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Degree of Fruit Ripeness Affecting Infestation of Papaya by Two Species of Fruit Flies (Diptera: Tephritidae)[1]

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Abstract

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Infestation of papaya fruits by two species of fruit flies, the oriental fruit fly, *Bactrocera dorsalis* (Hendel), and the melon fly, *B. cucurbitae* (Coquillett), was tested in the laboratory for mature green, 1–2 yellow-stripe, 2–3 yellow-stripe, 5 yellow-stripe, and mature yellow (fully ripe) fruits of the 'Tainung No. 2' papaya (*Carica papaya* L.), and mature green, quarter, half, and mature yellow fruits of the 'Sunrise' papaya. The fruit ripeness levels were categorized visually based on the extent of the skin's yellow color development. Mechanical measurements of colorimetric values, soluble solid contents, acidity, and flesh hardness for each ripeness category were also carried out. Oriental fruit flies only laid eggs in fully ripe fruits of the 'Tainung No. 2' papaya, while melon flies could lay eggs in both the 5 yellow-stripe and fully ripe fruits. The 2–3 yellow-stripe 'Tainung No. 2' papayas, which is the ripeness degree the export papayas being harvested, were never infested by both fly species. For 'Sunrise' papayas, oriental fruit flies laid eggs in half yellow and fully ripe fruits, while melon flies laid eggs in fruits of all ripeness levels except of the mature green fruits. Whether the papaya fruit was subject to fruit fly oviposition depended not only on the ripeness level of the fruit but also on the fly density. As fly densities become high, the ripeness degree that would suffer fly infestation could become lower. We also found that a well-established screenhouse with a multiple-layer-door design could effectively prevent fruit fly invasion. Thus, this study suggested that the protocol for export papayas, at least the 'Tainung No. 2', to be harvested at proper ripeness degrees in combination with cultivation in a well-established screenhouse should be possible to replace the current vapor heat quarantine treatment. Further intensive field screen of melon fly infestation in papaya screenhouses need to be conducted to determine if screenhouse cultivated 'Sunrise' papayas could also be exempted from additional quarantine treatments.

Key words: *Bactrocera dorsalis*, *Bactrocera cucurbitae*, Papaya, Fruit fly infestation, Quarantine.

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Introduction

The oriental fruit fly, *Bactrocera dorsalis* (Hendel), and the melon fly, *B*. *cucurbitae* (Coquillett) (Diptera: Tephritidae), are widely distributed in Taiwan, and papayas are in their host ranges (White & Elson-Harris 1992). Our export papayas before shipping to those countries free of these two species of fruit flies require quarantine treatments to eliminate any possible fly eggs and larvae in the fruits. For example, papaya fruits of ‘Tainung No. 2’, the principal papaya cultivar grown in Taiwan, prior to export to Japan need going through a 47.2℃ vapor heat treatment for 4–5 hours. This is also a requirement by the US for papayas exported from fruit fly infested countries (Couey *et al*. 1984; Chen & Lin 2003; Shiesh & Hsueh 2005). Papayas after going through the vapor heat treatment would meet quarantine security to the importing country, yet results in a reduced quality and an increased cost that lowers their market competitiveness. In fact, these two species of fruit flies in the field usually do not damage unripe papayas implying a strong relationship between fruit fly infestation and papaya ripeness levels (Seo *et al*. 1982; Armstrong 1983; Liquido *et al*. 1989; Liquido & Cunningham 1990).

For shipping considerations, papayas usually are harvested before fully ripe, and allowed for a period of post-ripening time. Different cultivars of papaya permit different post-ripening times which determine their time of harvest (Shiesh 2001; Tsai & Ke 2005). Besides, most papayas in Taiwan are now grown in screenhouses to be protected from aphids which serve as vectors for papaya ringspot virus. The screenhouse cultivation could also avoid infestation of papayas by fruit flies. If it can be demonstrated that papaya fruits are not subject to fruit fly infestation at any ripeness level before harvest, then, it in combination with sound screenhouse cultivation might provide a reliable quarantine system for export papayas to be exempted from the currently used vapor heat treatment. This would help export papayas preserve high fruit quality and better commodity competitiveness. This study was therefore conducted to determine the relation between the ripeness levels of the ‘Tainung No. 2’ and ‘Sunrise’ papayas and the infestation of *B*. *dorsalis* and *B*. *cucurbitae*, thus providing government agency important information for international trade negotiations.

