Management guidelines for *Anastrepha obliqua* associated with mango in Central America

LF JIRÓN
CIPROC
Estación Experimental
Fabio Baudrit
Universidad de Costa Rica
San José
Costa Rica

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ABSTRACT
Management guidelines for *Anastrepha obliqua* associated with mango have been proposed in Central America, and are summarized in this review: the use of mango varieties which fruit during the dry season when the fruit fly population density is low; the selection of mango varieties into well defined plots; the placement of long planting distances between trees; the prevention of using secondary fruit fly hosts and broad-leaved trees as live posts for fences; the monitoring of the adult population in relation to fruit plant phenology; the determination of levels of fruit infestation; the application of insecticide based on the levels of fruit infestation; and the removal of remnant fruit after harvest. Other measures related to control of *A obliqua* are also briefly discussed.

Recommandations pour le contrôle de *Anastrepha obliqua* en vergers de manguiers d'Amérique centrale.

RÉSUMÉ
Cette revue bibliographique présente certaines recommandations permettant de contrôler, dans les vergers de manguiers *(Mangifera indica)* d'Amérique centrale, le développement de la mouche des fruits *Anastrepha obliqua (Diptera : Tephritidae)* : utilisation de variétés de manguiers productives en saison sèche (faibles populations de mouches des fruits) ; sélection des variétés plantées dans une même parcelle ; respect d'un espace de plantation suffisant entre les arbres ; élimination des arbres de bordure susceptibles d'être des plantes-hôtes secondaires du parasite ; introduction de populations de parasitoïdes microhyménoptères dans le verger ; élimination des fruits à maturité précoce ou tardive ; contrôle des populations d'insectes adultes en fonction de la phénologie des arbres fruitiers ; suivi du niveau d'infestation des fruits ; application d'insecticide en fonction de ces niveaux d'infestation des fruits ; élimination des fruits restants après la récolte. D'autres mesures sont présentées succinctement.

Recomendaciones para el control de *Anastrepha obliqua* en huertos de mangos de America central.

RESUMEN
Esta revisión bibliográfica presenta ciertas recomendaciones permitiendo controlar, en los huertos de mangos (*Mangifera indica*) de América Central, el desarrollo de la mosca de las frutas *Anastrepha obliqua (Diptera : Tephritidae)* : utilización de variedades de mangos productivas en estación seca (poblaciones de moscas de frutas escasas) ; selección de las variedades plantadas en una misma parcela ; respecto de un espacio de plantación suficiente entre los árboles ; eliminación de los árboles de las cercas, susceptibles de ser plantas-húespedes secundarias del parasito ; introducción de poblaciones de parasitoides microhimenópteros en el huerto ; eliminación de las frutas de madurez precoz o tardía ; control de las poblaciones de insectos adultos, en función de la fenología de los árboles frutales ; seguido del nivel de infestación de las frutas ; aplicación de insecticida en función de estos niveles de infestación de las frutas ; eliminación de las frutas resultantes después de la cosecha. Otras medidas son presentadas sucintamente.

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KEYWORDS
Central America, *Mangifera indica*, *Anastrepha obliqua*, *Tephritidae*, insect control, integrated control, crop management.

MOTS CLÉS
Amérique centrale, *Mangifera indica*, *Anastrepha obliqua*, *Tephritidae*, lutte anti-insecte, lutte intégrée, conduite de la culture.

PALABRAS CLAVES
America central, *Mangifera indica*, *Anastrepha obliqua*, *Tephritidae*, control de insectos, lucha integrada, manejo del cultivo.

introduction

Since the early 1980s, a number of researchers have been developing specific work related to the fruit fly associated with mango in Central America (WHARTON et al, 1981 ; ESKAFI and CUNNINGHAM, 1987). These workers have identified a series of factors that lead to a high infestation rate in mango. In commercial mango orchards in Costa Rica, the infestation rate easily reaches 70% of the total crop at harvest time (SOTO-MANITIU et al, 1986). In Central America, mango fruit flies have been traditionally controlled by foliar application of insecticides mixed with an alimentary attractant such as hydrolyzed protein, torula yeast or molasses.

Research programmes carried out on *Mangifera indica* in Costa Rica and Guatemala (1986-1988) found that the Mediterranean fruit fly, *Ceratitis capitata* (Wied), is not the major mango pest (ESKAFI and CUNNINGHAM, 1987), but a related species, the West Indies fruit fly, *Anastrepha obliqua* (Macquart), is the major pest.

