Current status of sweetpotato weevil control and fruit fly researches in Taiwan

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Abstract

The sweetpotato weevil is an important pest of sweetpotato in Taiwan. In general, the damage caused by the weevil is now under satisfactory control with an integrated pest management strategy based on the use of sex pheromone traps and the granule insecticides. The oriental fruit fly is another pest which seriously infests major fruit crops in all parts of Taiwan. Although the area-wide control program for oriental fruit fly mainly relying on the use of methyl eugenol has been conducted for many years, its population remains at a high level in the field. Studies including the ecology of the fruit fly in a small-scale and fairly diversified farming system, the development of female-targeted lures, the potential of using mulch for fruit fly control in abandoned orchards, etc., were focus ed in recent years. Some encouraging results obtained from these researches are presented in this report.

Keywords: sweetpotato weevil, oriental fruit fly, melon fly, pest management, Taiwan

Introduction

The sweetpotato weevil (*Cylas formicarius*) and the oriental fruit fly (*Bactrocera dorsalis*) are two key pests of sweetpotato and many fruit crops respectively in Taiwan. The adults of sweetpotato weevil cause damage on the sweetpotato plant and the tuber, while the larvae feed and tunnel in the tuber. An integrated pest management system has been developed for sweetpotato weevil since 1991. Although it remains an important pest for the sweetpotato so far, it is under well control with the combining use of pheromone-baited trap and the insecticides in most of the sweetpotao growing area. Area-wide control of sweetpotato weevil is encouraged in major sweetpotato production area to assure the control efficacy. Due to the drastic declines of the cultivation acreages during the past 30 years, no more research work on the sweetpotato weevil control has been conducted since 1991 in Taiwan.

The oriental fruit fly lay eggs in the pericarp and larvae feed inside the fruits. It not only causes damage by reducing both fruit production and quality, but also impedes exportation of fresh fruit due to the quarantine restrictions. Poisoned protein hydrolyzates baits and male annihilation with methyl eugenol are the practices adopted by the government for area-wide control of this pest in Taiwan. However, fruit bagging, net-house cultivation, and regular insecticide sprays have been the major strategies used by the growers for protection of their crops against the fruit flies. These control methods are effective, yet the fruit bagging is labor intensive and raise the cost of production while heavy use of insecticides have serious impacts on the environment and increase the risk of toxic residues on the fruits.

The already-existing high population of the oriental fruit fly, the extremely broad host ranges including many non-economically important plants, the increase of abandoned orchards, and the effects of global warming make their control very difficult. Area-wide control program is indispensable for fruit flies with strong flying capacity and frequently moving habits. However, getting many growers in an area involved in the project has been challenging, especially when lands owned by individual farmers are small and the crops are diversified. Further studies in the ecology and behavior of fru it flies, the lures for monitoring and control, habitat reconstructions, and the integration of useful methods for the management are needed.

Sweetpotato weevil management

The cultivation area of sweetpotato used to be ranked the second only to paddy rice in Taiwan. It once reached 230,000 ha in 60's, and now drastically drop to about 9,000 ha (Fig. 1). The sweetpotato was grown and used as the staple food and the animal feeds, but now it becomes a popular vegetable, both the tuber and leaves, due to the richness of fiber and vitamin A. Regardless of the role it plays to serve as the nutrient sources, sweetpotato weevil remains the most destructive pest of sweetpotato, both in the field and in storage. It occurs seven or eight generations a year in Taiwan. Yen (1982) reported that the rate of tuber damage caused by sweetpotato weevil is typically at least 18%, sometimes reaches 88% in severely infested fields.

