealed that irradiation in hypoxic or anoxic atmospheres increases organismal survival and performance at a particular dose, the mechanisms underlying this “oxygen effect” have been poorly explored.

Work at the researchers laboratory has shown that exposing late pupae of the Caribbean fruit fly, *Anastrepha suspensa*, (pharate adults 2 days before eclosion) to one hour of anoxia approximately doubles total antioxidant capacity and dramatically increases the activities of mitochondrial superoxide dismutase and glutathione peroxidase, although there was no detectable effect on catalase and little effect on cytosolic superoxide dismutase. Thus, exposure to anoxia increases the ability of cells to protect themselves against secondary irradiation damage due to free radicals and other pro-oxidants. When exposed to a range of irradiation doses from 0-400 Gy, irradiation in anoxia is indeed protective wherein the proportion of adults successfully eclosing from pupae treated in anoxia is substantially higher at 200, 300, and 400 Gy doses. Interestingly, pupae that were exposed to one hour of pre-treatment in anoxia and then were brought back to normoxia prior to irradiation showed intermediate levels of adult eclosion. Anoxia-treated pupae clearly had lower adult emergence than those irradiated in normoxia, but substantially higher adult emergence than those...
never exposed to anoxia. Despite clear differences in adult emergence and other performance metrics in caribfly pupae irradiated in anoxia, we did not find any effect of on fertility in our lowest dose of 70 Gy. Thus, we conclude that exposure to anoxia can have substantial effects on insect physiology regardless of whether insects are irradiated in anoxia or not. Clearly more work in needed to determine how low-oxygen affects insect physiology and potentially the efficacy of phytosanitary irradiation treatments.

The research group are currently investigating the effects of modified atmospheres, including low O\textsubscript{2} and high CO\textsubscript{2}, on the efficacy of irradiation treatments in the last instar larvae and pupae of the cabbage looper *Trichoplusia ni* (Lepidoptera: Noctuidae). We have preliminarily shown that irradiation of pupae in anoxia leads to greater adult eclosion across a dose range including 0, 50, 100, and 150 Gy, but we do not yet know whether anoxia affects sterility in the irradiated generation or in the F\textsubscript{1} generation. Over the next 18 months we expect to test a series of graded oxygen concentrations from 1-2 kPa to 21 kPa to determine at what level oxygen deprivation affects irradiation efficacy. Based on the above data from the literature, we expect that mild hypoxia (O\textsubscript{2} > 6 kPa) will have little effect on the efficacy of irradiation whereas extreme hypoxia (O\textsubscript{2} < 6 kPa) will impact the efficacy of phytosanitary irradiation treatments.

**Development of Generic Irradiation Doses.**

**USA; Mr Guy HALLMAN (Agreement Holder 15626)**

Research continued seeking radiation doses for phytosanitary control of *Heliothis virescens* (Lepidoptera: Noctuidae), *Liriomyza trifolii* (Diptera: Agromyzidae), and *Diaphorina citri* (Hemiptera: Psyllidae) as representatives of insufficiently studied pest groups are needed for generic treatments. Research was extended to add another noctuid, *Helicoverpa zea* and a snail, *Cantareus aspersus*.

Large-scale dose confirmatory testing for *H. virescens* with 14,366 irradiated last instars (maximum dose = 175 Gy) resulted in no emergence of normal-looking adults (the measure of efficacy). A total of 2,197 last instar *H. zea* was irradiated at a maximum dose of 175 Gy with no adult emergence.

The late puparial stage of *L. trifolii* is the most developed, hence, most tolerant one that can occur on shipped commodity. The measure of efficacy used is prevention of F\textsubscript{1} mine formation when the late puparial stage is irradiated. This was accomplished with a maximum dose of 214 Gy (n = 3,271). This study on phytosanitary irradiation of *L. trifolii* was recently published (Hallman et al. 2011).

Because *D. citri* needs fresh foliage to oviposit, bioassays were conducted on orange jasmine, *Murraya paniculata*, a citrus plant that, unlike most commercial citrus trees, continually produces new foliage. F\textsubscript{1} egg hatch was prevented with a maximum [measured] dose of 171 Gy (n = 1,200 adults). [To date this is the only irradiation data available for a pest psyllid]. Small-scale testing with the snail *C. aspersus* indicates that a dose ~100 Gy would prevent hatch of F\textsubscript{1} eggs laid by irradiated adults.

Low-oxygen storage is used increasingly to preserve the quality of fresh commodities and they could be irradiated after having been in low-oxygen storage. It is known that replacement of oxygen in storage with nitrogen reduces efficacy of PI, and that is currently the largest use of low-oxygen storage (apples). Unknown is the effect of replacing oxygen with carbon dioxide. A reasonable hypothesis is that replacing O\textsubscript{2} with CO\textsubscript{2} would result in an equivalent amount of secondary damage because irradiation of CO\textsubscript{2} could also result in oxidative radicals.