This fruit fly seems to be responsible for some 94% of the total fruit fly damage (JIRÓN and HEDSTRÖM, 1988; JIRÓN et al, 1988). Therefore, most of the efforts to control fruit flies on mango have been focused towards *A obliqua* (SOTO-MANITIU et al, 1986 ; JIRÓN and HEDSTRÖM, 1988), including studies on *A obliqua* populations also associated with other plants belonging to the same family (Anacardiaceae), commercially with no importance, but affected by this fruit fly species at different periods of time (SOTO-MANITIU et al, 1986).

A series of measures are discussed here in an attempt to integrate and interpret findings and data offered by different researchers, and to formulate a set of guidelines for management of *A obliqua* associated with mango production. These guidelines could be improved when more information about behaviour, host plant phenology, insect population patterns, sex pheromones, mango peel kairomones, and insect pest physiology becomes available.

harvesting in the dry season

None of the mango varieties grown in Costa Rica for export are harvested during the dry season (December to April). Most are harvested after the middle of April (early varieties), and the harvest period extends until September. Fruit fly populations peak during the rainy season, just after mango fruit reaches physiological ripeness (JIRÓN and HEDSTRÖM, 1991). Therefore, since the beginning of mango production for export, researchers oriented their efforts to obtain a dry season harvest by utilizing flowering induction by chemical methods. Unfortunately, more research is still needed to obtain consistent results (DAVENPORT, 1992). Some mango varieties (Irwin, Haden, Keitt) respond to high potassium nitrate concentration as a flowering inducer (RAM, 1992). More recently, a physical method has also been tested to obtain early mango flowering. Either the trunk or some of the primary branches are girdled in August were harvested in March, when the fruit fly population had reached its lowest density (JIRÓN and HEDSTRÖM, 1991). It is important to clarify that girdling requires an appropriate fertilization program a year before. Otherwise, trees stressed in this way could be killed if they are girdled when they are not well nourished during the previous rainy season. In the past 4 or 5 years some new flowering induction products have been recommended but more research is needed on the use of these new products to varieties commonly grown in Central America (CHACKO, 1992; DAVENPORT 1992).

selection for synchronous flowering

It is well known among mango growers that some varieties flower and fruit quite precociously. Fruit fly populations increase within a mango plot a few days after the early fruits become suitable for oviposition (JIRÓN and HEDSTRÖM, 1991). Early mango production plays an important role in the fruit fly reinfestation process (SOTO-MANITIU et al, 1986). This is especially evident when several mango varieties are grown together, leading to asynchronous flowering and fruit set. Thus, when some trees are bearing fruits and need chemical protection from insect pests, others are flowering and need insects for pollination. Insecticide applications will affect insects associated with all mango varieties, including both pollinators and fruit parasites.

To decrease such problems, planting of separate varietal plots are recommended. In that case, agrochemicals, culture measures and harvesting activities can be used. Growing varietal plots also provides the opportunity to learn more of the behaviour of each mango variety, under specific ecological conditions of a given region.

appropriate planting distances

Tropical fruit flies need an appropriate microclimate for migrating, feeding, mating and ovipositing. Preliminary observations (ALUJA, 1994) suggest that a mango tree with dense foliage is more susceptible to fruit fly infestation. Mango trees usually grow rapidly during the rainy season (vegetative growth), and a tree spacing of less than 14 m will produce some overlapping after 5 years. Then this situation necessitates heavy pruning, and such a canopy presents two problems: i) pruning stimulates vegetative growth instead of seasonal production of panicles (flowers) ; ii) a closer canopy makes it easier for gravid females to fly from one tree to another seeking appropriate fruits. Wider spacing between trees can increase fruit production and, by producing an open canopy, lead to microclimatic disruption for adults of *Anastrepha* and/or *Ceratitis* (PROKOPY and ROITBERG, 1984). The establishment of mango tree hedges has seemed to be a reasonable alternative when a high yield is sought. However, a hedge increases a microclimate in which fruit flies move freely space and high relative humidity makes fruit fly control and control of anthracnose and diseases difficult.

live fence management

Field studies carried out in Costa Rica (JIRÓN and HEDSTRÖM, 1988; SOTO-MANITIU and JIRÓN, 1990) have demonstrated that *A obliqua* shows a strong preference for ovipositing on plants of the family *Anacardiaceae,* including trees commonly used as live fences by mango growers in Central America. Alternate host plants include *Spondias mombin* L (jobo), *S purpurea* (Spanish plum) and *Anacardium excelsum* L (espavel). This latter species naturally grows near rivers and creeks in areas where mango is also grown commercially.