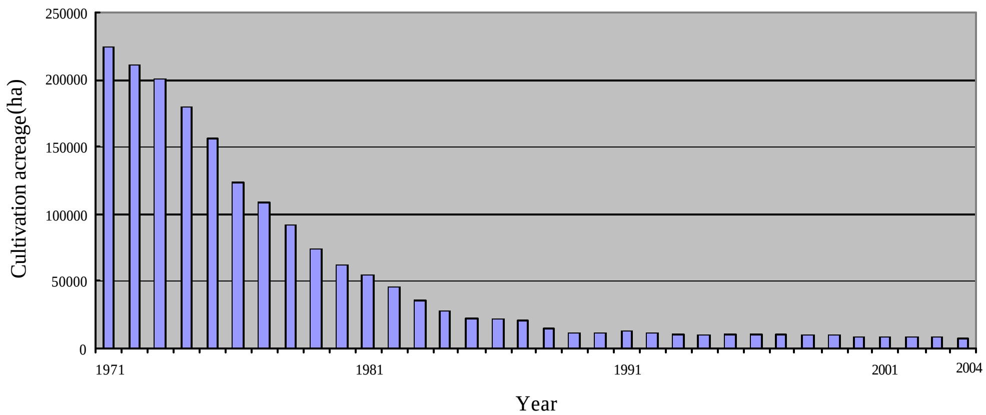


Fig. 1. The cultivation acreages of sweetpotato in Taiwan.

Infested tubers usually lose the market value due to its bad terpene smell and bitter taste. The underground feeding habits of the larvae and the nocturnal activity of the adults make it necessary for farmers to apply insecticides three to five times during each 5- to 6-month growing season. The use of pheromone-baited traps, together with soil insecticides, in the integrated control of sweetpotato weevil has given promising results.

Synthetic sex pheromone and trap design

In order to develop cheaper and more effective sex pheromone lures, the attractiveness and persistence of synthetic sex pheromones dispensed onto rubber septa and polyethylene (PE) microtubes with different doses were compared. Results showed that 1 mg of synthetic sex pheromone dispensed in PE microtubes had a stronger attractiveness than other types of lure. The attractiveness of the formulation was more than ten times higher than the equivalent of 20 virgin females, and the lure remained effective for more than two months. The cost of each PE microtube lure was as low as US$ 0.1 only, significantly cheaper than the rubber septum which costs about US$ 0.5 a lure.

A double funnel trap made of recycled soft-drink polyethylene terephthalate (PET) bottle was developed. When baited with 1 mg of s ynthetic sex pheromone in the microtube, it could effectively trap several thousand male weevils in a single day. The cost of the hand-made double funnel PET bottle trap is only about US$ 0.1. Recently, a commercial product of double funnel plastic trap which costs US$ 1.5, is widely used by the sweetpotato growers in Taiwan. The clear (transparent) PET bottle traps were more effective in capturing weevils than green-colored PET bottle traps, however, there was no significant difference between traps with 8.8 cm or 12 cm funnel diameter. Traps with a pheromone lure 4 cm above the funnel caught significantly more male weevils than those traps with pheromone lures 0 cm or 8 cm above the funnels. No significant difference was found in trap catches when the traps were placed with the top of the funnel 4, 8, or 16 cm above the plant canopy. Proshold *et al*. (1986) reported that traps placed with the height of the top of the funnel higher than 30 cm above the canopy had very poor capture rates.

Effective distance of the pheromone trap

The percentages of mark and recaptured males in pheromone-baited traps that located at 5, 10, 20, and 40 meters away from the release point were 69.1, 10.7, 1.5 and 0.4%, respectively. According to this result, the maximum active distance of sweetpotato weevil pheromone traps was estimated to be around 10-15 meters. Total recapture rates increased with an increase in temperature. The rates reached 97.1% when the ambient temperature were 29?.

Effectiveness of insecticides

Five commonly used granule insecticides, chlorpyrifos, fensulfothion, phorate, carbofuran and terbufos, were tested in sweetpotato fields. Each of them was applied twice to the soil, once before planting and again at the time of earthing-up. The results showed that application of chlorpyrifos, fensultothion, and phorate significantly reduced the tuber-damage rate, and the treatment of chlorpyrifos had the highest control rate (76.8%) (Hwang and Hung, 1994). The timing and dose of insecticide applications were also found affecting the control efficacy. When chlorpyrifos 5% granules were applied at a rate of 4.5 kg a.i./ha (double the recommended dose) with a single treatment at the time before planting, the control rate was higher than those applied only once with half dosage or twice with half dosage at two different times (Table 1). This insecticide application method not only promotes insecticide efficacy, but also saves the labor cost of a second insecticide application.