Materials and Methods

Fruit flies

The oriental fruit flies and the melon flies used for this study were from the laboratory colonies. Larvae of the oriental fruit fly were fed on an artificial diet described by Chiu (1978), and melon flies on a diet described by Liu & Shiao (1984). Adults of both fly species were maintained on a diet containing yeast and sucrose (3 : 1) in a cage (30 by 30 by 30 cm) with wetted sponge on the top. The rearing units were kept in the insectary at 25 ± 1℃, 75 ± 10% RH, and a photoperiod of 12 : 12 (L : D). Wild colonies were introduced into the laboratory stocks at least twice every year.

Test papayas and measurements of physical and chemical properties

Different ripeness degree of papaya fruits in two varieties, ‘Tainung No. 2’ and ‘Sunrise’, were respectively collected from the export-papaya supplier orchards. Each fruit sample was wiped to remove the dirt and possible pesticides, and then respectively weighted. The maturity levels of the papayas were determined by the common standards used by the growers. This standard classifies the ‘Tainung No. 2’ papayas, based on the extent of yellow color development on the fruit skin, into five ripeness degrees: mature green (entirely green with no streaks of yellow), 1–2, 2–3, and 5 yellow-stripe, and mature yellow (entirely yellow). While the yellow color of the ripening ‘Sunrise’ papayas does not appear at specific parts, ripeness degrees of ‘Sunrise’ papayas are classified into four categories as mature green (entirely green), quarter-, half-, and mature-yellow (more than half of the entire fruit being yellow). The visually categorized papaya fruits were then subjected to mechanical measurements of colorimetric values, sweetness, sourness, and hardness. The apparent color of the fruit was measured using a spectrophotometer (Nippon Denshoku, Japan) reading respectively from the blossom end and the equatorial regions. The colorimeter outputs three color readings: *L* (lightness of the surface being tested), *a* (greenness to redness), and *b* (blueness to yellowness). Soluble solids content of the fruit was measured using a refractometer (PR-1, Atago, Japan), acidity measured by titration using malic acid as the titrator, and flesh hardness measured using a rheometer (NRM-2010J-CW, Fudoh, Japan). For measurements of the fruit soluble solids content and acidity, four points on the surface of a fruit were sampled along the fruit equatorial plane with each sample point separated from one another by a 90° rotation. For measuring the fruit hardness, the sample fruit was peeled first, and three pieces of fruit flesh, each sizing 3 cm long by 3 cm wide by 1.5 cm thick, and equally spaced along the fruit equatorial region were taken. For each measurement of the fruit properties, a total of 5-10 fruits for each ripeness category were used.

Fly oviposition frequency on papaya fruits in relation to fruit ripeness levels

Individual papaya fruits of different ripeness degrees were put in separate screen cages [26 cm × 15 cm × 15 cm (L × W × H)]. Specific pairs of 12–14 days old fruit fly were then introduced into each cage. These test units were maintained in the laboratory at 25 ± 1°C and 75 ± 10% RH under the natural light. After a period of six hours, the papaya fruits were taken out of the cages and examined under a microscope (Wild M3Z; Heerbrugg, Switzerland). The number of fly eggs deposited in each fruit was counted and recorded. This study was conducted respectively for two papaya cultivars, 'Tainung No. 2' and 'Sunrise'; two fruit fly species, the oriental fruit fly and the melon fly; and three fly densities, 5, 10, and 20 pairs. Degrees of fruit ripeness tested were mature green, 1–2, 2–3, and 5 yellow-stripe, and mature yellow for the 'Tainung No. 2' papaya, and mature green, quarter-, half-, and mature-yellow for the 'Sunrise' papaya. Ten replications for each test were conducted first, and if results showed zero infestation of fly eggs, then, additional 5 replications were carried out for further confirmation.

