The effect of gamma irradiation on the internal and external quality of avocados

N du Rand, Z van Rooyen and J de Graaf

Westfalia Technological Services
PO Box 1103, Tzaneen 0850, South Africa
E-mail: 962082021@ukzn.ac.za

in collaboration with
JP Bower

Horticultural Science, University of KwaZulu-Natal
Private Bag X01, Scottsville 3209, South Africa
E-mail: bowerj@ukzn.ac.za

and
G Lunt and R Lunt

Gamwave (Pty) Ltd
PO Box 26406, Isipingo Beach 4115, South Africa

ABSTRACT
The South African (SA) avocado industry is export driven and requires reliable disinfestation treatments for existing and new markets. This requirement is true for markets that have suitable climates for SA quarantine pests. Gamma irradiation has proven to be a reliable disinfestation treatment but the effect of this treatment on SA avocados needed to be investigated. Two cultivars of avocado, 'Carmen' and 'Hass' (early , mid- and late-season) were subjected to gamma irradiation (Co^{60}) at three different dose levels, 100 Gy, 200 Gy and 400 Gy. The experimental design was divided into two treatments, i.e., irradiation in country of export and irradiation in country of import. Both of these treatments consisted of a 28 day sea freight simulation at 5.5ºC. The fruit was evaluated externally and internally. In terms of external quality, only few differences were detected between the non-irradiated control fruit and the irradiated fruit (100 Gy, 200 Gy and 400 Gy). However, the internal quality of irradiated avocado compared to non-irradiated avocado was poor. The results indicated that avocados are very sensitive to Gamma irradiation as low as 100 Gy, and therefore are not suitable for use of irradiation as a quarantine treatment.

INTRODUCTION
Gamma irradiation has been a successful alternative disinfestation treatment for various fruits and vegetables (Torres-Rivera & Hallman, 2007; Hallman, 2008). Regulations for the irradiation of fresh fruit and vegetables as a disinfestation method have been established by the United States Department of Agriculture's (USDA) Animal and Plant Health Inspection Services (APHIS). However, not all fruits and vegetables can tolerate gamma irradiation (Kader, 1986). Some of the fruits that are known to tolerate irradiation include: apple, mango, strawberry and papaya (Kader, 1986).

Gamma irradiation is not only used as a disinfestation method but may also be used to prolong the shelf life of fresh fruits such as avocados which can be beneficial during exportation when the fruit is shipped over long periods of time (Young, 1965).

South African avocados are attacked by different insect pests (De Villiers & Van den Berg, 1987). Fruit flies are considered the most serious pests from a quarantine perspective (De Villiers & Van den Berg, 1987). The accepted generic irradiation dose for fruit flies in South Africa is 150 Gy (IPPC, 2007), although the required doses for individual species in South Africa may be as low as 100 Gy (Torres-Rivera & Hallman, 2007; Hallman, 2008). These low doses of irradiation do not necessarily kill the quarantine pests, however; this treatment does prevent these pests from developing into adults or in some cases render them sterile (Hallman, 2008).

Avocado fruits are known to be sensitive to irradiation doses above 150 Gy (Follett & Neven, 2006), but Arvalo *et al.* (2002), Follett and Neven, (2006) and Torres-Rivera and Hallman (2007) suggested that irradiation of avocados at approximately 100 Gy may be feasible. Low dose irradiation can form part of a systems approach (or even a single quarantine treatment) against quarantine pests of avocado in South Africa (Follett & Neven, 2006).

The aim of the study was to investigate fruit quality after applying low gamma irradiation doses to two avocado cultivars at different times of the season while simulating irradiation in South Africa and the import country.

MATERIALS AND METHODS

Two avocado cultivars, i.e., 'Carmen Hass' and 'Hass' (early, mid- and late-season) were harvested and packed according to standard packhouse treatments (fungicide and waxing) at the Westfalia Packhouse in Tzaneen, SA. The 4 kg cartons consisted of size 16 count fruit.

Two main irradiation treatments, irradiation "in country of import" (Treatment 1) and irradiation "in country of export" (Treatment 2), were conducted. Both of these treatments consisted of a 28 day sea freight simulation at 5.5ºC. The former treatment entailed irradiation after cold storage for 28 days and the latter treatment irradiation before cold storage for 28 days.