Table 1. Efficacy of different doses and application methods of Chlorpyrifos 5% granules in control of *C. formicarius* on sweetpotato

Treatment	% tuber damage[1]	% control
A. 4.5 kg a.i./ha applied before planting	8.5 a	81.3
B. 2.3 kg a.i./ha applied before planting	31.4 ab	30.8
C. 2.3 kg a.i./ha applied on earthing-up	33.2 ab	26.9
D. B + C	22.8 ab	49.8
E. Untreated control	45.4 b	0

(1) Mean derived from 5 replicates. Data were transformed to arc sine√x prior to analysis, and means followed by the same letters were not significantly different at a 5% level by DMRT.

Integrated control of sweetpotato weevil with sex pheromone and insecticide

A field experiment was conducted in 1989 to evaluate the integrated effects of sex pheromone and insecticides in the control of sweetpotato weevil (Hwang and Hung, 1991). Each plot received one of the following five different treatments: (A) pheromone-baited traps only, (B) pheromone-baited traps and pre-planting application of chlorpyrifos (Dursban) granules in the furrows, (C) applications of chlorpyrifos before planting and at the time of earthing-up, (D) three applications of terbufos granules, and (E) untreated control. In order to investigate the weevil densities in plots which had received different treatments, pheromone-baited traps were set out two weeks before harvest at a rate of 4 traps/plot. The trapped male weevils were counted five days later. Percentage of damaged plant and tuber, average number of tuber, and tuber yield were also investigated. The results showed that the percentage of plants with vine damage ranged from 19.6% in plots treated with two applications of chlorpyrifos to 32.1% in untreated plots (Table 2),however, no significant difference among all treatments. Percentages of tuber damage measured by number or weight were significantly reduced for all plots treated with pheromone traps and/or insecticides. Weevil infestation did not appear to have much impact on the potential yield of sweetpotato, but it did reduce the sweetpotato quality for human and livestock consumption. However, the weight of tubers was significantly reduced (27%) in the untreated plots, compared to the plots that received the conventional, relatively intensive application of terbufos. Another seven field tests were conducted at different parts of Taiwan, and similar results were obtained.

The correlation between the number of weevils trapped in pheromone traps and sweetpotato weevil damage to various parts of the plant was quite weak. Therefore, the pheromone trap may be used as a tool for monitoring the occurrence of the weevil, but the trap catch alone is not a good indicator of the weevil infestation. The efficacy of using sex pheromone for the mass-trapping of male adults to suppress insect pests on crops is a controversial question.

The results presented here indicate that the use of pheromone-baited traps alone in the field is effective for sweetpotato weevil control. Combing use of pheromone trap and chlorpyrifos granules is recommended to achieve an effective and safe control of sweetpotato weevil. When pheromone traps are used in the integrated management of the weevil, it is estimated that 1 to 3 applications of insecticide are saved, comparing to the conventional control measure used by the farmers.

Table 2 . The effect of integrated application of sex pheromone and insecticide on the control of *C. formicarius* in Taichung, Taiwan

Treatment	% plant damaged	% tuber damaged		No. tuber /10 plants	Tuber wt. / 10 plants	No. weevil/trap
		by no.	by weight			
A	25.4 a	5.4 a	5.7 a	28.6 a	7.1 a	22.5 a
B	25.0 a	4.8 a	4.6 a	37.2 a	9.0 ab	13.8 a
C	19.6 a	2.5 a	3.0 a	38.9 a	8.3 ab	26.8 a
D	25.0 a	4.4 a	5.3 a	40.8 a	9.5 b	17.2 a
E	32.1 a	14.2 b	20.0 b	29.4 a	6.9 a	95.5 b

(1) A: pheromone-baited traps only, B: pheromone-baited traps and pre-planting application of chlorpyrifos (Dursban) granules in the furrows, C: applications of chlorpyrifos before planting and at the time of earthing-up, D: three applications of terbufos granules, and E: untreated control.

Fruit fly researches:

Movement of the oriental fruit fly in and out of the orchard (Chen *et al*., 2006)

This study investigated the annual population dynamics and the diel population changes of the oriental fruit fly in orchards. It provides information on the movement of this pest and may help the improvement of the control efficiency for individual orchards and action programs in area-wide control.