Monitoring of fruit fly occurrence in an export-papaya supplier screenhouse

A model export-papaya supplier screenhouse situated at Likang, Pingtung was monitored for populations of the oriental fruit fly and the melon fly. This screenhouse sized 0.3 ha, and was built with an overlapping multiple-layer door. Fifteen yellow sticky boards (28 cm long by 32 cm wide, Jenn Yeong Biotech Ltd) (see Fig. 1A) were hung in the screenhouse, and replaced with new ones every 10 days. Besides, three of the screenhouse's outside corners were each set up with a modified bottle trap developed by the Taichung District Agricultural Research and Extension Station, Council of Agriculture (see Fig. 1B). Each trap was fitted with a fiber board containing methyl eugenol, cuelure, and naled to monitor the population densities of the oriental fruit fly and the melon fly in the areas surrounding our investigated screenhouse. The baits were changed once a month. Fruit flies trapped by the yellow sticky boards and the bottle traps were collected once every 10 days, and the fly species and numbers were examined and recorded in the laboratory. In addition, vegetation types in the neighboring areas were investigated using aerial photographs.

Data analysis

Unprotected Fisher's LSD procedures were directly applied to separate the mean numbers of the egg deposited in different ripeness levels of papayas by specific densities of the fruit fly, without consideration of ANOVA results first for the following reasons: (1) the model assumptions of consistency of the error variance and normality of the error distributions were violated for some scenarios, (2) the unprotected LSD procedures allow that corrections for multiple comparisons be done while interpreting data. The significance level was set at $P < 0.05$. All analyses were conducted using STATGRAPHICS Centurion XV software, 2005 (Statpoint, Herndon, VA).

Results

Table 1 showed certain physical and chemical properties of the various ripeness degrees of the test papayas. As fruit ripeness increased in both 'Tainung No. 2' and 'Sunrise' papayas, the *L* (skin lightness) value increased. The *a* value progressed from negative (indicating greenness of the fruit skin) to positive (indicating increasing redness). The *b* values increased, but all in the positive range indicating yellowness on the fruit skin for all tested maturity degrees. Fruit flesh hardness decreased, soluble solid contents increased, and acidities increased with increasing fruit ripeness. The tested 'Tainung No. 2' papayas had mean fruit weights ranging from 884.4–925.5 g, while 'Sunrise' papayas had the mean weights ranging from 448.6–511.1 g. The export 'Tainung No. 2' papayas are usually harvested at

Fig. 1. The yellow sticky board (A) and the modified bottle trap (B) used in this study.

Table 1. Fruit characteristic parameters (mean ± SE) of 'Tainung No. 2' and 'Sunrise' papayas at various ripeness levels

