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IRRADIATION PROTOCOL DEVELOPMENT FOR ORIENTAL FRUIT FLY STERILE INSECT TECHNIQUE (SIT) AND QUARANTINE STUDIES

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ABSTRACT

Study on the effect of gamma irradiation treatment on oriental fruit flies, Bactrocera dorsalis (Diptera: Tephritidae) is important in the field of sterile insect technique, SIT (50-100 Gy) and quarantine (100-400Gy). The purpose of the protocol is to ensure an implementation of good irradiation practice that would result in consistent and reliable outcome of absorbed dose during the entire study period as long as the sample configuration and radiation processing settings are maintained. Polypropylene plastic containers (11.5 x 10 x 5.3 cm) containing synthetic media were used to mimic actual samples of pupae of B. dorsalis. When the protocol is developed and used, expected minimum doses achieved should not fall below the target doses. In this study, the target doses during routine exposure of actual sample (n=5) to 50, 100, 150, 200, 250, 300, 350 and 400 Gy with implementation of the protocol gave minimum dose results as expected; 54.5 ± 2.8, 106.0 ± 2.3, 159.2 ± 1.9, 210.8 ± 3.0, 263.4 ± 2.6, 314.7 ± 3.7, 365.3 ± 4.1 and 410.1 ± 8.2 Gy, respectively.

***Keywords / Kata kunci**: fruit fly, irradiation, protocol*

INTRODUCTION

The Oriental fruit fly, *Bactrocera dorsalis* (Hendel), has been recognised as the world's most important pest of horticulture (Clarke et al., 2005) and prohibited for the export markets by quarantine restrictions on most fruits and fresh agricultural products (Stephens et al., 2007). It caused economic losses to fruit and vegetable growers, and listed as a major economic concern globally. Irradiation treatment has been suggested as one of the methods to control and prevent this pest from entering any country or region by implementing post-harvest quarantine treatment of fresh agricultural commodities (Follet, 2010). Another approach is to suppress fruit fly population from the very beginning in the field through application of sterile insect technique as part of a sustainable are-wide integrated pest management (AW-IPM) practice (Chinvinijkul et al., 2016).

Both methods use irradiation and different levels of exposure are applied to induce different biological effects. One of the principal advantages of ionising radiation as a tool is the ability to achieve precise biological effects by the delivery of known doses of radiation. Accurate dosimetry has always been, therefore, an important component of radiation processing, the minimum and maximum doses, and dose rates involved providing particular challenges (Seung-Woo et al., 2010). From the dosimetry point of view, the main activity required is dose mapping of representative samples of actual product, to determine the positions and values of maximum and minimum doses

(Mehta, 2017). Thus, the irradiation process can be monitored so that consistent results can always be ensured as desired at all times.

The purpose of this study was to establish irradiation protocol by investigating the dose distribution characteristics and at the same time to determine appropriate process parameters so that the desired minimum doses of 50, 100, 150, 200, 250, 300, 350 and 400 Gray (Gy) are always adhered to and consistently reached in ensuring consistent radiation effect to the target samples throughout the study.

MATERIALS AND METHODS

Dummy preparation and configuration

Dummy used in the study is consisted of three units of polypropylene plastic container, 11.5 x 10 x 5.3 cm each containing synthetic media which is the medium used for the cultivation of fruit fly larvae without any live pupae (Figure 1).

Figure 1: Front view of polypropylene plastic containers including synthetic media

Gamma irradiation conditions, dosimeters and instruments

Gamma irradiation was conducted at Gamma Cell Acute Irradiation Facility, Agrotechnology and Bioscience Division, Malaysian Nuclear Agency using ^{137}Cs source. A BB75-4 beaker having the volume of 7.5 litres was used to measure the dose distribution in air of the dummies using Biobeam GM 8000 irradiation device (GmbH, Germany). Target doses were monitored by Fricke dosimeters (IAEA, 2013). A total of five (5) Fricke dosimeter ampules were located at five (5) positions of plastic containers stacking. Samples configuration and dosimeters positions are as Figure 2 below. Dummies arranged vertically as in Figure 2 and were first irradiated at 60 Gy to investigate working dose rate and also dose distribution pattern throughout the configuration. The experimental parameter used was Fixed Source at 0mm with one dwell point, HT 100%, oscillation speed of 10 mm/s, beaker rotation speed of 10 1/min and exposure time of 9 minutes and 29 seconds.