The transportation of the fruit took place overnight from Tzaneen to Pietermaritzburg, at 9ºC in a refrigerated truck. The fruit was irradiated at a gamma irradiation facility in Durban (Gamwave [Pty] Ltd., KwaZulu-Natal, SA). A ±8 hr cold chain break occurred due to transportation to and from the irradiation facility. This resulted in condensation formation on the fruit.

Each irradiation treatment consisted of five cartons of fruit that were exposed to the following doses: 100 Gy, 200 Gy and 400 Gy. The dosimetery was conducted according to Du Rand *et al.*, 2009. The control consisted of non-irradiated fruit. All the fruit were ripened at ambient temperature at the University of KwaZulu-Natal in Pietermartitzburg, KwaZulu-Natal, SA.

Fruit evaluation

The fruit was evaluated according to the following criteria once they reached eating ripeness:

External evaluation

Black chilling injury – The fruit was scored on a scale of 0-3 where 0 represents no chilling injury.

Brown chilling injury – The fruit was scored on a scale of 0-3 where 0 represents no chilling injury.

Lenticel damage – The fruit was scored on a scale of 0-3 where 0 represents no lenticel damage.

Skin colour – The fruit was scored on a scale of 0-3 where 0 represents green skin and 3 represents total darkening of the skin.

Shrivel – The fruit was scored on a scale of 0-3 where 0 represents no shrivelling.

General appearance of the fruit – The fruit was scored on a scale of 0-3 where 0 represents unacceptable. Days to ripe were not determined as it was difficult to determine if the fruit was soft due to ripeness or post-harvest disease infection.

Internal evaluation

Anthracnose – The fruit was scored on a scale of 0-3 where 0 represents no anthracnose.

Stem-end rot – The fruit was scored on a scale of 0-3 where 0 represents no stem-end rot.

Grey pulp – The fruit was scored on a scale of 0-3 where 0 represents no grey pulp.

Vascular browning – The fruit was scored on a scale of 0-3 where 0 represents no vascular browning.

Taste – The fruit was scored on a scale of 0-3 where 0 represents unacceptable taste.

Statistics

The data was subjected to one way ANOVA at 95% confidence levels. The mean differences were separated using Duncan's method.

RESULTS AND DISCUSSION

External evaluation

The results of the external evaluations on 'Carmen', early, mid- and late-season 'Hass' is presented in **Table 1-4**. Results for Treatment 2 were not available due to availability of fruit. Some statistical differences were observed in the external evaluations of irradiated and non-irradiated fruit, but few were of notable biological significance.

Table 1. External quality of 'Carmen' avocados irradiated at different doses.

Treatment	Dose (Gy)	Black chilling injury	Brown chilling injury	Lenticel damage	Skin colour	Shrivel
1	Control	0.40 ± 0.59[x] ab[y], A[z]	0.00 ± 0.00 a, A	1.32 ± 0.83 a, AB	2.73 ± 0.51 a, B	0.35 ± 0.58 b, B
	100	0.18 ± 0.38 a, A	0.00 ± 0.00 a, A	1.48 ± 0.78 a, BC	2.98 ± 0.16 b, C	0.08 ± 0.35 a, A
	200	0.18 ± 0.45 a, A	0.25 ± 0.16 a, A	1.83 ± 0.75 b, D	2.95 ± 0.22 b, C	0.08 ± 0.27 a, A
	400	0.43 ± 0.59 b, A	0.00 ± 0.00 a, A	1.98 ± 0.36 b, B	2.98 ± 0.16 b, C	0.00 ± 0.00 a, A
2	Control	0.25 ± 0.54 a, A	0.05 ± 0.22 a, A	1.13 ± 0.69 a, A	2.93 ± 0.27 b, C	0.15 ± 0.43 b, A
	100	0.28 ± 0.64 a, A	0.25 ± 0.67 a, B	1.90 ± 0.71 b, D	2.55 ± 0.60 a, A	0.08 ± 0.27 ab, A
	200	0.38 ± 0.67 a, A	0.18 ± 0.45 ab, AB	1.30 ± 0.56 a, AB	2.98 ± 0.16 b, C	0.00 ± 0.00 a, A
	400	0.38 ± 0.49 a, A	0.45 ± 0.64 b, C	1.70 ± 0.72 b, CD	3.00 ± 0.00 b, C	0.05 ± 0.22 ab, A