Fruit ripeness level	Fruit weight (g)	Fruit color at equatorial plane[z]			Fruit color at blossom end			Flesh hardness (kg/cm^2)	Total soluble solid (°Brix)	Titratable acidity (%)
		L	*a*	*b*	*L*	*a*	*b*			
'Tainung No. 2' papaya										
Mature green	884.2 ± 139.2	37.65 ± 3.61	-9.10 ± 0.56	15.61 ± 2.89	36.61 ± 2.37	-7.51 ± 3.70	14.52 ± 4.92	1.51 ± 0.07	7.34 ± 2.06	0.25 ± 0.24
1-2 yellow- stripe	928.7 ± 123.6	38.28 ± 2.58	-9.25 ±1.85	18.33 ± 3.09	36.59 ± 3.51	-8.34 ± 1.33	15.97 ± 3.30	1.31 ± 0.19	8.39 ± 2.95	0.20 ± 0.08
2-3 yellow- stripe	895.8 ± 147.0	40.93 ± 3.41	-8.34 ± 5.42	23.21 ± 5.44	37.33 ± 5.86	-8.90 ± 2.06	18.29 ± 2.56	1.15 ± 0.19	11.02 ± 1.20	0.25 ± 0.09
5 yellow- stripes	966.9 ± 300.3	53.64 ± 4.49	14.17 ± 15.15	44.09 ± 9.38	44.29 ± 6.03	-3.01 ± 6.80	29.96 ± 5.85	0.34 ± 0.36	12.86 ± 0.67	0.28 ± 0.06
Mature yellow	888.3 ± 152.7	54.35 ± 2.92	18.69 ± 6.76	44.69 ± 5.27	50.48 ± 4.83	5.55 ± 7.91	38.24 ± 7.14	0.12 ± 0.08	13.01 ± 0.44	0.32 ± 0.06
'Sunrise' papaya										
Mature green	472.1 ± 53.0	40.96 ± 1.34	-9.21 ± 0.33	21.23 ± 3.53	40.00 ± 2.01	-8.92 ± 0.31	16.53 ± 1.22	1.94 ± 1.85	11.78 ± 0.33	0.19 ± 0.05
Quarter yellow	511.1 ± 51.2	41.39 ± 0.79	-9.17 ± 0.73	22.54 ± 0.75	41.92 ± 1.15	-8.98 ± 0.71	22.96 ± 3.15	1.26 ± 0.16	12.52 ± 0.63	0.19 ± 0.07
Half yellow	448.6 ± 85.7	49.56 ± 2.58	-0.57 ± 3.88	37.12 ± 4.28	53.95 ± 2.51	4.09 ± 4.31	44.09 ± 4.54	0.70 ± 0.28	13.64 ± 1.05	0.24 ± 0.13
Mature yellow	475.2 ± 50.8	55.22 ± 2.99	12.40 ± 7.58	47.64 ± 3.69	57.40 ± 0.69	16.15 ± 4.18	50.29 ± 5.01	0.59 ± 0.23	14.42 ± 0.33	0.36 ± 0.08

[z] *L*: lightness; *a*: color-opponent dimensions (a positive value indicates magenta, and negative indicates green); *b*: color-opponent dimensions (a negative value indicates blueness, a lower positive value indicates greeness, and higher positive values indicate yellowness).

the 2-3 yellow-stripe ripeness degree. Based on the results, this degree of ripeness had a *L* value of 40.93, *a* value of -8.34, and *b* value of 23.21 reading from the equatorial plane; and a *L* value of 37.33, *a* value of -8.90, and *b* value of 18.29 reading from the blossom end. The measure- ments of fruit hardness, soluble solid contents, and acidity were 1.15 kg/cm^2, 11.02°Brix, and 0.25%, respectively. The export 'Sunrise' papayas are visually categorized as quarter-yellow. Compared with the 2–3 yellow-stripe 'Tainung No. 2' papayas, the quarter-yellow 'Sunrise' papayas appeared less red on the fruit skin with *L* value of 41.39, *a* value of -9.17, and *b* value of 22.54 reading from the equatorial plane; and *L* value of 41.92, *a* value of -8.98, and *b* value of 22.96 reading from the blossom end. Furthermore, the quarter-yellow 'Sunrise' papayas were measured harder (fruit hardness = 1.26 kg/cm^2), sweeter (soluble solids content = 12.52°Brix), and less acid (acidity = 0.19%) than the 2–3 yellow-stripe 'Tainung No. 2' papayas.

Both oriental fruit flies and melon flies at the densities of 5 and 10 pairs did not respond to any ripening levels of the 'Tainung No. 2' papayas (Table 2). However, as the fly density increased to 20 pairs, the oriental fruit fly could deposit eggs on 'Tainung No. 2' papayas at the mature yellow ripeness level, while melon flies deposited eggs not only on the mature yellow papayas but also on the 5 yellow-stripe ones with no significant differences in the infestation rates and total number of eggs laid between these two ripeness degrees (Table 2). For 'Sunrise' papayas, no oviposition occurred with oriental fruit flies at the density of 5 pairs, but the flies at the density of 10 pairs did lay eggs on the mature yellow fruits; and at 20 pairs, the flies could infest both the half yellow and mature yellow fruits (Table 3). On the other hand, the melon flies laid eggs on the mature yellow 'Sunrise' papayas at the densities as low as 5 pairs; and as fly density reached 20 pairs, even the quarter yellow papayas were infested (Table 3). Fruit fly infestation rate and total number of eggs laid in the 'Sunrise' papayas increased with fruit ripeness.