A comparison of the fruit set period of mango and these alternative host plants shows some overlap, which ensures *A obliqua* several months of fruit. Flies can be captured almost all year long in such a situation (JIRÓN and HEDSTRÖM, 1988); therefore, mango growers should not use species of *Anacardiaceae* for life fence posts.

Tropical fruit flies tend to mate on broad-leaved trees, and these play an important role as a mating place for fruit flies (PROKOPY and ROITBERG, 1984; ALUJA, 1994). Therefore, it is important to use small-leaved trees as live fences and wind breakers.

parasitoid introductions

In Costa Rica, both *Ceratitis* and *Anastrepha* are parasitized by microhymenopterans, even when the fruit fly larvae are underneath the mango peel (PICADO, 1920). Since the mid-1950s, several parasitoid species have been introduced to Central America as part of a programme to control the Mediterranean fruit fly (JIRÓN and SALAS, 1992). WHARTON et al (1981) published the first formal evaluation of the impact of the parasitoid liberation. These authors found that several years after the wasp liberation is stopped, parasitism rate decreases and it stabilizes up to 5.5% in *C capitata* and at about 10.5% in *Anastrepha*.

In 1989, JIRÓN and MEXZON evaluated parasitism of fruit flies in Costa Rica and they found that, besides several native parasite species, *Biosteres longicaudatus* (imported braconid) is also well established. More recently, it was found that several parasitic wasps associated with tropical insect pests feed on flowers or nectaries of weeds growing in the plantations (MEXZON and CHINCHILLA, 1991). This finding suggests that fruit fly parasitoids may also feed from the flowers of weeds in the mango orchards in Central America.

Unfortunately specific information is not available for mango, but it is feasible to infer an ecological association between fruit fly pest parasitoid wasps and weeds. Once information related to this association is available, parasitoid releases could become a useful tool in fruit fly pest management, and beneficial weeds could be promoted within the mango orchard to attract parasitoids.

synchronization of mango fruiting

In a commercial mango orchard, it is common to observe a small percentage of early panicles (flowers). These first panicles are distributed at random in the orchard, and they will produce fruits several weeks before the main crop. This earlier production can be heavily attacked by fruit flies, and can also play an important role as a focus of infestation for the main crop. During the same mango season, several generations of fruit flies can be produced, starting with the earliest fruits. This situation also occurs when different mango varieties are grown together (SOTO-MANITIU and JIRÓN, 1990).

Similarly, a small percentage of fruit is left on the tree after the commercial harvest. Fruit that remains unharvested can permit the pest population to develop a further generation (SOTO-MANITIU and JIRÓN, 1990); therefore burning or destruction of unharvested fruits is recommended.

fruit fly monitoring

Several studies have demonstrated that fruit fly population dynamics are very closely related to mango phenology, and rain frequency (ALUJA and MARTINEZ, 1985; JIRÓN and HEDSTRÖM, 1991). However, each mango variety shows a different behaviour when it is growing in a given microclimate.

Therefore, the mango grower must know how each variety behaves throughout the year on his farm, as well as the fruit fly population dynamics, which are correlated with mango phenology. There is a simple method to monitor fruit fly populations, utilizing McPhail traps (plastic or glass) baited with an alimentary attractant, which is commonly a wet solution of dehydrated protein or torula yeast (ALUJA and MARTINEZ, 1985; JIRÓN and HEDSTRÖM, 1988).

Once the baited trap is placed in the field, it must be checked once or twice a week. Capture rates must be related to plant phenology, seasonality, flower set, fruit set and physiological fruit maturity. It is also important to note that the presence of adult fruit flies does not mean harvestable fruits necessarily are infested. It is common to observe both *Ceratitis* and *Anastrepha* fruit fly adults feeding on overripe fruits, or on the trap attractant. Therefore, if fruit flies are captured during the monitoring period, fruits on the trees must be dissected and checked for oviposition evidence.

It is important to clarify that, at any time, the fruit fly population can be divided into three main components:

– immature, recently emerged adults: these are mostly seeking food (sugar and protein), and they are not attracted by sexual volatile compounds (pheromones); preliminary observations show that immature *A obliqua* adults reach sexual maturity after 15-16 days, under laboratory conditions; it is possible to infer from this that, during this period, flies are seeking food, and sexual activity generally occurs elsewhere away from the site where the adult originally emerged; therefore, the traditional idea that fruit fly adults reinfest fruits of the same individual tree is not always true; rather, there can be considerable dispersal among mango orchards (BRESSAN and TELES, 1991);