Third instar Mexican fruit fly, *Anastrepha ludens*, in diet was irradiated (12 Gy) under 3 atmospheres with mean percentage emergence of normal-looking adults following:

<table>
<thead>
<tr>
<th>Atmosphere</th>
<th>Mean percentage emergence of normal-looking adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient air (78 kPa N\textsubscript{2}, 21 kPa O\textsubscript{2}, 0.93 kPa argon, 0.04 kPa CO\textsubscript{2})</td>
<td>0.069±0.047</td>
</tr>
<tr>
<td>Nitrogen (99.8 kPa N\textsubscript{2}, 0.2 kPa O\textsubscript{2})</td>
<td>31.8±4.11</td>
</tr>
</tbody>
</table>
Replace O₂ with CO₂: (78.8 kPa N₂, 21 kPa CO₂, 0.2 kPa O₂)  39.8±4.62
Non-irradiated control 91.0±1.69

The effect of irradiation in an atmosphere where O₂ was replaced with CO₂ was similar to irradiation in nitrogen where no oxidative radicals are formed. Thus, CO₂ did not have the same effect as O₂, and its effect on the efficacy of phytosanitary irradiation must be taken into consideration for commercial application of the technology to commodities in atmospheres containing increased levels of CO₂.


Discussion: Mr Hallman presented a table of Generic PI treatments for proposal at end of the CRP:
Whiteflies (100 Gy); aphids (100 Gy); Weevils (170 Gy); Thrips (250 Gy); Mealybugs (250 Gy); Scale insects (250 Gy); Insects (minus Lep pupae 250 Gy); Mites (350 Gy).

Effects of Gamma Irradiation at Quarantine Doses on Three Species of Mealybugs (Hemiptera: Pseudococcidae) Infesting Red Dragon Fruits.

Viet Nam; Ms Thi The DOAN (Research Contract 15635)

Dysmicoccus neobrevipes, Planococcus lilacinus and Planococcus minor (Beardsley) (Hemiptera: Pseudococcidae) were collected from the field on dragon fruit in Binh Thuan province (Vietnam). They were reared in the laboratory and mass-produced on the surface of pumpkin (Cucurbita moschata) to obtain populations for experiments. Adults were determined as the most radio-tolerant stage in all three mealybug species. For D. neobrevipes, the estimated dose for preventing reproduction of adult females was 201 Gy. Meanwhile, the experimental results showed that the reproduction of adult female of P. lilacinus was inhibited completely at 103 Gy. It means that no nymphs emerged from irradiated adult females at this dose. All eggs of irradiated adult female P. minor failed to hatch at the measured dose of 154.5 Gy. Based on the results, it is concluded that D. neobrevipes is the most radio-tolerant stage in this species. Adult female of D. neobrevipes were used in the large scale confirmatory test (see below).

For preliminary testing, 1,032 individuals of 3-4 day old female adult D. neobrevipes were irradiated at a target dose 200 Gy by gamma radiation, with three replicates. A minimum effective dose (211 Gy in range 204.8 to 227.1 Gy) to sterilize completely female adults was determined by the observation of reproduction. All F1 1st instars that emerged from eggs of irradiated adults died before reaching the 2nd instar, meanwhile the mealybugs in the control treatment reproduced normally. Based on results from this experiment, large scale tests were performed to confirm a required efficacy dose to sterilize adult female D. neobrevipes with number of estimated individuals at 31,750. All tests were irradiated at a minimum target dose of 200 Gy. The mean measured dose was 206.4 Gy by using Fricke dosimeters with the maximum being 231 Gy. Therefore, 231 Gy should be the minimum dose required for commercial application. Efficacy and confidence level of the treatment is ED99.9906 at the 95% confidence level (no reproduction beyond F1 1st instar for 31,750 irradiated female adults, all 1st instars that emerged from eggs of irradiated adults died before reaching the 2nd instar). Because D. neobrevipes is the most radio-tolerance species, the minimum absorbed dose of 231 Gy is the efficacious dose needed to prevent reproduction of adult females of Dysmicoccus neobrevipes, Planococcus lilacinus, and Planococcus minor. A proposed efficacy dose [of 231 Gy?] for Dysmicoccus neobrevipes, Planococcus lilacinus and P. minor (Hemiptera: Pseudococcidae) has been submitted to IPPC via National Plant Protection Organization, Vietnam.

The tolerance of dragon fruit was investigated over the range 0, 200, 400, 600 and 800 Gy. It was determined that irradiation doses from 600 Gy and 800 Gy could influence the firmness, vitamin C content and could change the appearance of fruits during storage time, especially after 3 weeks. Other parameters such as weight loss, TSS, TA and colour changes of irradiation treatments were not different significantly as compared with non-treatment (control) after 1 and 2 weeks in storage.

Future work: 1) Determining the effect of electron beam irradiation on the reproduction of adult females of Dysmicoccus neobrevipes mealybug as compared with gamma irradiation; 2) Efficacy of the determined
quarantine dose on the sterility of adult females *Dysmicoccus neobrevipes* under commercial storage conditions (10±1°C; 85-90% RH; 3) Studying effects of different dose rates of gamma radiation on the reproduction of adult females of *Dysmicoccus neobrevipes* mealybug.

A treatment has been put forward to the IPPC and a paper with the data was published in 2012. The, Doan Thi; Khanh, Nguyen Thuy; Lang, Vo Thi Kim; van Chung, Cao; An, Tran Thi Thien; Thi, Nguyen Hoang Hanh (2012). Effects of gamma irradiation on different stages of mealybug *Dysmicoccus neobrevipes* (Hemiptera: Pseudococcidae). Radiation Physics and Chemistry, Volume 81, Issue 1, p. 97-100.

Note: A treatment dose of 400 Gy has been used in practice for many years for dragon fruit exported to the USA. Irradiation to meet the treatment dose of 400 Gy gives rise to a maximum dose of the order of 600 Gy. Therefore being able to use a treatment dose lower than 400 Gy will ensure that dragon fruit will receive a maximum dose which is less than the 600 Gy dose where fruit quality begins to be an issue.