Fruit fly monitoring results showed that neither oriental fruit flies nor melon flies were ever found inside the screenhouse; yet, the fly population densities outside the screenhouse were always high (Fig. 2). The traps set at the outside corners of the screenhouse, site A and B, caught over ten thousand of oriental fruit flies per 10 days in May with an average of more than eight thousands over the three corner sites. The highest population density of the melon fly monitored during the whole investigation periods was around 200 (Fig. 2). The aerial photograph showed that vegetations surrounding the study screen-house were mixed wood land, grass land, fallow grounds, and a big guava orchard which was not under well managements (Fig. 3).

Discussion

This study showed that probability of both the oriental fruit fly and the melon fly depositing eggs on the 'Tainung No. 2' and 'Sunrise' papayas increased with fruit ripeness where the fruit had decreased flesh hardness and increased

Table 2. Infestation of 'Tainung No. 2' papayas of varying ripeness degrees by fruit flies at different densities

	Fly density					
	5-pair		10-pair		20-pair	
Fruit ripeness level	% infested fruit	No. eggs[z] per fruit	% infested fruit	No. eggs per fruit	% infested fruit	No. eggs per fruit
Bactrocera dorsalis						
Mature green	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
1-2 yellow-stripe	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
2-3 yellow-stripe	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
5 yellow-stripe	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
Mature yellow	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	13.3	21.5 ± 74.5 a
Bactrocera cucurbitae						
Mature green	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
1-2 yellow-stripe	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
2-3 yellow-stripe	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
5 yellow-stripe	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	33.3	8.9 ± 14.0 ab
Mature yellow	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	33.3	37.8 ± 70.5 b

[z] Mean ± SE (n = 10–15). Means within the same column followed by the same letter are not significantly different at $P<0.05$ (Fisher's LSD test; STATGRAPHICS Centurion XV, 2005).

Table 3. Infestation of 'Sunrise' papayas of varying ripeness degrees by fruit flies at different densities

	Fly density					
	5-pair		10-pair		20-pair	
Fruit ripeness level	% infested fruit	No. eggs[z] per fruit	% infested fruit	No. eggs per fruit	% infested fruit	No. eggs per fruit
Bactrocera dorsalis						
Mature green	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
Quarter yellow	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
Half yellow	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	6.7	10.9 ± 42.1 a
Mature yellow	0.0	0.0 ± 0.0 a	10.0	2.2 ± 7.0 a	60.0	44.4 ± 55.8 b
Bactrocera cucurbitae						
Mature green	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a
Quarter yellow	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	6.7	5.4 ± 20.9 a
Half yellow	0.0	0.0 ± 0.0 a	0.0	0.0 ± 0.0 a	33.3	16.3 ± 36.2 a
Mature yellow	20.0	20.1 ± 46.9 b	40.0	83.4 ± 131.6 b	40.0	112.9 ± 242.0 b

[z] Mean ± SE (n = 10–15). Means within the same column followed by the same letter are not significantly different at $P < 0.05$ (Fisher's LSD test; STATGRAPHICS Centurion XV, 2005).