The population changes of the oriental fruit fly were conducted in the guava, plum, peach, and loquat orchards. The fruit flies on the whole trees were examined systematically by sight, and the numbers of male and female flies found on each tree in the orchard were recorded. During the evening censuses, a flash light was used.

The results from the whole year censuses showed that the female was significantly the major sex in the guava orchard throughout the year with the mean ratio of 3.69 : 1, and the ratio was even higher in the afternoon (Fig. 2.).

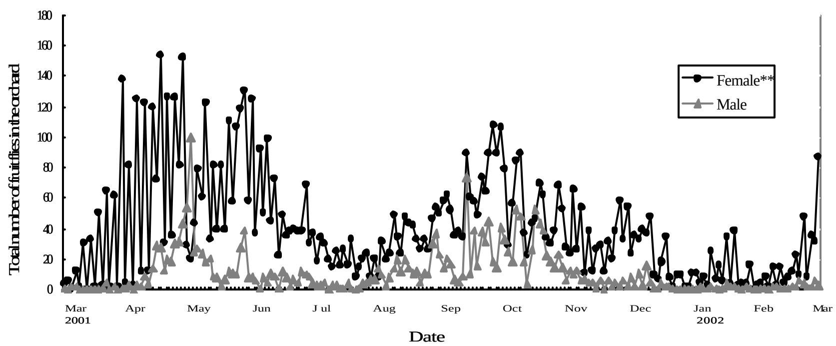


Fig. 2. Population dynamics of different sexes of *Bactrocera dorsalis* surveyed in a guava orchard at Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week. Data represent total number of fruit flies sighted at each census date. Double asterisks indicate a significant difference between number of flies of different sexes at *P* ? 0.01 (Student *t* test; SPSS 10.0 for windows 1999) (Chen, *et al*., 2006).

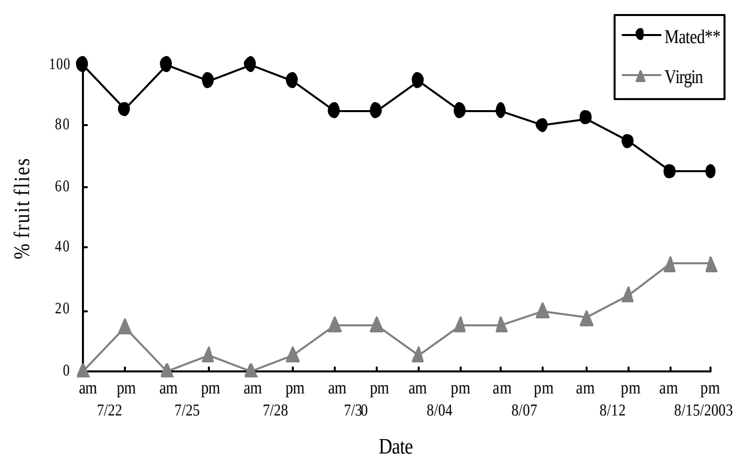
The female populations in the plum and peach orchards were significantly higher than the male ones. However, there was no significant different in fly population between female and male in the loquat orchard.

Most females in the guava orchard were mated (Fig. 3).

The populations of both sexes in the guava orchard were significantly higher in the afternoon than in the morning. The diel pattern of the oriental fruit fly was further confirmed with two consecutive 3-day investigations conducted three times a day at 9:00 am, 3:00 pm and 8:00 pm. No flies were found in the orchard at the evening censuses, however, the flies were sighted again at the morning censuses and the fly population reached the peak in the afternoon. These results implied that the oriental fruit fly exhibited diurnal movements into and out of guava orchard.

The female populations in the plum and peach orchards were significantly higher than the males ones although there was not an obvious diurnal pattern between the fly populations of the morning and of the afternoon. However, there was no significantly difference in fly populations between female and male in the loquat orchard.

The marked and released sexually mature or sexually immature flies of both sexes were found rapidly moving out of the guava orchard within one day. Less than 5% of the marked flies appeared in the guava orchard in the following 5 days, and were not found in the guava orchard during 11- and



25-day-period censuses (Fig. 4).