### 4.3 Review of CRP Results Achieved so far and Planning for the Future

The meeting reviewed the research results achieved to date and evaluated the progress towards meeting the CRP objectives and outcomes. The overall objective of the CRP is to validate generic treatment doses for groups of arthropod pests of quarantine significance in international trade and it is evident that the majority of participants have been undertaking research in this regard. Secondary objectives include an examination of the effects of low oxygen commodity storage and dose rate on efficacy and commodity tolerances. These issues are also being investigated; there is some information on the effects of oxygen (e.g. research in USA and Brazil) and data is being produced on commodity tolerances (e.g. work in Turkey has included this as has research in Australia and the study by Mexico is focused on fruit quality at a commercial scale irradiation facility; a new participant in Uruguay will also address this research area). Some research has investigated the effects of dose rate on efficacy but this issue has not been explored in great detail so far.

The CRP is generating data for a number of insect groups that have not been researched in great detail, including one or more species of dermestid beetles; eriophyid and spider mites; leaf miners; white flies; diaspid scales; mealybugs; psyllids; carpospinid, gelechiid, noctuid and tortricid moths (Annex C). The meeting attempted to prioritize an order of preference for future work and in descending order of preference the following was proposed: Mites, scales, thrips, weevils (Premnotrypes spp.). whiteflies (Bemisia tabaci).

Research outputs are already assisting in the development of a generic dose treatment and the CRP is assisting in setting doses for the specific pests. Four new irradiation treatments (all produced by CRP participants) have been submitted to the TPPT in response to the 2012 Call for Treatments for inclusion in ISPM28:

- **2012-009 - Irradiation for Ostrinia nubilalis**
- **2012-011 - Irradiation for Dysmicococcus neobrevipes Beardsley, Planococcus lilacinus (Cockerell), and Planococcus minor (Maskell) (Hemiptera: Pseudococcidae)**
- **2012-008 - Generic Irradiation Treatment for Eggs and Larvae of Lepidoptera**
- **2012-012 - Generic Irradiation Treatment for pupae of Lepidoptera**

In addition, research under this CRP is suggesting that 250 Gy (not 400 Gy) may be sufficient for the majority of insect pests excluding *Lepidoptera* (adults and pupae) and possibly mites. A previous generic treatment [*Generic irradiation treatment for all insects (Arthropoda: Insecta) except lepidopteron pupae and adults (Insecta: Lepidoptera) in any host commodity*] is being retained by the TPPT of the IPPC for future consideration. It is likely that the data generated by this CRP will help modify and develop this submission by providing additional support for a generic dose treatment for this broad range of significant insect pests.

Dosimetry issues were discussed and it was emphasised that actual measured doses of irradiation as received by the irradiated samples and the dose distribution / dose uniformity ratio should be reported. One of the problems is that studies available in the scientific literature do not always include these data, quoting only target (intended) irradiation dose in place of the dose actually delivered. The irradiation treatments approved by the IPPC use the maximum dose utilized in the research as the minimum dose for the commercial application (i.e. as the minimum dose specified for that treatment in the ISPM). This is why it is important to
record data on the distribution of dose throughout the irradiation chamber when undertaking experiments and to minimize the dose distribution (dose uniformity ratio) so that it is as close to 1.0 as possible. Ideally the minimum dose, the maximum dose and some measure of the dose range should be available for each experiment as agreed in the research guidelines produced by the first RCM and available in Annex C of the meeting report\(^2\). In practice, detailed dosimetry data can be difficult to obtain if the product is irradiated by a third party.

The CRP is aware that dose mapping (e.g. product validation) is carried out in commercial situations to take into account the processing conditions (packet size, density, etc.) and “target dose” under commercial conditions can be used to ensure that the minimum (treatment) dose is exceeded for all parts of a consignment. In practice, some parts of the consignment will receive considerably more than the treatment dose.

In conclusion, data generated by the CRP in combination with other studies available in the literature suggest that an irradiation quarantine treatment of 250 Gy might be sufficient for the majority of insect pests and the CRP may also result in the development of future generic quarantine treatment doses; e.g. a generic treatment for weevils and a treatment for mites. It may also be possible to propose generic doses for other insect groups, e.g. whiteflies; aphids; thrips; mealybugs; scale insects.

The next TPPT meeting is in Nagoya, Japan in December 2012 and Ray Cannon will provide feedback from this meeting to inform the TPPT of progress.

Each participants work was discussed in turn and the work plans for next phase of research was discussed. The table of insects that the CRP is studying was revised (Annex C). It was felt that 2013 will be too early for the final RCM as there is on-going research and time will be needed to write and finalize papers for publication in a special edition of a scientific journal. A RCM in early 2014 was thought to be more appropriate.

5. Conclusions and Recommendations of the Third RCM

CONCLUSIONS

1. All CRP participants were present at the meeting and a number of observers also attended, representing over 28 participants from 14 different countries.

2. The presentations demonstrated excellent progress in achieving the objectives of the CRP; Studies have used considerable numbers of insects in confirmatory tests and several treatments are almost finalized. CRP participants were responsible for all four treatments (including two generic treatments) submitted to the IPPC in response to the 2012 call for irradiation treatments for consideration as annexes to ISPM28. Other treatment doses will be proposed by the end of the project. It is worth noting that the two generic treatment proposals relied heavily on SIT expertise and data demonstrating the importance of interactions between sections of the Joint FAO/IAEA Division.