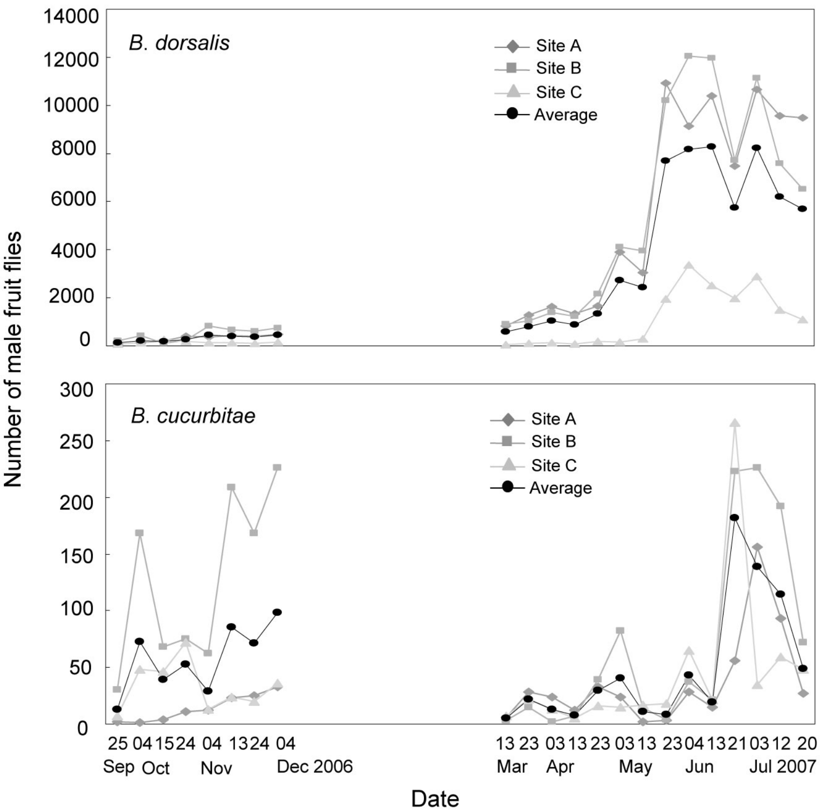

Fig. 2. Numbers of male *Bactrocera dorsalis* and *B. cucurbitae* caught at three outside corners of an export- papaya supplier orchard located at Likang, Pingtung.

