The Dilemma of Fruit Fly Area-wide Control.

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In most Asian developing countries, traditional control of fruit fly pests via fruit bagging and sanitation has given way to the more convenient and easy to use conventional pest control by individual farmers/producers. Often, conventional control, particularly spraying of insecticide, is simple and convenient plus it does not require sophisticated knowledge of pest biology and ecology as well as expertise in technological application. Nonetheless, at best, it is an effective short term measure, and lacks efficacy and efficiency in the long term. It virtually does not require planning to obtain results as its main aim is to protect the commodities - fruits and/or vegetables. Frequently, it is accompanied by many undesirable effects. Due to i) rising costs and routine use of insecticides, problems related to a) pest resistance or resurgence, b) insecticide residues affecting health of domestic animals and humans, and c) environmental contamination; together with ii) the ever increasing demand for uncontaminated fresh fruits and vegetables by domestic and international consumers, a long term, more effective, non-disruptive and sustainable area-wide integrated pest management is necessary. Area-wide control programs implemented over a large contiguous area needs to be or has been initiated by some governments. This can be done with or without collaboration from international agencies of the United Nations such as the Food and Agriculture Organization and the International Atomic Energy Agencies.

Area-wide control or management of fruit fly pests incorporates various components. The diverse components are: a) pest biology and ecology, b) pest population size and dispersal pattern, c) topography of targeted area with possible availability of geographical isolation or buffer zone, and d) various highly effective techniques of pest destruction. Most importantly, it is planned and implemented over a long term without serious ill-effects on domestic animals and human health, our fragile environment, and the existing rich biodiversity found in many natural ecosystems. Pest destruction in an area-wide program to control fruit fly pests may be conducted using one or often a combination of two or more of the following techniques: a) biological control/biocontrol, b) male annihilation (MAT), and c) protein bait cum more environment friendly toxicant (PBT). Therefore, for a successful area-wide management program, it has to be well funded, planned, and strategically coordinated and implemented by a highly motivated and trained work force from several governmental and non-governmental agencies. Further, the support of the public, especially stakeholders ranging from producers and extension workers right through to financiers/sponsors and policy makers, that is well informed about the program throughout the implementation of the program is essential. This is because any one group of the stakeholders can have direct and substantiate influence on the success or failure of an area-wide program especially when it involves quarantine procedures.

Successful area-wide control of fruit fly pests leading to eradication, hitherto, has been limited to invasive species. For example, the eradication of *Bactrocera dorsalis* and *B. cucurbitae* in Okinawa, Japan by the use of MAT and sterile insect technique (SIT); of *B. papayae* (= *B. dorsalis*) in Queensland, Australia via MAT and PBT, of *B. dorsalis* in Mauritius through sanitation, PBT and MAT, and in Rota Island via MAT. Additionally, successful area-wide suppression of fruit fly pest species has been conducted in Hawaii against *B. dorsalis* and *B. cucurbitae*, and in Taiwan against the latter species. Nonetheless, there are also failure cases of area-wide control program for targeted *Bactrocera* pest species.

In the light of the successful cases of area-wide control program against certain fruit fly pest species, some governments in the Asia Pacific region are either planning to implement or have started an area-wide control program against indigenous fruit fly pest species in their respective countries.

Here in, lies the dilemma of an area-wide control of *Bactrocera* fruit fly pests that are endemic in areas where they are shown to be sole pollinators for many indigenous plant species especially the *Bulbophyllum* orchids.

Most of the Bactrocera pest species are strongly attracted to either methyl eugenol (ME) or raspberry ketone (RK) [cue-lure is not discussed in this paper as it is a synthetic analog of RK and, to date, is not found naturally]. Both ME and RK are found naturally in many plant species, the former in over two hundred species belonging to 46 families, and the latter in 12 genera of plants. Unfortunately, from the area-wide control view point, some *Bulbophyllum* orchid flowers, depending on the species, have floral attractants that contain either a ME, RK or zingerone component, which acts as a chemical reward to the attracted fruit fly visitor. Any one of these chemicals can act as floral synomone to entice the male fruit fly pest to assist in cross pollination. Therefore, with the drastic reduction or eradication of fruit fly pest population as a primary and ultimate aim of any area-wide control program, it will interfere with pollination of the orchid flowers. This will eventually lead to disruption in sexual reproduction with a possible consequence of extinction of the indigenous orchid species - hence, further impacting on the rich biodiversity of our natural rain forest/jungles.