3. In recognition of the importance of dosimetry practices and dosimetry systems, CRP participants have implemented procedures to record doses and have presented these data during the RCM. However, some have difficulties in obtaining appropriate data from their irradiation treatment provider.

4. Participants have been collaborating and exchanging information using email and an on-line internet forum. However, more proposals could have been produced for the IPPC with improved communication. Also, links could be improved with national counterparts at National Plant Protection Organizations (NPPO).

\(^2\) http://www-naweb.iaea.org/nafa/fep/crp/generic-irradiation-1st-meeting.pdf
5. The presence of observers at the meeting enriched the discussions, and encouraged further discussions.

RECOMMENDATIONS

1. The CRP is developing both generic dose treatments and species-specific dose treatments. Participants are encouraged to submit phytosanitary treatments that are species specific especially in those cases where the specific treatment dose will be lower than the generic (the majority of cases). A lower dose may be more cost effective and help maintain product quality in circumstances where product is sensitive to radiation treatment.

2. Participants should continue to use the dosimetry reporting guidelines agreed at the first RCM and contained in the Research Protocol (Annex C of the first RCM meeting report³).

3. Participants need to keep in touch with each other. The final phase of the CRP will involve writing up the results for publication. First draft manuscripts are needed at the next RCM which should be held in early 2014 at the earliest. Email should be used to keep in touch, announce important activities, exchange information, review and discuss and help each other. For example participants working on the same group of insects should share lists of references, results and conclusions.

4. Participants should establish a mutually beneficial relationship with their NPPO. This will help participants understand phytosanitary issues in their country and region. It will also help the NPPO understand the expertise participants can provide and solutions for solving these issues. For example contact your NPPO and tell them about this meeting.

5. Observers should be encouraged to attend meeting, for example this is an effective way of ensuring continued liaison and cooperation with both the IPPC secretariat and the TPPT in order to facilitate the adoption of generic irradiation dose treatments stemming from this CRP.

### 6. Agreed Action Plan and Logical Framework

#### Action Plan (Activities)

<table>
<thead>
<tr>
<th>Activity</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advertise the CRP (December 2008). Receipt of research contract and agreement proposals. Award contracts and sign agreements by end April 2009.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organise 1st RCM (July/August 2009) to discuss overall CRP work plan, agree on research protocols, governance, quality assurance, record keeping and reporting.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Award Research Contracts</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 1: 18 months work programme</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organise 2nd RCM in March/April 2011 to review the work conducted in Phase 1 based on progress reports and presentations. Develop the detailed work plan for Phase 2 and ensure that the CRP objectives are met.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 2: Work programme</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organise 3rd RCM (Oct 2012) to review work conducted in Phase 2 and agree final phase 3 work programme.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 3: Work programme</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final RCM: Late 2013 Early 2014 Review Phase 3 work. Prepare a TECDOC and/or research papers for publication in a special edition of an appropriate journal.</td>
<td>X (2014)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Logical Framework

<table>
<thead>
<tr>
<th>Overall Objective</th>
<th>Project Design Elements</th>
<th>Verifiable Indicators</th>
<th>Means of Verification</th>
<th>Important Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Objective</strong></td>
<td>Enhance opportunities for international trade in foods of plant origin subject to insect infestation</td>
<td>Decrease in detained/rejected consignments after inspections</td>
<td>Reports to national authorities and regional plant protection organisations</td>
<td>Commitment by all participating partners to report on national data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific Objective</th>
<th>Project Design Elements</th>
<th>Verifiable Indicators</th>
<th>Means of Verification</th>
<th>Important Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific Objective</strong></td>
<td>Provide data to develop generic irradiation doses for quarantine treatments for consideration in providing an appropriate level of assurance against insect pest incursions</td>
<td>Monitoring programmes for surveillance of quarantine pests</td>
<td>Reports to national authorities and regional plant protection organisations</td>
<td>Commitment by all participating partners to report on national data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Project Design Elements</th>
<th>Verifiable Indicators</th>
<th>Means of Verification</th>
<th>Important Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcomes</strong></td>
<td>Generic doses for a range of quarantine pests/commodities adopted by Commission on Phytosanitary Measures</td>
<td>Data and including dose response information published and provided to IPPC Technical Panel on Phytosanitary Measures</td>
<td>Laboratory results and published reports</td>
<td>Acceptance of recommended generic doses by IPPC Member States</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Project Design Elements</th>
<th>Verifiable Indicators</th>
<th>Means of Verification</th>
<th>Important Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outputs</strong></td>
<td>Validated generic doses/commodities and protocols recognised, harmonised SOPs</td>
<td>Protocols and SOPs produced</td>
<td>Reports submitted to the IPPC, IAEA, FAO and national authorities</td>
<td>Continued commitment by all partners</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activities</th>
<th>Project Design Elements</th>
<th>Verifiable Indicators</th>
<th>Means of Verification</th>
<th>Important Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activities</strong></td>
<td>Consultants meeting</td>
<td>Consultants Meeting report</td>
<td>Meeting report and recommendations</td>
<td>Consultants identified, available and meeting held</td>
</tr>
</tbody>
</table>

| Research contract and agreement holders identified; contracts and agreement signed | First RCM | Meeting report and recommendations | Continued commitment by all parties |

| Work programme to develop and validate dosimetry and research methodology | 1st, 2nd and 3rd RCM | Meeting reports | Continued commitment by all parties |

| Quality check protocols for generic doses | 3rd RCM | Meeting reports | Continued commitment by all parties |

| Prepare SOPs, scientific papers and TECDOC. | Final RCM | Meeting reports, TECDOC, SOPs and papers published | Continued commitment by all parties |
# Annex A

