The Hawaii Fruit Fly Area-Wide Pest Management Program: Accomplishments and Future Directions

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Abstract. Melon fly, *Bactrocera cucurbitae* (Coquillett), Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), oriental fruit fly *Bactrocera dorsalis* (Hendel), and the so-called Malaysian (solanaceous) fruit fly, *Bactrocera latifrons* (Hendel), have accidentally become established in Hawaii, and attack more than 400 different host fruits. These fruit flies inhibit development of a diversified tropical fruit and vegetable industry, require that commercial fruits undergo quarantine treatment prior to export, and provide a breeding reservoir for their introduction into other parts of the world. Present fruit fly control measures in Hawaii rely heavily on the application of organophosphate insecticides to crops. In 1999 a 5 yr Area-Wide Pest Management (AWPM) program was initiated for management of fruit flies in Hawaii. The AWPM program integrated two or more control components (field sanitation, protein bait sprays, male annihilation, sterile insects, and parasitoids) into a comprehensive package that has been economically viable, environmentally acceptable, and sustainable. The program has resulted in areawide suppression of fruit flies, a reduction in the use of organophosphate insecticides, and the impetus for further growth and development of diversified agriculture in Hawaii.

Introduction

Four economically important fruit flies (Diptera: Tephritidae) have been inadvertently introduced into Hawaii, and are now established on all of the major Hawaiian islands: melon fly, *Bactrocera cucurbitae* (Coquillett), (introduced in 1895), Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), (in 1910), oriental fruit fly *Bactrocera dorsalis* (Hendel), (in 1945), and the so-called Malaysian (solanaceous) fruit fly, *Bactrocera latifrons* (Hendel), (in 1983). This foursome infests over 400 different host fruits and represents one of the greatest bottlenecks to expansion or development of diversified agriculture in Hawaii. Tephritid flies have had a serious detrimental economic impact on tropical and sub-tropical agriculture in many parts of the world and pose a continuing and increasing threat of establishment in new areas (Vargas et al. 2000). The Hawaiian foursome has inhibited development of a profitable diversified fruit and vegetable industry for local consumption and export causing direct damage to crops and requiring expensive post-harvest quarantine treatments.

Objectives of the Hawaii Area-Wide Pest Management Program for fruit flies. In 1994, USDA commenced an IPM initiative to achieve a national goal of implementation of IPM on 75% of the crop acres by the year 2000. To promote this goal, Agricultural Research Service (ARS) initiated Area-Wide Pest Management (AWPM) programs (Faust and Chandler 1998; Chandler and Faust 1998), which included research, education, and assessment components. The goal was to conduct research and transfer results and novel technology to the farmers. Generally, AWPM programs are funded up to 5 yr, and then are carried on by cooperators, growers and land users. In 1999 an AWPM fruit fly program

was funded for Hawaii (Vargas et al. 2003a). It was not aimed at total eradication of fruit flies but predicated on an IPM strategy that would reduce overall populations in and around cropping areas where economic damage occurred. This was part of a comprehensive plan where potential pest problems (including fruit flies) were identified, and factored into an economic cost-benefit analysis (McGregor 2005). The inclusion of IPM strategies into a well-defined agricultural production and marketing plan resulted in a better understanding of the potential for Hawaii agriculture in local, national, and international markets. Furthermore, in the absence of eradication programs in Hawaii, systems approaches utilizing IPM methodologies were thought to be the best approach for reducing pesticide usage, achieving quarantine security, while at the same time producing higher quality, safe fruits and vegetables for niche export markets.

Thus, the initial objective of the Hawaii AWPM program was to develop and integrate biologically based pest management approaches that would result in area-wide suppression and control of fruit flies throughout three selected agricultural areas of Hawaii. The AWPM program attempted to integrate two or more technologies into a comprehensive package that was economically viable, environmentally acceptable and sustainable. Components (Fig. 1) of the AWPM program include (1) field sanitation (Klungness et al. 2005), (2) protein bait sprays (Peck and McQuate 2000; Vargas et al. 2001,2002; Prokopy et al. 2004), (3) male annihilation lures and attractants (Vargas et al., 2000, 2003b), (4) augmentative parasitoid releases (Knipling 1995; Wong et al. 1991, 1992; Vargas et al. 2004) and (5) sterile insect releases (Vargas et al. 1994, 1995; Koyama 1996; Vargas et al. 2004). Program implementation required formation of ARS, APHIS, state of Hawaii, university and community partnerships.