Fig. 3. Occurrence of different mating status of female *Bactrocera dorsalis* was surveyed in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week. Double asterisks indicate a significant differences

between number of flies of different mating status at *P* ? 0.01 (Student *t* test; SPSS 10.0 for windows 1999).(Chen, *et al*., 2006)

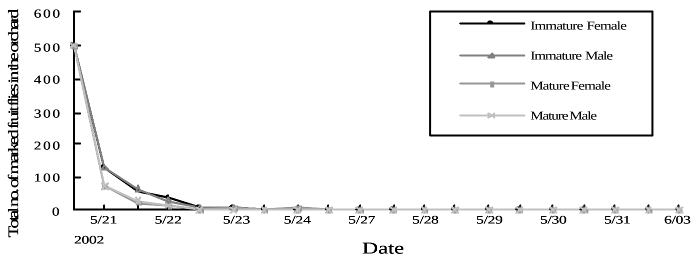


Fig. 4. Occurrence of marked and released *Bactrocera dorsalis* in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Five hundred pairs of mature (18- to 20-day-old, mated) and 500 pairs of immature (3- to 5-day-old, unmated) flies were released at 9:00 am on May 21, 2002. Searches of the marked flies were started at 3:00 pm on May 21, and continued to June 3, 2002 twice a day at 9:00 am and 3:00 pm. Data represent total number of marked flies sighted at each census date. (Chen, *et al*.,2006)

Effects of the removal of the noncommercial crop

It is very common that several kinds of fruit orchards locate within a fruit production area in Taiwan. Sometimes more than two fruit crops are grown in an orchard, and this is especially true when the orchard is managed in a type of so-called “leisure farm”. Host plants provided the fruit flies with the fruits to grow and reproduce, therefore, removal of both the wild hosts and unwanted commercial crops can reduce the amount of available fruits for fruit fly oviposition thus bringing down the fly population in an area.

Lin *et al*. (2006) reported that the number of oriental fruit fly captured in a guava-pear-mixed orchard was decreased after the removal of the guava trees. This practice also reduced the fruit fly number captured in an adjacent pomelo orchard. There was no significant difference in the number of captured flies between these two orchards after destruction of the guava trees. The results revealed that sanitation of the orchard is important in an area-wide control project.

Development of female lures

Although the male attractant and food bait such as methyl eugenol and protein hydrolysates are currently used in the area-wide control of the oriental fruit fly (Cheng, *et al*., 2003), there is a strong interest in the development of female lures for use either in the area-wide control or in individual orchards. The ethyl ether extract of *Garcinia dulcis* leaves had shown to be attractive to the female flies which revealed that the chemical compounds existing in the leaves may have great potential to be developed as an attractant for the oriental fruit fly (Chen and Dong, 2000).

Further extraction and identification of the compounds in *Garcinia dulcis* leaf were conducted (Chen, 2006; Chen and Dong, unpublished). Preliminary GC-MS analyses revealed the presence of 33 compounds in the water layer of an extract that extracted with n-hexane and water (7:3). Eleven compounds were identified, which are 5-amino-1-naphthol, p-benzoquinone, docosane, n-heneicosane, n-heptadecane, n-hexadecane, myristic acid, palmitic acid, n-pentadecane, naphthalene, and tributyl phosphate. Laboratory olfactometer tests of these compounds showed that only n-hexadecane and n-pentadecane were attractive to both sexes, and the former significantly trapped more female flies (Table 3).

The volatile components of fresh *Garcinia dulcis* leaf were also collected with a charcoal ventilating installation and 7 sesquiterpene compounds including cubebene, copaene, caryophyllene, germacrene D, a-caryophyllene, elemene, cadine-3,9-diene were identified. GC-EAD technique was applied to separate as well as to determine the effective volatile components to the female adults. With the 3 commercial available compounds, cubebene, copaene, and caryophyllene, tested, the female flies showed an obvious EAG response to caryophyllene, but not to cubebene and copaene.

Table 3. Attraction of the oriental fruit fly to two compounds extracted from *Garcinia dulcis* leaves

Treatment	Mean no. flies trapped		
	Male	Female	Total
n-Hexadecane	14.0 a	15.2 a	29.2 a
n-Pentadecane	5.8 a	6.8 b	12.6 b

Control	0.0 b	0.0 c	0.0 c

Means within a column followed by the same letter are not significantly different ($p > 0.05$; Duncan's multiple range test).