## List of Participants

### 3rd RCM on Development of Generic Irradiation Doses for Quarantine Treatments

**Buenos Aires, Argentina**

**15-19 October 2012**

<table>
<thead>
<tr>
<th>Country</th>
<th>Name and Address</th>
</tr>
</thead>
</table>
| Argentina | **Ms Celina I. HORAK**  
Biological Applications Group  
Comisión Nacional de Energía Atómica (CNEA)  
Presbitero Juan Gonzalez y Aragon 15  
Ezeiza Pcia.de Buenos Aires  
B1802AYA BUENOS AIRES  
ARGENTINA  
horak@cae.cnea.gov.ar  |
| Argentina | **Mr Gerardo GASTAMINZA**  
Estacion Experimental Agroindustrial Obispo Colombres  
Seccion Zoologica Agricola  
Willaim Cross 3150Las Talita  
TUCUMAN 94101  
ARGENTINA  
ggastaminza@eeaoc.org.ar  |
| Australia | **Mr Peter LEACH**  
Queensland Horticulture Institute  
Department of Agriculture Fisheries and Forestry  
P.O. Box 46  
4001 BRISBANE QLD  
AUSTRALIA  
Peter.Leach@daff.qld.gov.au  |
| Brazil | **Mr Valter ARTHUR**  
Centro de Energia Nuclear na Agricultura  
Avenida Centenario, 303  
Piracicaba  
13400-970 São Paulo  
BRAZIL  
arthur@cenab.usp.br  
vaarthur@cenab.usp.br  |
| Brazil | **Mr Vinicius BARROS**  
Universidade Federal de Pernambuco  
Centro de Tecnologia  
Departamento de Energia Nuclear  
Rua prof. Luiz Freire, 1000, Cidade Universitária  
50740-540 - RECIFE  
BRAZIL  
vsmdbarros@gmail.com  |
<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Affiliation</th>
<th>Address</th>
<th>Email Addresses</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Ms Mei Ying HU</td>
<td>South China Agricultural University</td>
<td>483 Wushan, Tianhe, GUANGZHOU 510642, CHINA</td>
<td><a href="mailto:humy3323@hotmail.com">humy3323@hotmail.com</a></td>
</tr>
<tr>
<td></td>
<td>Mr Guoping ZHAN</td>
<td>Institute of Equipment Technology</td>
<td>Bld. No.241, Huixinli, Huixin XijieChaoyang District, BEIJING 100029, CHINA</td>
<td><a href="mailto:zhgp136@126.com">zhgp136@126.com</a>, <a href="mailto:zhanguoping@gmail.com">zhanguoping@gmail.com</a></td>
</tr>
<tr>
<td></td>
<td>Mr Qunfang WENG (observer)</td>
<td>South China Agricultural University</td>
<td></td>
<td><a href="mailto:humy@scau.edu.cn">humy@scau.edu.cn</a></td>
</tr>
<tr>
<td>India</td>
<td>Ms Ranjana SETH</td>
<td>University of Delhi</td>
<td>Kalkaji, NEW DELHI 110019, INDIA</td>
<td><a href="mailto:seth.ranjana.27@gmail.com">seth.ranjana.27@gmail.com</a></td>
</tr>
<tr>
<td>Indonesia</td>
<td>Mr Achmad Nasroh KUSWADI</td>
<td>National Nuclear Energy Agency (BATAN)</td>
<td>Jalan Lebak Bulus Raya No. 49, P.O. Box 7002, JAKARTA 12070, INDONESIA</td>
<td><a href="mailto:akuswadi2@gmail.com">akuswadi2@gmail.com</a></td>
</tr>
<tr>
<td>Mexico</td>
<td>Mr Yeudiel GOMEZ SIMUTA</td>
<td>Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion</td>
<td>Ave. Costa Rica Mz. 61 Casa 1, TAPACHULA 30798, MEXICO</td>
<td><a href="mailto:yeudiel.gomez@iica-moscafrut.org.mx">yeudiel.gomez@iica-moscafrut.org.mx</a>, <a href="mailto:yeudielgomez@hotmail.com">yeudielgomez@hotmail.com</a></td>
</tr>
<tr>
<td>Pakistan</td>
<td>Mr Inamullah KHAN</td>
<td>Pakistan Atomic Energy Commission (PAEC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>Contact</td>
<td>Address</td>
<td>Email</td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------------</td>
<td>----------------------------------------------</td>
<td>------------------------------</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>Mr Hendrik HOFMEYR</td>
<td>Mr Hendrik HOFMEYR Citrus Research International P.O. Box 212 CITRUSDAL-7340 SOUTH AFRICA <a href="mailto:jhh@telkomsa.net">jhh@telkomsa.net</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ms Marsheille HOFMEYR (observer)</td>
<td>Ms Marsheille HOFMEYR (observer) Citrus Research International P.O. Box 212 CITRUSDAL-7340 SOUTH AFRICA <a href="mailto:jhh@telkomsa.net">jhh@telkomsa.net</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syrian Arab Republic</td>
<td>Mr Mohammed MANSOUR</td>
<td>Mr Mohammed MANSOUR Atomic Energy Commission of Syria (AECS) Department of Agriculture Kafar Sousah, 17 Nissan Street DAMASCUS SYRIAN ARAB REPUBLIC <a href="mailto:mmansour@aec.org.sy">mmansour@aec.org.sy</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>Ms Berna OZYARDIMCI</td>
<td>Ms Berna OZYARDIMCI Saraykoy Nuclear Research and Training Center Istanbul Yolu 30, KM Atom CAD. No 27 06983 Saraykoy-Kazan ANKARA TURKEY <a href="mailto:berna.ozyardimci@taek.gov.tr">berna.ozyardimci@taek.gov.tr</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Mr Ray CANNON</td>
<td>Mr Ray CANNON Department of Environment, Food and Rural Affairs Central Science Laboratory (CSL) Sand Hutton YORK, YORKSHIRE YO41 1LZ UNITED KINGDOM <a href="mailto:Rcannon992@aol.com">Rcannon992@aol.com</a> <a href="mailto:Ray.Cannon@fera.gsi.gov.uk">Ray.Cannon@fera.gsi.gov.uk</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States of America</td>
<td>Mr Guy James HALLMAN</td>
<td>Mr Guy James HALLMAN US Department of Agriculture (USDA) Agricultural Research Service (ARS) CGAHR-SPIRU 1515 College Avenue MANHATTAN, KS 66502 UNITED STATES OF AMERICA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vietnam</td>
<td>Ms Thi The DOAN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>---------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vietnam Atomic Energy Institute (VINATOM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Research and Development Centre for Radiation Technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>202 A, Stree 11, Linh Xuan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HO CHI MINH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VIETNAM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><a href="mailto:doanthithe@yahoo.com">doanthithe@yahoo.com</a></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Joint FAO/IAEA Division</th>
<th>Mr Carl M. BLACKBURN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><a href="mailto:C.Blackburn@iaea.org">C.Blackburn@iaea.org</a></td>
</tr>
<tr>
<td></td>
<td>Mr Andrew PARKER</td>
</tr>
<tr>
<td></td>
<td><a href="mailto:A.G.Parker@iaea.org">A.G.Parker@iaea.org</a></td>
</tr>
</tbody>
</table>
# AGENDA