The role of *Bactrocera* fruit fly pest species as sole pollinators of wild orchid species is sadly not fully appreciated and understood, probably due to ignorance as well as lack of funding for basic scientific investigation or research, in many Asia Pacific countries where indigenous *Bulbophyllum* orchids are coevolving with endemic *Bactrocera* fruit flies, particularly the pest species. To understand the true mutualism that exists between *Bactrocera* pest species and *Bulbophyllum* orchids, it is important to comprehend floral adaptations and reward system offered by orchid flowers to facilitate pollination by male fruit flies. Unlike many flowers pollinated by birds, bees and butterflies that produce the sugary liquid as reward for pollination, flowers of most *Bulbophyllum* species do not produce nectar, but instead, offer floral attractant as reward in the form of ME, RK or zingerone that is produced and released as floral fragrance. Flowers of Bu. cheiri and Bu. vinaceum offer ME as reward to fruit fly during pollination. Males of ME-sensitive pest species, namely B. carambolae, B. dorsalis, and B. umbrosa, consume floral ME that is biotransformed to its analog(s) in the crop and transported to the male rectal gland for temporary storage and subsequent release as sex pheromone to attract and mate with female flies. On the other hand, flowers of *Bu.*

apertum, Bu. cornutum and Bu. emiliorum offer RK as attractant and chemical reward in enticing male flies to facilitate cross pollination. Males of RK-sensitive pest species, such as *B. albistragata, B. caudata, B. cucurbitae* and *B. tau*, consume and sequester RK together with endogenously synthesized components to form male sex pheromone to attract females or as allomone to deter vertebrate predation. Interestingly, although zingerone is a relatively weak floral attractant, it was recently discovered to attract both ME- and RK-sensitive species. Males of *B. dorsalis* convert zingerone to zingerol that attracts females, while males of *B. cucurbitae* sequester it as a component of their respective male sex pheromone that attracts conspecific females for reproductive purposes. Zingerone, as a floral attractant and reward chemical to male fruit flies that act as sole pollinating agents for orchid flowers, has been recently discovered in *Bu. baileyi, Bu. patens,* and *Bu. praetervisum.* Undoubtedly, in this unique mutualism, both parties - the male Bactrocera fruit flies and wild orchid *Bulbophyllum* flowers, secure reproductive benefits from the chemical attractant(s) released as floral fragrance/synomone.

The *Bulbophyllum* flower is characterized by the highly moveable lip, which is well adapted and modified to aid primarily in fly pollination. To date, three mechanisms have been identified to facilitate pollinarium removal and deposition: a) see-saw lip with a high concentration of fruit fly attractant - e.g. *Bu. apertum, Bu. baileyi and Bu. cheiri*, b) see-saw lip with little or no attractant acting in tandem with the inner slippery surfaces of lateral sepals - e.g. *Bu. macranthum* complex species, such as *Bu. emiliorum, Bu. macranthum* and *Bu. praetervisum*, and c) 'spring-loaded' lip as found only in one species, *Bu. vinaceum*. These will be discussed in detail in this paper.

Finally, I strongly believe it is in the Asia Pacific region - especially member countries of the Association of Southeast Asian Nations (ASEAN), and Papua New Guinea, that each country will truly face the dilemma in implementing a fruit fly area-wide control program. Therefore, the direct impact of *Bactrocera* pests as pollinators on an area-wide control program, together with the possible solution to the dilemma encountered will also be discussed in the light of socio-economic perspectives (particularly research funding into the co-evolution between *Bactrocera* pest species and *Bulbophyllum* orchids in each country). The control should be implemented in a socially responsible manner, with sustainable pest management and at the same time maintaining the rich biodiversity in the Asia Pacific Region.

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