[x] Standard deviation
[y] No significant differences within a given dose level is represented by the same lower-case letters within a treatment (p >.05)
[z] No significant differences within a given dose level is represented by the same upper-case letter when treatments were compared (p >.05)

Internal evaluation

The detrimental effects of irradiation were mainly observed during the internal evaluation of the fruit (**Table 5-8**). The level of anthracnose, stem-end rot, grey pulp and vascular browning increased considerably when the fruit was irradiated (**Table 5-8**). Gamma irradiation is known to cause internal browning in avocados at doses <1 kGy (Kader, 1986). This was found to be true during this investigation and occurred at a very low dose of 100 Gy for both 'Carmen' and 'Hass' (early, mid- and late-season) (**Table 5-8**). The high level of anthracnose infection is similar to research conducted by Cia *et al.* (2007), who found that irradiation doses <1 kGy increased anthracnose, *Collectotrichum gloeosporioides*, sporulation in papaya. The level of anthracnose was found to increase with irradiation (**Table 5-8**).

Significant differences in the internal quality of the fruit were observed between the non-irradiated control fruit and the irradiated fruit (100 Gy, 200 Gy and 400 Gy) of 'Carmen' and 'Hass' (early, mid- and late-season) with regard to all the internal evaluation criteria (**Table 5-8**).

Table 2. External quality of early season 'Hass' avocados irradiated at different doses.

Treatment	Dose (Gy)	Black chilling injury	Brown chilling injury	Lenticel damage	Skin colour	Shrivel
1	Control	0.78 ± 0.83[x] a[y], B[z]	0.50 ± 0.32 a, A	0.90 ± 0.67 a, AB	2.75 ± 0.44 a, BC	0.45 ± 0.55 c, B
	100	0.90 ± 0.98 a, B	0.05 ± 0.22 a, A	1.25 ± 0.90 a, BC	2.93 ± 0.27 b, CD	0.18 ± 0.50 b, A
	200	0.83 ± 0.90 a, B	0.10 ± 0.38 a, A	0.95 ± 0.68 a, AB	3.00 ± 0.00 b, D	0.00 ± 0.00 a, A
	400	0.93 ± 0.89 a, B	0.15 ± 0.43 a, A	0.90 ± 0.71 a, AB	3.00 ± 0.00 b, D	0.00 ± 0.00 a, A
2	Control	0.33 ± 0.69 a, A	0.25 ± 0.71 a, A	1.05 ± 0.90 a, AB	2.73 ± 0.51 a, B	0.60 ± 0.50 a, BC
	100	0.35 ± 0.62 a, A	0.65 ± 1.08 b, B	0.78 ± 0.62 ab, A	2.48 ± 0.64 a, A	0.60 ± 0.63 a, BC
	200	1.38 ± 0.77 b, C	0.20 ± 0.56 a, A	1.20 ± 0.82 b, BC	2.58 ± 0.50 a, AB	0.80 ± 0.41 a, C
	400	1.45 ± 0.75 b, C	0.25 ± 0.59 a, A	1.35 ± 0.80 c, C	2.58 ± 0.50 a, AB	0.80 ± 0.41 a, C

[x] Standard deviation
[y] No significant differences within a given dose level is represented by the same lower-case letters within a treatment (p >.05)
[z] No significant differences within a given dose level is represented by the same upper-case letter when treatments were compared (p >.05)

Table 3. External quality of mid-season 'Hass' avocados irradiated at different doses.

Treatment	Dose (Gy)	Black chilling injury	Brown chilling injury	Lenticel damage	Skin colour	Shrivel
1	Control	0.60 ± 0.63[x] a[y], B[z]	0.08 ± 0.27 a, A	0.88 ± 0.65 a, A	2.73 ± 0.51 a, B	0.13 ± 0.33 a, A
	100	0.88 ± 0.79 ab, BC	0.45 ± 0.68 b, BCD	1.48 ± 1.09 b, BC	2.88 ± 0.33 b, B	0.10 ± 0.30 a, A
	200	1.08 ± 0.83 bc, CD	0.70 ± 0.69 b, DE	1.73 ± 0.93 b, BC	2.98 ± 0.16 b, B	0.25 ± 0.49 ab, A
	400	1.33 ± 0.83 c, CD	0.95 ± 0.75 c, E	1.63 ± 0.70 b, BC	2.98 ± 0.16 b, B	0.35 ± 0.53 b, AB
2	Control	0.10 ± 0.30 a, A	0.18 ± 0.38 a, AB	1.40 ± 0.71 a, BC	2.98 ± 0.16 b, B	0.10 ± 0.30 a, A
	100	1.15 ± 0.80 b, CDE	0.60 ± 0.74 b, CD	1.28 ± 0.99 a, B	2.35 ± 0.83 a, A	0.33 ± 0.62 ab, A
	200	1.15 ± 0.89 b, CDE	0.38 ± 0.70 ab, BC	1.83 ± 0.78 b, BC	2.45 ± 0.68 a, A	0.30 ± 0.61 ab, A
	400	1.48 ± 0.60 c, D	0.60 ± 0.71 b, CD	1.48 ± 0.99 ab, BC	2.35 ± 0.74 a, A	0.58 ± 0.82 b, B