**Third Research Coordination Meeting (RCM) of CRP D62008 on the Development of Generic Irradiation Doses for Quarantine Treatments**

Buenos Aires, Argentina  
Hotel Dolmen and Ezeiza Atomic Center  
15 – 19 October, 2012

<table>
<thead>
<tr>
<th>08.00 – 09.00</th>
<th>Registration at meeting room in Hotel Dolmen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Session A: Welcome and Opening</strong></td>
<td></td>
</tr>
<tr>
<td>09:00</td>
<td>Welcome and Opening Address – By <strong>Ms María Julia Palacín</strong>, Vegetal Quarantine Director in SENASA (National Food Safety and Quality-Phytosanitary Regulatory Authority) and <strong>Ms Eulogia Kairiyama</strong>, Radiations Technology and Application Manager</td>
</tr>
<tr>
<td></td>
<td>Opening Remarks – Carl Blackburn and Andrew Parker, FAO/IAEA</td>
</tr>
<tr>
<td></td>
<td>Introduction and presentation of participants - All</td>
</tr>
<tr>
<td>09:30</td>
<td>Appointment of chair and co-chair</td>
</tr>
<tr>
<td></td>
<td>Overview of meeting arrangements</td>
</tr>
<tr>
<td></td>
<td>Selection of rapporteur</td>
</tr>
<tr>
<td></td>
<td>Adoption of Agenda</td>
</tr>
<tr>
<td>10:00</td>
<td>FAO/IAEA CRP Objectives and scope of this 3rd Research Coordination Meeting – Carl Blackburn</td>
</tr>
<tr>
<td><strong>10:30 – 11:00</strong></td>
<td>Coffee / tea break – [Group photograph]</td>
</tr>
<tr>
<td><strong>Session B: Introductory Presentations</strong></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>Update on The IPPC Technical Panel on Phytosanitary Treatments (TPPT) and forward look to the TPPT meeting in December. <strong>Mr Ray CANNON</strong>,</td>
</tr>
<tr>
<td></td>
<td>Recent Developments in Generic Dose Phytosanitary Treatments and expectations for the CRP outputs and outcomes. <strong>Mr Guy HALLMAN</strong>,</td>
</tr>
<tr>
<td>11:30</td>
<td>The Case for a Generic Phytosanitary Irradiation Dose of 250 Gy for Lepidoptera Eggs and Larvae. Submitted to Radiation Physics and Chemistry. <strong>Mr Carl BLACKBURN</strong></td>
</tr>
<tr>
<td>12:15</td>
<td>Publication of CRP research in a Scientific Journal (e.g. Special issue of Radiation Physics and Chemistry) Discussion led by <strong>Mr Andrew PARKER</strong></td>
</tr>
<tr>
<td><strong>12:30 – 13:30</strong></td>
<td>Lunch</td>
</tr>
<tr>
<td><strong>Session C: Participants Reports</strong></td>
<td></td>
</tr>
<tr>
<td>13:30</td>
<td>Evaluation and Characterization of Alanine/EPR Dosimetry System for Low Energy x-ray Irradiation (Technical Contract) <strong>Brazil - Mr Vinicius BARROS</strong>,</td>
</tr>
<tr>
<td>14:15</td>
<td>Gamma Radiation Quarantine Treatments for Different Groups of ArthropodsArgentina - <strong>Ms Celina HORAK</strong> and <strong>Mr Guido Van Nieuwenhove</strong>,</td>
</tr>
<tr>
<td><strong>15:00 – 15:30</strong></td>
<td>Coffee / tea break</td>
</tr>
<tr>
<td>15:30</td>
<td>Development of Generic Dose Quarantine treatmentsAustralia - <strong>Mr Peter LEACH</strong>,</td>
</tr>
<tr>
<td>16:15</td>
<td>Use of Ionizing Radiation to Control of Eriophyes Litchi (Litchi Rust Mite), Ecdytolopha Aurantiana (Orange Fruit Borer) and Tuta Absoluta (Tomato Worm) <strong>Brazil - Mr Valter ARTHUR</strong>,</td>