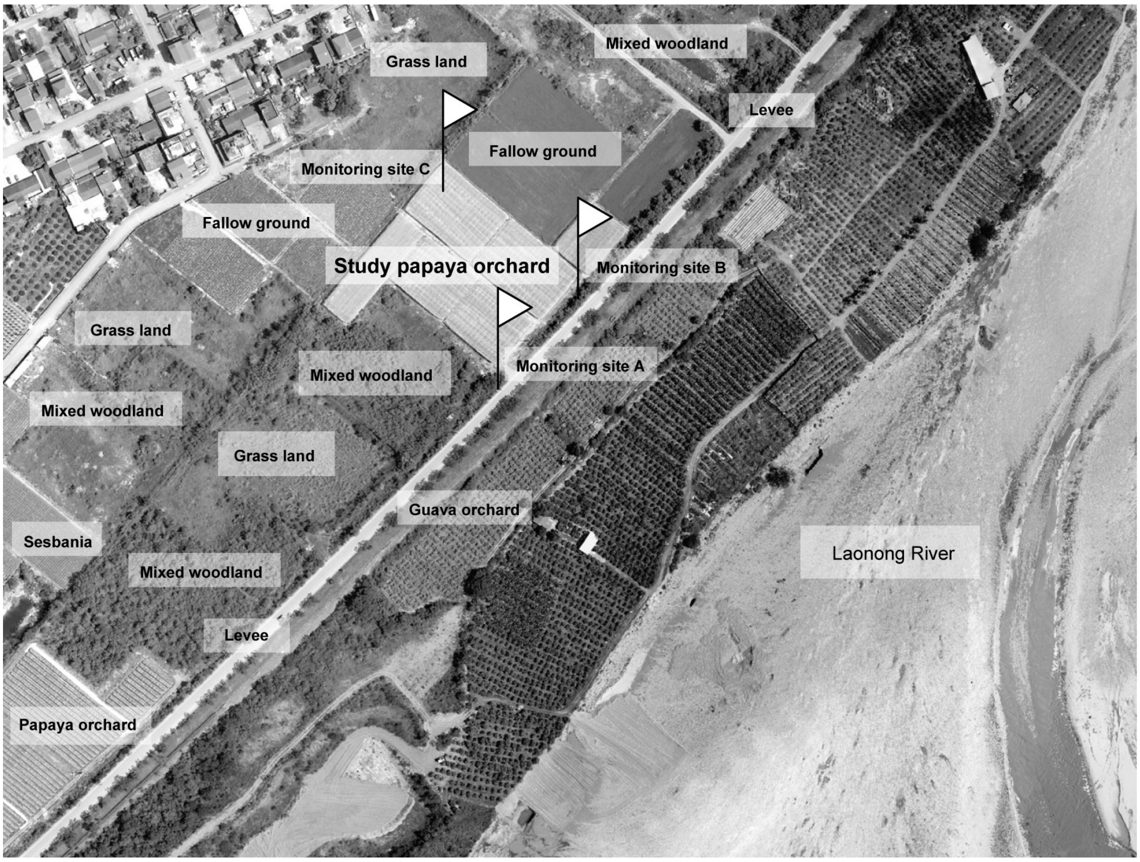

Fig. 3. An aerial view of the experimental papaya orchard located at Likang, Pingtung and its surroundings.

yellow color and soluble solid contents. It has been indicated that the yellow color, softening fruit flesh, and certain emitted odors accompanying with ripening fruit may make the fruit more attractive to fruit flies for oviposition (Liu 1981; Fletcher 1987). Conversely, the turgor pressure of the milky, acrid latex in mature green fruits prevents lodging of eggs (Mason 1932), and the benzyl isothiocyanate present in the latex of green papaya is toxic to eggs and early instars, and probably deters oviposition (Seo & Tang 1982; Seo *et al*. 1983).

Although Taiwan belongs to a fruit fly infestation area, our papayas are granted for export to Hong Kong, Singapore, Malaysia, China, Canada, and Japan, with quarantine treatments required only by Japan. The 'Tainung No. 2' papayas for export to Japan are usually harvested at the 2-3 yellow-strip ripeness. This study demonstrated that 'Tainung No. 2' papayas at this ripeness level would not get any risk of egg infestations by the oriental fruit fly and the melon fly, even at an extremely high fly density such as a papaya fruit surrounded by 20 female flies in the field. Seo *et al*. (1982) reported that mature green, color-break and quarter-ripe field-collected papayas are free of oriental fruit fly infestation year round, while only half- to fully ripe fruits are infested. Couey *et al*. (1984) reported that mature green and color-break fruits are never infested, but quarter-ripe fruits are rarely infested. Seo *et al*. (1982) did not report any infestation of papaya by melon fly, whereas Couey *et al*. (1984) found melon fly infestation in only half- to fully ripe fruits. Liquido & Cunningham (1990) concluded their study that natural infestations of oriental fruit fly and melon fly in papaya rarely occurred in fruits acceptable by the double dip quarantine procedure (probability of infestation <0.049). Our data are mostly consistent with these previous reports. The slightly differences might be due to the different papaya cultivars investigated (their 'Kapoho Solo' vs. our 'Tainung No. 2'), and the different apparent classifications of papaya fruit ripeness. Liquido

& Cunningham (1990) reported a $Bb \leq 23.4$ (a *b* value reading from the blossom end) for the mature green and color-break 'Kapoho Solo' papayas, while we measured a *b* value of 18.30 from the blossom end for our export 2–3 yellow-stripe 'Tainung No. 2' papayas. The variation in the fruit skin color and the underlying physical/chemical qualities may cause differences in ovipositional responses and behavior of the fruit flies.