[x] Standard deviation
[y] No significant differences within a given dose level is represented by the same lower-case letters within a treatment (p >.05)
[z] No significant differences within a given dose level is represented by the same upper-case letter when treatments were compared (p >.05)

Table 4. External quality of late-season 'Hass' avocados irradiated at different doses.

Treatment	Dose (Gy)	Black chilling injury	Brown chilling injury	Lenticel damage	Skin colour	Shrivel
1	Control	0.13 ± 0.33[x] a[y]	0.03 ± 0.16 a	0.85 ± 0.58 a	2.73 ± 0.55 a	0.08 ± 0.35 a
	100	0.63 ± 0.67 b	0.18 ± 0.45 bc	1.15 ± 0.53 b	2.78 ± 0.53 a	0.00 ± 0.00 ab
	200	0.58 ± 0.59 b	0.83 ± 0.90 d	1.43 ± 0.55 c	3.00 ± 0.00 b	0.25 ± 0.44 b
	400	1.35 ± 0.66 c	0.45 ± 0.81 c	1.43 ± 0.68 c	3.00 ± 0.00 b	1.08 ± 0.57 c
2	Control	-	-	-	-	-
	100	-	-	-	-	-
	200	-	-	-	-	-
	400	-	-	-	-	-

[x] Standard deviation
[y] No significant differences within a given dose level is represented by the same lower-case letters within a treatment (p >.05)
[z] No significant differences within a given dose level is represented by the same upper-case letter when treatments were compared (p >.05)

Table 5. Internal quality of 'Carmen' avocados irradiated at different doses.

Treatment	Dose (Gy)	Anthracnose	Stem-end rot	Grey pulp	Vascular browning	Taste
1	Control	1.60 ± 1.17[x] a[y], A[z]	1.55 ± 1.22 a, A	0.35 ± 0.62 a, A	1.90 ± 1.03 a, A	1.95 ± 0.39 b, D
	100	3.00 ± 0.00 b, C	3.00 ± 0.00, b, C	2.95 ± 0.32 b, C	3.00 ± 0.00 b, B	0.00 ± 0.00 a, A
	200	3.00 ± 0.00 b, C	3.00 ± 0.00, b, C	3.00 ± 0.00 b, C	3.00 ± 0.00 b, B	0.00 ± 0.00 a, A
	400	3.00 ± 0.00 b, C	3.00 ± 0.00, b, C	3.00 ± 0.00 b, C	3.00 ± 0.00 b, B	0.00 ± 0.00 a, A
2	Control	1.523 ± 1.13 a, A	1.68 ± 1.29 a, A	0.30 ± 0.56 a, A	1.68 ± 1.21 a, A	1.55 ± 1.08 c, C
	100	2.50 ± 0.91 b, B	2.33 ± 1.10 b, B	0.98 ± 0.89 b, B	2.83 ± 0.45 b, B	0.68 ± 0.92 b, B
	200	2.98 ± 0.16 c, C	3.00 ± 0.00 c, C	3.00 ± 0.00 c, C	3.00 ± 0.00 b, B	0.00 ± 0.00 a, A
	400	3.00 ± 0.00 c, C	3.00 ± 0.00 c, C	3.00 ± 0.00 c, C	3.00 ± 0.00 b, B	0.00 ± 0.00 a, A

[x] Standard deviation
[y] No significant differences within a given dose level is represented by the same lower-case letters within a treatment (p >.05)
[z] No significant differences within a given dose level is represented by the same upper-case letter when treatments were compared (p >.05)

Table 6. Internal quality of early season 'Hass' avocados irradiated at different doses.