</tr>
<tr>
<td>17:00</td>
<td>Closing</td>
</tr>
<tr>
<td>Time</td>
<td>Session</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:00</td>
<td>Irradiation as Quarantine Treatment of Orange Against Citrus Mites</td>
</tr>
<tr>
<td></td>
<td><strong>China - Ms Mei Ying HU</strong></td>
</tr>
<tr>
<td>09:45</td>
<td>Irradiation as a Phytosanitary Treatment for Controlling Carposina Sasakii Matsumura</td>
</tr>
<tr>
<td></td>
<td><strong>China - Mr Guoping ZHAN</strong></td>
</tr>
<tr>
<td>10:30 – 11:00</td>
<td>Coffee / tea break</td>
</tr>
<tr>
<td>11:00</td>
<td>Development of Generic Irradiation Doses for Phytosanitary Treatment of Mealy Bug Spp. Infesting Agricultural Commodities</td>
</tr>
<tr>
<td></td>
<td><strong>India - Ms Ranjana SETH</strong></td>
</tr>
<tr>
<td>11:45</td>
<td>Generic Dose of Gamma Irradiation for Quarantine Treatment of Mangosteen Insect Pests</td>
</tr>
<tr>
<td></td>
<td><strong>Indonesia - Mr Achmad Nasroh KUSWADI</strong></td>
</tr>
<tr>
<td>12:30 – 13:30</td>
<td>Lunch</td>
</tr>
<tr>
<td>13:30</td>
<td>Determination of Generic Doses for Control of Insect Pest Other Than Fruit Flies in Mango, Mamey and Rambutan by Irradiation as Quarantine Treatment</td>
</tr>
<tr>
<td></td>
<td><strong>Mexico - Mr Yeudiel GOMEZ SIMUTA</strong></td>
</tr>
<tr>
<td>14:15</td>
<td>Use of Irradiation as Phytosanitary Treatment for the Control of Citrus Psyllids Diaphoronia Citri and Scale Insects</td>
</tr>
<tr>
<td></td>
<td><strong>Pakistan - Mr Inamullah KHAN</strong></td>
</tr>
<tr>
<td>15:00 – 15:30</td>
<td>Coffee / tea break</td>
</tr>
<tr>
<td>15:30</td>
<td>Evaluating Gamma Irradiation as a Post-Harvest Treatment for the Control of Citrus Mealybug on Citrus in South Africa</td>
</tr>
<tr>
<td></td>
<td><strong>South Africa - Mr Hendrik HOFMEYR</strong></td>
</tr>
<tr>
<td>16:15</td>
<td>Irradiation as a Phytosanitary Measure for Grapes Infested with the Grape Vine Moth, Lobesia Botrana</td>
</tr>
<tr>
<td></td>
<td><strong>Syrian Arab Republic - Mr Mohammed MANSOUR</strong></td>
</tr>
<tr>
<td>17:00</td>
<td>Closing</td>
</tr>
</tbody>
</table>
### Visit to Ezeiza Atomic Center

**Tour of the irradiation facility and dosimetry laboratory.**

*(Remain at Ezeiza Atomic Center for the afternoon session)*

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:15</td>
<td>(A bus will be waiting at the Dolmen Hotel)</td>
</tr>
<tr>
<td>13:00 – 14:30</td>
<td>Lunch</td>
</tr>
<tr>
<td>14:30</td>
<td>Generic Irradiation Dose to Provide Quarantine Security for Agromyzid Leafminers&lt;br&gt;<strong>Turkey</strong> - Ms Berna OZYARDIMCI</td>
</tr>
<tr>
<td>15:15</td>
<td>Development of Generic Irradiation Doses for Quarantine Treatments Using E-Beam, x-ray and Gamma Irradiation.&lt;br&gt;<strong>USA</strong> – Mr Carlos BOGRAN</td>
</tr>
<tr>
<td>16:00 – 16:30</td>
<td>Coffee / tea break</td>
</tr>
<tr>
<td>16:30</td>
<td>Exploring the Effects of Controlled Atmospheres on Insect Stress Physiology and the Efficacy of Irradiation Treatments for Insect Control.&lt;br&gt;<strong>USA</strong> – Mr Daniel HAHN</td>
</tr>
<tr>
<td>17:15</td>
<td>Closing and return to hotel</td>
</tr>
</tbody>
</table>