The Taiwanese export 'Sunrise' papayas are harvested at quarter yellow if via ocean shipping, and harvested at half yellow if by air cargo. Our study demonstrated that 'Sunrise' papayas at these ripeness levels did have the risk of fruit fly egg infestation, where the papayas over half yellow ripe could be infested by oriental fruit flies, and papayas over quarter yellow ripe by melon flies. In Hawaii, their papayas ('Kapoho Solo') were reported readily infested by oriental fruit flies in the field, but only occasionally infested by melon flies, except under unsanitary field cultural conditions where the papaya could become a common host of melon flies (Seo *et al*. 1982; Coury *et al*. 1984; Liquido 1991). Our study showed a different result that the melon fly infested papayas at a higher frequency than the oriental fruit fly. This may be due to the different papaya varieties being studied. However, our study revealed similarly that probability of a papaya fruit subject to fruit fly infestation would depend on not only the ripeness of the fruit, but also the field densities of the fruit flies. As the field densities become high, the ripeness degree that would suffer fly damage could become lower. This study suggested that export 'Sunrise' papayas harvested at quarter ripe could avoid infestation of oriental fruit flies, but would not be secured from melon fly infestations. It also showed that 'Sunrise' papayas are more susceptible to fruit fly infestation than 'Tainung No. 2' papayas.

Papayas in Taiwan have all been cultivated in screen-houses to be protected from aphids which can transmit papaya ringspot potyvirus. A common simple screen-house might have holes or crevices to allow fruit fly invasion. Nevertheless, our study demonstrated that a well-established screenhouse with a multiple-layer-door design could effectively prevent fruit fly invasion, even at locations where fruit flies occur at high densities. This, in combination with our findings mentioned above that 'Tainung No. 2' papayas if harvested at 2–3 yellow strips can be free of fruit fly infestation even with high fly densities, suggested that 'Tainung No. 2' papayas cultivated in well-established screenhouses, harvested at proper ripeness level, and packed in the well sanitized packing house should be possible to negotiate for waiving of the current vapor-heat quarantine treatment. Consequently, it would help reduce costs and preserve a better fruit quality. Although the export 'Sunrise' papaya fruits can be infested by fruit flies, it requires high fly densities. Since none of the fruit flies were found within our screenhouse in this study, further extensive investigations on fruit fly infestation rates of papayas grown in screenhouses need to be conducted to determine if 'Sunrise' papayas could be exempted from the current quarantine treatments.

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木瓜成熟度影響瓜果實蠅 (Diptera: Tephritidae) 之感染[1]

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摘　要

董耀仁、宋家瑋、莊益源、蔣國司、吳文哲、鄭玲蘭、陳健忠。2011。木瓜成熟度影響瓜果實蠅 (Diptera: Tephritidae) 之感染。台灣農業研究 60:253–262。

本研究依木瓜果皮顏色轉黃的程度進行果實成熟度分級，並檢測台農二號木瓜全綠、1–2 黃溝、2–3 黃溝、5 黃溝、8–9 分熟等五種成熟度以及日陞木瓜全綠、1/4 熟、1/2 熟、8–9 分熟等四種成熟度之果實成熟性狀，同時探討木瓜果實成熟度與受東方果實蠅 (*Bactrocera dorsalis* (Hendel)) 及瓜實蠅 (*B. cucurbitae* (Coquillett))產卵感染的關係。台農二號木瓜之測試結果顯示，東方果實蠅只在 8–9 分熟果實上產卵，瓜實蠅則可在 5 黃溝與 8–9 分熟木瓜上產卵，而外銷採收之 2–3 黃溝台農二號木瓜則完全不會受東方果實蠅及瓜實蠅產卵為害。對日陞木瓜之測試，東方果實蠅可在 1/2 熟和 8–9 分熟之木瓜上產卵，瓜實蠅則可在除了全綠以外之所有成熟度木瓜上產卵。木瓜是否會遭受瓜、果實蠅產卵為害，除了取決於果實本身之成熟度外，也與瓜、果實蠅之密度有關。瓜、果實蠅在高密度下，會危害較低成熟度的木瓜。此外調查結果也顯示設置良好的網室搭配多層門設計可有效阻隔瓜、果實蠅入侵。綜合試驗結果顯示，台農二號木瓜以網室栽培，果實於適當成熟度採收，具有取代現行蒸熱檢疫處理之潛力。至於日陞木瓜，則有賴進一步廣泛調查網室內不同成熟度果實之瓜果實蠅感染率，方得評估日陞木瓜免除現行蒸熱檢疫處理之可能性。

關鍵詞：東方果實蠅、瓜實蠅、木瓜、果實蠅感染、檢疫。

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