Hwang *et al*. (2002) extracted and identified 24 compounds with solid-phase microextraction method and GC-MS from guava fruits. According to the results of the bioassay in net house, ethyl acetate and ß-caryophyllene attracted more female and male adult oriental fruit flies than other components. Further study by Hwang revealed that the number of fruit flies attracted by the three multiple-compound formulations (JGS1, JGS3, and JGS7) was significantly higher than that by the formulation of Yen-C or ethyl acetate alone (Table 4). These three potentially effective attractants are being modified to improve their attractancies for the oriental fruit fly.

Table 4. Attraction of formulations derived from guava fruit components to oriental fruit fly tested by rotated wheel method in net house

Formulations	% of total flies attracted [1]			
	??		??	
JGS1	14.3	± 6.6 a[1]	13.5	± 8.1 a
JGS3	17.2	± 8.7 a	9.8	± 4.7 ab
JGS7	13.4	± 5.8 a	8.9	± 4.0 ab
Yen-C	3.5	± 2.4 b	3.5	± 3.8 c
Ethyl acetate	5.3	± 5.7 b	6.6	± 8.0 bc
Blank	0.1	± 0.2 c	0	

[1] Mean± S.D. derived from 10 trials. Data were transformed to arc sinvx prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

A poison bait based on yeast power, sugar, malathion, and other ingredients in tablet form was developed for the melon fly (*Bactrocera cucurbitae*) control (Chen *et al*., unpublished). The mortality of melon flies was determined for the bait with a cage olfactometer (1 x 1 x 1.4 m) in the laboratory. The results showed that a 100% mortality was reached within 24 hours for melon flies with food-provided or food-starved. However, the time to obtain 100% mortality varied with the starving status of the melon flies. The bait killed almost 100% of 1-day-starved melon flies in 24 hours after it was aged in the field for 4 weeks. Bait formulations containing mold-inhibited and water-resistant ingredients or with no insecticides were also studied to extend its effectiveness to the highly humid and frequently raining environments.

Mulches with artificial materials to control the fruit flies

The polyethylene mulch can impact insect population. In fact, the main advantages of its use are not only excluding the pests but also helping maintain higher soil temperatures, reduce evaporation and fertilizer leaching, limit soil compaction, and inhibit weed growth (Lamont, 1993; Orozco and Lopez. 1995; Vincent *et al*., 2003). The uses of PE mulch film in the fruit orchard are not common except in papaya orchard in Taiwan. However, PE mulches may be used to block the way of fruit fly larvae entering into the soil for pupation. This practice is especially useful in not-well-managed orchards or the abandoned ones. Therefore, the application of insecticide-coated plastic mulch which performed as a barrier and/or killing agent in the fruit fly control is worth studying. Chen *et al*. found when dropped 3rd instar oriental fruit fly larvae onto a diazinon-coated PE sheet, the larval mortalities were 100%, and the effectiveness of the diazinon lasts for 5 months under the laboratory condition (unpublished data). The results also showed the following tendencies: (1) the total distance (mean = 198.3 cm, n = 11) a larva could jump before death increased, (2) the number of jumping (mean = 38.4, n = 11) by the larva increased, (3) the distance from the site of the final jump to that of the first jump (original site) (mean = 40.3, n = 11) increased, (4) the time to death increased, as the time after diazinon application on the PE sheet proceeded.

The temperature of PE mulch surface could reach up to 47?during the midday in the loquat orchard. Mortality of the oriental fruit fly pupae was 100% when they were placed on the PE mulch without the shade of canopy for 5 minutes at noon. The survival rates of the pupae averaged about 10% when the pupae were placed under the shade of the tree for 4 hours with the maximal temperature of 40? on the surface of PE sheet. These revealed that the high temperature of the PE mulch served as an effective lethal factor for the fruit fly and various shading of the tree canopy might affect the control efficacy of this physical method.