### Thursday, 18 October - Hotel Dolmen

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Development of Generic Irradiation Doses&lt;br&gt;<strong>USA</strong> – Mr Guy HALLMAN</td>
</tr>
<tr>
<td>09:45</td>
<td>Effects of Gamma Irradiation at Quarantine Doses on Three Species of Mealybugs (Hemiptera: Pseudococcidae) Infesting Red Dragon Fruits.&lt;br&gt;<strong>Viet Nam</strong> – Ms Thi The DOAN</td>
</tr>
<tr>
<td>10:30 – 11:00</td>
<td>Coffee / tea break</td>
</tr>
<tr>
<td>11:00</td>
<td>Review of results to date and evaluation of progress towards the project objectives and outcomes</td>
</tr>
<tr>
<td>12:30 – 13:30</td>
<td>Lunch</td>
</tr>
<tr>
<td>13:30</td>
<td>Evaluation of progress towards achieving the Expected Research Outputs</td>
</tr>
<tr>
<td></td>
<td>Expected Research Outputs</td>
</tr>
<tr>
<td></td>
<td>• Data on applications of irradiation on pests of quarantine significance;</td>
</tr>
<tr>
<td></td>
<td>• Validation of irradiation doses for the quarantine treatment of specific insect species;</td>
</tr>
<tr>
<td></td>
<td>• Determination of the effect of low oxygen gas content (i.e. modified atmosphere storage)</td>
</tr>
<tr>
<td></td>
<td>• The tolerance of specific products to irradiation, and;</td>
</tr>
<tr>
<td></td>
<td>• Communication of research findings to the wider scientific community.</td>
</tr>
<tr>
<td>15:40 – 16:00</td>
<td>Coffee / tea break</td>
</tr>
<tr>
<td>16:00</td>
<td>Review of Expected Research Outcomes and planning for next phase of work</td>
</tr>
<tr>
<td></td>
<td>Expected Research Outcomes</td>
</tr>
<tr>
<td></td>
<td>• Consideration of the project findings by the IPPC and national plant protection organisations;</td>
</tr>
</tbody>
</table>
• Additions to International Standards for Phytosanitary Measures, including ISPM 28 on Phytosanitary Treatments for Regulated Pests;

• Beneficial outcomes to developed and developing countries by increasing international trade in high value crops and fruits that are subjected to irradiation treatments, and;

• An increase in international trade and a lowering of trade barriers by addressing quarantine requirements for insect pests.

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:00</td>
<td>Close</td>
</tr>
<tr>
<td>Early evening</td>
<td>Evening Reception</td>
</tr>
</tbody>
</table>

**Friday, 19 October - Hotel Dolmen**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Working session: Analysis of progress towards Project Outcomes and provisional conclusions and recommendations</td>
</tr>
<tr>
<td>10:30 – 11:00</td>
<td>Coffee / tea break</td>
</tr>
<tr>
<td>11:00</td>
<td>Continuation of working session: Analysis of progress towards Project Outcomes and provisional conclusions and recommendations</td>
</tr>
</tbody>
</table>
| 12:00    | Discussion of  
- meeting report  
- meeting conclusions  
- meeting recommendations |
| 13:00 - 14:00 | Lunch                                                                     |
| 14:00    | Finalization of Meeting Conclusions  
Finalization of Meeting Recommendations  
Discussion and finalization of meeting report |
| 16:00    | Adoption of the Meeting Report  
Closing Remarks  
Close |
## Taxonomic groups represented in CRP on the development of generic irradiation doses for quarantine treatments

### Annex C

<table>
<thead>
<tr>
<th>Order</th>
<th>Insects</th>
<th>Mites</th>
<th>Mites</th>
<th>Insects</th>
<th>Insects</th>
<th>Insects</th>
<th>Insects</th>
<th>Insects</th>
<th>Insects</th>
<th>Insects</th>
<th>Insects</th>
<th>Insects</th>
<th>Insects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coleoptera</td>
<td>Dermentidae</td>
<td>Eriophyidae</td>
<td>Tetranychidae</td>
<td>Agromyzidae</td>
<td>Hemiptera</td>
<td>Diaspidae</td>
<td>Hemiptera</td>
<td>Pseudococcidae</td>
<td>Hemiptera</td>
<td>Psyllidae</td>
<td>Diaspididae</td>
<td>Thysanoptera</td>
</tr>
<tr>
<td>Common name</td>
<td>Dermentid beetles</td>
<td>Eriophyid mites</td>
<td>Spider mites</td>
<td>Leaf miners</td>
<td>White flies</td>
<td>Diaspid scales</td>
<td>Mealybugs</td>
<td>Psyllids</td>
<td>Carpospid moths</td>
<td>Gelechid moths</td>
<td>Noctuid moths</td>
<td>Thripid moths</td>
<td>Thripididae</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Argentina</th>
<th>Brazil</th>
<th>China</th>
<th>China2</th>
<th>Vietnam</th>
<th>Turkey</th>
<th>China1</th>
<th>Syria</th>
<th>Indonesia</th>
<th>India</th>
<th>Mexico</th>
<th>Pakistan</th>
<th>USA1</th>
<th>USA2</th>
<th>S Africa</th>
<th>USA2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>G.</td>
<td>P. oleivora; A. litchii</td>
<td>P. citri; T. urticae</td>
<td>L. sativae; L. huidobrensis; L. trifolii</td>
<td>T. vaporariorum</td>
<td>H. lataniae; A. auranti</td>
<td>Ph. jackbeardseleyi; Pl. citri; Pl. ficus; Pl. fuscus</td>
<td>E. aurantiana</td>
<td>S. frugiperda; F. occidentalis</td>
<td>F. leucoctera; L. botrana</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Total | 1 | 2 | 2 | 5<sup>A</sup> | 1 | 1 | 8 | 1 | 1 | 1 | 1 | 2 | 3 | 2 |

<sup>A</sup> [6 species] | [2 species]

*Mango and citrus scale (Pakistan)*

Order of preference for future work: Mites, scales, thrips, Weevils (*Premnotrypes* spp.), whiteflies (*Bemisia tabaci*),