Results

By 2005, the major accomplishments of the Hawaii AWPM Program included multiagency collaboration, transfer of area-wide IPM approaches to farmers for suppression of melon fly and Mediterranean fruit fly at three demonstration sites, replacement of cover sprays with spot spinosad bait (GF-120) applications, and a state-label to use the male annihilation technique with methyl eugenol and cue-lure for fruit fly control. In cooperation with the University of Hawaii, Hawaii Department of Agriculture, growers and other organizations, ARS developed site specific implementation plans and initiated trapping, sanitation and control measures within demonstration sites. Three geographical areas on Hawaii, Kula, and Oahu Islands (Table 1 from Vargas et al. 2003a) were selected for program implementation based on population monitoring, and economic assessments throughout the state that identified areas most likely to benefit from application of the AWPM approach. In cooperation with the University of Hawaii, the Hawaii Department of Agriculture, growers and industry, ARS secured special local needs registrations for agricultural chemicals, implemented a fruit fly IPM extension educational program, developed site specific implementation plans and initiated trapping, sanitation and control measures.

Waimea (Hawaii). Suppression activities aimed at control of melon fly (Prokopy et al. 2003, Vargas et al. 2004) were initiated in selected cropping areas within a 40 km^2 area. Technologies included sanitation, spinosad GF-120 fruit fly bait, male annihilation with cue-lure, *Psyttalia fletcheri* (Silvestri) parasitoid releases and sterile melon fly releases. Melon fly populations were significantly reduced within crop production areas.

Kula (Maui). Suppression activities were initiated in selected crop areas within a 45 km^2 area for both melon fly and Mediterranean fruit fly. For melon fly, the suppression activities included sanitation, GF-120 bait, sprays, and male annihilation. Fruit fly damage was reduced from >40% to <5%. The Mediterranean fruit fly suppression program utilized

Figure 1. Six components of the Hawaii AWPM program.

GF-120 fruit fly bait and a three-component food attractant called Biolure® to suppress populations in commercially grown persimmons. An important part of the program was the reduction of populations in alternative host crops such as loquat, peach, guava, coffee and citrus. Surveys and testimonials from persimmon growers indicated that populations had been controlled more effectively as a result of the AWPM activities than in any previous year.

Kunia/Ewa (Oahu). Suppression activities were implemented on a few large farms, rather than on the many small farms found in the Waimea and Kula areas. Supression tactics included sanitation, GF-120 fruit fly bait and male annihilation against melon fly. Infestation of melons was reduced to <5% on farms compared to >30% before the program

Discussion

During the first 5 yr of the AWPM program impacts have included reduced fruit fly infestations, increased crop yields, reduced pesticide use, increased knowledge by growers on fruit fly control, a "can-do" attitude by farmers, expansion of diversified agriculture, and some economic growth. To date the greatest successes have been achieved with melon fly and Mediterranean fruit fly. The program has been extended 2 additional years to address control of oriental fruit fly. Future plans include expansion of area-wide implementation activities in satellite areas near demonstration sites, suppression of oriental fruit fly, and continued research to address problems that inhibit implementation of the IPM program. Technology transfer will include development of area-wide methods for suppression of oriental fruit fly with GF-120 fruit fly bait, male annihilation with methyl eugenol, *Fopius*

arisanus (Sonan) parasitoid releases, and releases of male-only lines of sterile oriental fruit flies (Steiner et al. 1965; Steiner et al. 1970; Cunningham et al. 1975; Koyama et al. 1984. Important economic, environmental and non-target data will continue to be collected on suppression technologies for all fruit fly species. Specific plans include expansion of melon fly AWPM programs on Kauai and Molokai Islands, expansion of oriental fruit fly AWPM programs on all islands, development of an oriental fruit fly AWPM demonstration site in the Puna area of Hawaii Island to include 800 acres (324 hectares) of newly planted papaya, and obtaining a permanent federal registration of the lures methyl eugenol and cue-lure for use in Hawaii against fruit flies.

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Table 1. Impact of area-wide program on melon fly populations in targeted areas.

Suppression area	Peak melon fly population		Reductions due to program	
Commercial area under suppression (ha)	Before program in 2000 (flies/trap /day)	Population in 2003 (flies/trap /day)	Melon fly infestation (%)	Organophosphate usage for melon fly (%)
Waimea (46)	12	0.01	>20 to <2	100
Kula (100)	100	> 5	>40 to <5	90
Kunia/Ewa (5,300)	135	25	>30 to <5	90

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