Future prospectives

The researches and campaign to the control of the fruit flies have been continuous for several decades, however they remain the most important pests of many major fruit and vegetable crops in Taiwan. In fact, the present ecological environment favors the fruit flies even more than before, in terms of the increases of host diversity, extended growing and harvest seasons, abandoned orchards and fields, global warming effects, etc. Area-wide control of the fruit flies is believed to be the way and solution to mitigate the problems, however, the willingness and cooperation of hundreds of farmers in the area is the key to success. To assure the progresses of the control work for fruit flies we may need more efforts and focuses on:

? reduce the threat of fruit flies to crop growing areas by suppressing their populations in the public areas;

? find a solution to stop propagation of fruit flies in the abandoned orchards;

? improve the efficacy of currently used fruit-bagging methods, insecticides, and attractants, in individual farms and/or the area-wide control program;

? develop new lures especially for female flies;

? study the behavior of fruit flies infesting among various crops and wild hosts in time and space;

? continuously collaborate with other countries that have common fruit fly problems.

References

Chen, P. C. 2006. GC-EAD technique identification of the attractive components of *Garcinia dulcis* for attracting female oriental fruit fly. Master's Thesis, National Chung Univ., Taiwan. 53 pp.

Chen, C. C. and Y. J. Dong. 2000. Attraction of the oriental fruit fly (*Bactrocera dorsalis* Hendel) (Diptera: Tephritidae) to leaf extracts of five plants. Formosan Entomol. 20: 37-44.

Chen, C. C., Y. J. Dong, C. T. Li, K. Y. Liu, and L. L. Cheng. 2006. Movement of the Oriental Fruit Fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), in a Guava Orchard with Special Reference to Its Population Changes. Formosan Entomol. 26: 143-159.

Cheng, E. Y., C. H. Kao, M. Y. Chiang, and Y. B. Hwang. 2003. Modernization of oriental fruit fly control in Taiwan: the planning and execution of an area-wide control project. pp. 49-66. *In*: C. C. Ho, C. C. Tzeng, L. M. Hsu, J. T. Yang, and S. C. Wang, eds. Proceeding of the Workshop on Plant Protection Management for Sustainable Development: Technology and New Dimension. Plant Prot. Bull. Spec. Publ. New 5. Published by the Plant Protection Society of the Republic of China.

Hwang, J. S., and C. C. Hung. 1991. Evaluation of the effect of integrated control of sweet potato weevil, *Cylas formicarius* Fabricius, with sex pheromone and insecticide. Chinese J. Entomol. 11: 140-146.

Hwang, J. S., and C. C. Hung. 1994. Sweet potato insect pest management and the application of sex pheromone. pp. 229-245. *In*: Proceedings of a Symposium on Root Crop Yield Improvement, Processing and Utilization in Taiwan. TARI Special Publication No. 45, Chiayi Agricultural Experiment Station, Chiayi, Taiwan, ROC.

Hwang, J. S., Y. P. Yen, M. C. Chang, and C. Y. Liu. 2002. Extraction and identification of volatile components of guava fruits and their attraction to Oriental fruit fly, *Bactrocera dorsalis* (Hendel). Plant Prot. Bull. 44: 279-302.

Lamont, W. J. 1993. Plastic mulches for the production of vegetable crops. HortTechnol. 3: 35-39.

Lin, R. W., C. N. Chen, W. J. Wu, and C. J. Shih. 2006. Impact of the removal of a noncommercial crop from an orchard on the population management of the oriental fruit fly (*Bactrocera dorsalis* (Hendel)). Formosan Entomol. Vol. 26. (in press).

Orozco, S. M. and Z. O. Lopez. 1995. Effect of transparent mulch on insect population, virus diseases, soil-temperature, and yield of cantaloupe in tropical region. New Zealand J. Crop Hort. Sci. 23: 199-204.

Prodhold, F. I., J. L. Gonzalez, C. Asencio, and R. R. Heath. 1986. A trap for monitoring the sweet potato weevil using pheromone or live females as bait. J. Econ. Entomol. 79: 641-647.

Vincent, C., G. Hallman, B. Panneton, and F. Fleurat-Lessard. 2003. Management of agricultural insects with physical control methods. Annu. Rev. Entomol. 48: 261-281.

Yen, F. G., H. S. Chen, and H. Y. Chen. 1982. Report on investigation of major sweet potato pest damages in Taiwan. Taiwan Agriculture Bimonthly 18: 64-67.