Treatment	Dose (Gy)	Anthracnose	Stem-end rot	Grey pulp	Vascular browning	Taste
1	Control	1.33 ± 1.21[x] a[y], A[z]	1.00 ± 1.28 a, A	0.30 ± 0.69 a, A	1.55 ± 1.34 a, A	1.80 ± 0.16 b, C
	100	2.63 ± 0.90 b, CD	2.70 ± 0.91 b, D	1.65 ± 1.44 b, B	2.95 ± 0.32 b, C	0.15 ± 0.43 a, A
	200	3.00 ± 0.00 c, D	3.00 ± 0.00 b, D	3.00 ± 0.00 c, C	3.00 ± 0.00 b, C	0.00 ± 0.00 a, A
	400	3.00 ± 0.00 c, D	3.00 ± 0.00 b, D	3.00 ± 0.00 c, C	3.00 ± 0.00 b, C	0.00 ± 0.00 a, A
2	Control	1.80 ± 0.19 a, B	1.73 ± 1.28 a, B	0.48 ± 0.12 a, A	2.08 ± 1.14 a, B	1.80 ± 1.09 c, C
	100	2.33 ± 1.05 b, C	2.25 ± 0.20 b, C	0.48 ± 0.75 a, A	2.15 ± 1.08 a, B	0.85 ± 0.92 b, B
	200	3.00 ± 0.00 c, D	3.00 ± 0.00 c, D	3.00 ± 0.00 b, C	3.00 ± 0.00 b, C	0.00 ± 0.00 a, A
	400	3.00 ± 0.00 c, D	3.00 ± 0.00 c, D	3.00 ± 0.00 b, C	3.00 ± 0.00 b, C	0.00 ± 0.00 a, A

[x] Standard deviation
[y] No significant differences within a given dose level is represented by the same lower-case letters within a treatment (p >.05)
[z] No significant differences within a given dose level is represented by the same upper-case letter when treatments were compared (p >.05)

Table 7. Internal quality of mid-season 'Hass' avocados irradiated at different doses.

Treatment	Dose (Gy)	Anthracnose	Stem-end rot	Grey pulp	Vascular browning	Taste
1	Control	1.40 ± 1.08[x] a[y], B	1.25 ± 1.21 a, B	1.28 ± 1.15 a, BC	1.83 ± 1.6 a, B	1.60 ± 1.41 b, D
	100	2.78 ± 0.70 b, DE	2.75 ± 0.81 b, D	2.90 ± 0.50 b, C	3.00 ± 0.00 b, C	0.08 ± 0.27 a, AB
	200	2.90 ± 0.30 b, E	2.90 ± 0.30 b, D	2.90 ± 0.30 b, C	2.98 ± 0.16 b, C	0.00 ± 0.00 a, A
	400	2.98 ± 0.16 b, E	2.93 ± 0.47 b, D	2.98 ± 0.16 b, C	3.00 ± 0.00 b, C	0.00 ± 0.00 a, A
2	Control	0.48 ± 0.82 a, A	0.28 ± 0.85 a, A	0.23 ± 0.80 a, A	0.68 ± 1.10 a, A	2.60 ± 0.87 c, E
	100	1.88 ± 1.14 b, C	2.00 ± 1.24 b, C	0.98 ± 1.27 b, B	2.93 ± 0.35 b, C	1.13 ± 1.30 b, C
	200	2.10 ± 0.90 bc, C	2.25 ± 1.03 b, C	0.98 ± 1.21 b, B	2.85 ± 0.58 b, C	1.03 ± 1.14 b, C
	400	2.48 ± 0.78 c, D	2.33 ± 1.07 b, C	1.65 ± 1.31 c, C	2.98 ± 0.16 b, C	0.48 ± 0.91 a, B

[x] Standard deviation
[y] No significant differences within a given dose level is represented by the same lower-case letters within a treatment (p >.05)
[z] No significant differences within a given dose level is represented by the same upper-case letter when treatments were compared (p >.05)

Table 8. Internal quality of late-season 'Hass' avocados irradiated at different doses.