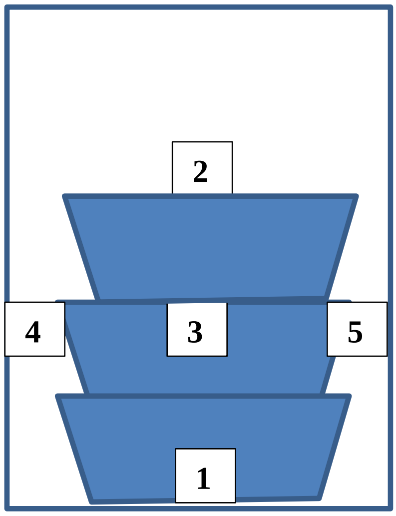

Figure 2: Side view of dummies in irradiation beaker BB75-4 and positions of dosimeters

Determination of exposure time correspond to required minimum dose

The administered various doses from 50, 100, 150, 200, 250, 300, 350 and 400 Gy to obtain actual absorbed dose above the minimum were determined from dose rate investigation which was done previously and later verified during five (5) sessions of routine irradiation.

RESULTS AND DISCUSSION

Characteristics of dose distribution throughout sample configuration

The objective of dose distribution or dose mapping study is to provide an accurate estimation of maximum and minimum radiation absorbed dose given during fruit fly pupae irradiation process (FAO/IAEA/USDA, 2019). The dose mapping results at 60 Gy are provided as in Table 1 in which the maximum dose was 74.4 Gy at position 4 while the minimum dose was 62.5 Gy at position 1, resulted in dose uniformity ratio (DUR) as 1.2. Average dose was found to be 68.7 Gy during 9 m 29 s exposure resulted in dose rate as 7.2 Gy/min. The position 4 and 1 were used for monitoring the maximum and minimum dose, respectively in routine irradiation of samples in this study. On the other hand, a study has opted the application of reference point position to get the relative dose at minimum and maximum points in which a particular reference point was selected and DUR calculated based on relationship between dose values at different points (Gomez-Simuta et al., 2021).

Table 1: Results of dosimeter analyses at different positions and their dose rates

Location of dosimeters	Dose (Gy)	Dose rate (Gy/min)	Notes
1	62.5	6.6	Minimum position
2	63.0	6.6	-
3	70.6	7.4	-

4	74.4	7.8	Maximum position
5	72.8	7.7	-
-	68.7	7.2	Average

Dose-uniformity ratio = maximum dose/minimum dose = 74.4/62.5 = 1.2

Exposure time correspond to required minimum dose

Since the target of this study was to achieve minimum dose and not overall average dose, only the dose rate at minimum position, 6.6 Gy/min was the one which being considered to construct simple arithmetic calculation through relationship between target dose and exposure time to estimate exposure time from 50 to 400 Gy simultaneously as showed in Figure 3.