– a second population component is made up of sexually mature adults which are attracted by male-produced pheromones: *A obliqua* adult males tend to form swarms, and then rest underneath broad-leaved trees in the host plant surroundings; this second population component (females) can be captured with traps containing artificial sexual pheromones;

– the third group, composed of gravid females, is the most important component for mango, since gravid females are responsible for adult fruit damage (parasitism): during the fruit maturation process *A obliqua* females are able to recognize when the fruit can be successfully colonized by larvae; each mango variety has its own schedule for physiological maturity; some mango varieties seem to be more susceptible to fruit fly infestation, and their suitability for fruit flies depends on glandular density per square centimetre in the peel, but not on peel thickness (PROKOPY and ROITBERG, 1984; JIRÓN, 1992; MURILLO and JIRÓN, 1995).

Regular sampling with standard McPhail traps and an alimentary attractant is satisfactory for population monitoring, but is not sufficient to reduce total fruit fly population in a given mango orchard. This practice does not capture gravid

females in good numbers and could attract flying adults from outside the plot. An optimal trapping system should combine traps containing alimentary attractant, sexual pheromones and kairomones obtained from fruits, which might then be able to catch gravid females. Central American technology for mango fruit fly management is not currently capable of producing *A obliqua* sexual pheromones. However, a joint research project between the University of Costa Rica, CONICIT and Simon Fraser University (British Columbia, Canada), expects to have this sexual attractant for Central American mango growers before 1997. Meanwhile, fruit fly trapping is appropriate for monitoring of mango fruit fly but is not yet adequate for fruit fly pest control.

opportune insecticide application

Once the beginning of the fruit fly infestation is determined, foliar insecticide application must be started. Each mango variety should be treated according to its own infestation schedule. Traditionally, a blend of insecticide (malathion, trichlorfon or fenthion) plus an alimentary attractant (torula yeast powder or dehydrated protein) is recommended (HARRIS et al, 1971; ALUJA and MARTINEZ, 1985). If just one variety is growing in a plot, three insecticide applications every other week will be enough for one season.

Insecticide applications, mixed with attractant and adherents, must be applied during the rainy season. Insecticides must be applied to mango trees as well as to other hosts in the surrounding area (Spanish plum and jobo). When the orchard is large, containing over 2 000 trees, fruit fly traps should be placed on previously numbered trees. This will allow a clear determination of the main pest fly access route(s). When fruit infestation surpasses 10% of the weekly samples, spot insecticide and attractant spraying should be made in patches at the canopy level. It is recommended to treat the orchard in alternate rows (Ca 150 ml per tree) (ALUJA and MARTÍNEZ, 1985).

Insecticide spraying in a mango plot containing more than one variety will affect the yield, because the insecticide used to protect the fruit also kills dipterans needed for pollinating the variety that flowers later (JIRÓN and HEDSTRÖM, 1985).

other measures

The technology of mango fly control has several aspects which could be improved. Aspects that are in need of research in the near future include:
– *A obliqua* sterile male release technique: this technique is well known for *Ceratitis capitata* (KATIYAR, 1973), but not for *A obliqua.* It requires an efficient mass-rearing technology, including the development of inexpensive artificial diet. Studies on *A obliqua* population fluctuations conducted in Costa Rica have demonstrated that the species is active all year (JIRÓN and HEDSTRÖM, 1991). Any programme of sterile fly release of *A obliqua* must be conducted whether mangos are in or out season. In addition, sterilized *A obliqua* adults have to be previously studied under laboratory and field conditions. Studies conducted in other fruit fly species have demonstrated that sterilized males can be less competitive than wild ones (KATIYAR, 1973);
– improvement of attractants: as mentioned earlier, current attractants utilized to capture *A obliqua* seem to be appropriate only for the monitoring of adults. The possibility of extracting attractive volatile attractants (kairomones) could be included in a good fruit fly capturing method in the field. Such a method could be developed through a series of field trials where fruit flies choose between the kairomone by itself or mixed with an alimentary attractant in the same trap.

It is possible that a kairomone extracted from the mango is not the best choice for *A obliqua*, but the volatile compounds from one of the endemic American host plants (*Anacardium* or *Spondias*) could be a very strong attractant to gravid females. The association between *A obliqua* and mango is only 200 or 300 hundred years old, and this new host plant for the fruit fly might not be the best alternative.

Extraction, identification and synthesis of attractive host plant volatiles (kairomones) is a new field for Latin American researchers, but it seems to be a promising element for pest management, and perhaps, in the near future, *A obliqua* pest control will have appropriate kairomones for the capture of gravid females before they land on mango fruit to start ovipositing.

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