Treatment	Dose (Gy)	Anthracnose	Stem-end rot	Grey pulp	Vascular browning	Taste
1	Control	1.08 ± 1.23[x] a[y]	1.17 ± 1.22 a	0.48 ± 1.06 a	1.50 ± 1.20 a	1.63 ± 1.08 b
	100	2.98 ± 0.16 b	2.95 ± 0.32 b	2.93 ± 0.35 b	3.00 ± 0.00 b	0.05 ± 0.32 a
	200	3.00 ± 0.00 b	3.00 ± 0.00 b	3.00 ± 0.00 b	3.00 ± 0.00 b	0.00 ± 0.00 a
	400	3.00 ± 0.00 b	3.00 ± 0.00 b	3.00 ± 0.00 b	3.00 ± 0.00 b	0.00 ± 0.00 a
2	Control	-	-	-	-	-
	100	-	-	-	-	-
	200	-	-	-	-	-
	400	-	-	-	-	-

[x] Standard deviation
[y] No significant differences within a given dose level is represented by the same lower-case letters when treatments were compared (p >.05)

CONCLUSION

Gamma irradiation may be a suitable method to use against quarantine pests but is not necessarily a compatible disinfestation method in all types of fruit. This was found to be true with regard to the gamma irradiation of avocados. Detrimental effects were evident at low doses of gamma irradiation (100 Gy) and the results obtained did not support the recommendations of Arvalo *et al.* (2002), Follett and Neven (2006) and Torres-Rivera and Hallman (2007), who suggested that irradiation of avocados at 100 Gy is feasible. Other methods such as low temperature storage, as suggested by Bower (2005b), are much better suited disinfestation methods and have much more promising results that gamma irradiation of avocados, although other fruits like citrus types, grapes and apples can withstand lower temperatures.

LITERATURE CITED

APHIS – 2008. Plant protection and quarantine fact sheet. www.aphis.usda.gov/publications/plant_health/content/printable_version/ifruit08.pdf (accessed 27/07/09).

AREVALO, L., BUSTOS, M.E. & SAUCEDO, C. 2002. Changes in the vascular tissue of fresh Hass avocados treated with cobalt 60. *Radiation Physics and Chemistry*, 63: 375-377.

BOWER, J.P. 2005a. Resolving long distance shipping disorders in 'Hass' avocados. New Zealand and Australian Avocado Growers' Conference, Session 6.

BOWER, J.P. 2005b. The effect of coatings and packaging on fruit quality in avocado cv. Hass stored at low temperature for phytosanitary purposes. *South Afican Avocado Growers' Association Yearbook*, 28: 28-31.

CIA, P., PASCHOLATI, S.F., BENATO, E.A., CAMILI, E.C. & SANTOS, C.A. 2007. Effects of gamma and UV-C irradiation on the postharvest control of papaya anthracnose. *Postharvest Biology and Technology*, 43: 366-373.

DU RAND, N., VAN ROOYEN, Z., DE GRAAF, J., BOWER, J.P., LUNT, G. & LUNT, R. 2009. The effect of Gamma irradiation on mango quality. *South African Mango Growers' Association Research Journal*, 29: 12-19.

DE VILLIERS, E.A. & VAN DEN BERG, M.A. 1987. Avocado insects of South Africa. *South African Avocado Growers' Association Yearbook*, 10: 75-79.

FOLLETT, P.A. & NEVEN, L.G. 2006. Current trends in quarantine entomology. *Annual Review of Entomology*, 51: 359-385.

HALLMAN, G.J. 2008. Potential increase in fruit fly (Diptera: Tephritidae) interceptions using ionizing irradiation phytosanitary treatments. *Journal of Economic Entomology*, 101: 716-719.

International Plant Protection Convention (IPPC). 2007. International Standards for phytosanitary Measures (ISPM) No. 28, Phytosanitary treatments for regulated pests. Irradiation treatments annexed 2009. FAO, Rome.

KADER, A.A. 1986. Potential applications of ionizing radiation in post harvest handling of fresh fruits and vegetables. *Food Technology*, 40: 117-121.

TORRES-RIVERA, Z. & HALLMAN, G.J. 2007. Low-dose irradiation phytosanitary treatment against Mediterranean fruit fly (Diptera: Tephritidae). *Florida Entomologist*, 90: 342-346.

YOUNG, R.E. 1965. Effect of ionizing radiation on respiration and ethylene production of avocado fruit. Nature, 205: 1113-1114.