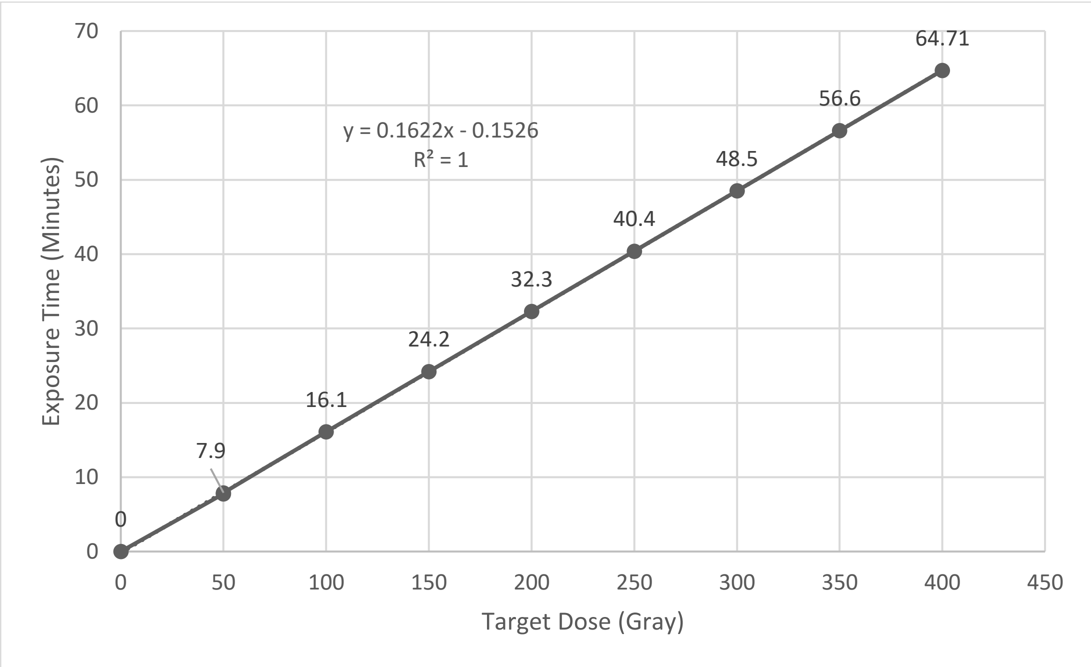

Figure 3: Relationship between target dose and exposure time

Then, due to decay nature of ^{137}Cs source, it is more important to set the parameters using Biobeam GM 8000 dose panel rather the exposure time panel. It is because the machine will automatically determine the current working exposure time after the required dose being set on the dose panel regardless when exactly the exercise will be carried out. In this particular study, dose parameter has been found to be set at 59.4, 120.9, 181.8, 242.0, 303.2, 363.0, 424.8 and 482.9 Gy corresponding to exposure time determined arithmetically to achieve minimum actual dose as required.

Table 2 shows that the dose parameter determined previously has been verified as indicated by the average doses achieved for the range between 50 to 400 Gy. A study by Narayan et al., (2008) confirmed similar linear response against gamma radiation in the range of 100 Gy to 10 kGy as long as dosimeters were calibrated accordingly prior to use.

Table 2: Actual absorbed minimum dose during five (5) session of routine irradiation

Target dose (Gy)	Exposure time (hh:mm:ss)	Dose (Gy)					Average dose (Gy)
		1	2	3	4	5	
50	00:07:54	59.1	54.3	51.9	52.7	54.6	54.5 ± 2.8
100	00:16:06	102.4	107.8	105.1	108.1	106.7	106.0 ± 2.3
150	00:24:12	156.7	161.4	158.1	159.1	160.5	159.2 ± 1.9
200	00:32:18	207.7	215.7	209.7	210.4	210.4	210.8 ± 3.0
250	00:40:24	260.9	267.8	262.2	263.3	262.8	263.4 ± 2.6
300	00:48:30	310.6	318.9	315.1	317.7	311.3	314.7 ± 3.7
350	00:56:36	361.3	370.8	366.2	367.0	361.0	365.3 ± 4.1
400	01:04:21	405.5	420.0	411.3	414.8	399.0	410.1 ± 8.2

Also as shown in Table 2 above, to ensure that all samples achieve actual minimum dose that is not less than the target dose, samples will actually be irradiated with a dose that is somewhat higher than the target dose. Furthermore, since the dose-uniformity ratio of maximum and minimum within the chamber is estimated to be considerably low as determined previously, maximum doses towards 50, 100, 150, 200, 250, 300, 350 and 400 Gy achieved are within acceptable limit; 60.7 ± 1.6, 123.0 ± 6.1, 179.8 ± 2.3, 239.0 ± 2.1, 295.3 ± 10.9, 355.2 ± 3.8, 414.6 ± 4.1 and 461.4 ± 8.2 Gy respectively as mentioned in Table 3. This is in agreement with Bakri et al., (2021) and Mehta, (2017) in which they believed the dose variation in the irradiated matter or sample is critical parameter and must be taken care of especially for insect irradiation study.

Table 3: Actual absorbed maximum dose during five (5) session of irradiation

Target dose(Gy)	Exposure time (hh:mm:ss)	Dose (Gy)					Average dose(Gy)
		1	2	3	4	5	
50	00:07:54	59.4	63.0	60.4	60.0	60.4	60.7 ± 1.6
100	00:16:06	118.9	120.5	120.4	132.1	121.3	123.0 ± 6.1
150	00:24:12	178.9	183.0	179.4	177.7	179.0	179.8 ± 2.3
200	00:32:18	237.6	242.2	238.1	238.2	236.9	239.0 ± 2.1
250	00:40:24	298.2	305.7	279.9	297.5	297.3	295.3 ± 10.9
300	00:48:30	356.6	358.9	355.3	349.9	345.8	355.2 ± 3.8
350	00:56:36	411.2	414.9	411.8	407.9	407.9	414.6 ± 4.1
400	01:04:21	459.8	472.4	454.4	447.6	447.6	461.4 ± 8.2

Hence, the size, shape and configuration of the container used to place the samples during routine irradiation processing and its position within the beaker and other relevant parameter information for Biobeam GM 8000 according to the dose range are defined and documented relevant for routine radiation processing and usage as long as all above criteria as maintained. Different design of irradiator and/or different configuration of samples used may affect dose distribution subsequently change the attainable dose range (FAO/IAEA/USDA, 2019).

CONCLUSION

The development of protocol could assist on the good irradiation practice to ensure implementation of consistent procedure. When the protocol is developed and applied, expected minimum doses achieved should not fall below the target doses. In this study, the target doses during routine exposure from 50 to 400 Gy with implementation of the protocol gave minimum dose results as expected.

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