A survey on the occurrence and flight periods of fruit fly species (Diptera: Tephritidae) in a fruit growing area in southwest Nicaragua, 1994/95

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Abstract

McPhail traps baited with hydrolysed protein and borax to trap mainly female fruit flies, Jackson traps baited with trimedlure to attract male *Ceratitis capitata* Wiedemann, and Jackson traps baited with cuelure and methyl eugenol to trap *Bactrocera* spp., were hung in fruit trees at 50 sites and serviced weekly from June, 1994 to March, 1995, over an area of 350 km^2 in Nicaragua. Samples of fruit were collected and kept separately to rear adult fruit flies and their hymenopterous parasitoids from known host plants. No *Bactrocera* spp. was trapped or reared from fruit at any site. *Ceratitis capitata* was caught in high numbers in McPhail and Jackson traps at nearly all sites in the dry season, attacking coffee berries and fruit of *Citrus* species. *Toxotrypana curvicauda* Gerstaecker was attracted to the food lure McPhail traps in low numbers and was widespread throughout the year, attacking papaya (Caricaceae). Of 29 *Anastrepha* species known to occur south of Mexico and north of Panama, ten were found during the study, occurring mainly in the rainy season; only two of them were trapped frequently and reared from collected fruit. *Anastrepha obliqua* Macquart proved to be the second most abundant fruit fly species, with a population peak from June to October when its preferred host plants *Mangifera indica, Spondias mombin* (Anacardiaceae) and *Psidium friedrichsthalianum* (Myrtaceae) were ripening. *Anastrepha striata* Schiner, trapped at 45 sites, occurred from June to November, attacking *P. friedrichsthalianum* and *P. guajava*. Sampled fruit of a further eight species in seven families were not attacked by tephritid flies. Parasitism by introduced braconid *Diachasmimorpha longicaudata* (Ashmead) was very low (3.7% in *C. capitata*, 2.7% in *A. obliqua* and 5.3% in *A. striata*).

Introduction

Since 1990, the government of Nicaragua has promoted the growing of non-traditional agricultural produce, especially fruit like mango and *Citrus* spp., for export. Production is also supported by national and international organizations. In the Meseta de los Pueblos, an important area of fruit production in Nicaragua, growing non-traditional fruits raises a number of problems. The most severe is the occurrence of several species of fruit fly (Diptera: Tephritidae), the larvae of which feed in and destroy the nutritional value of fruits, causing premature crop loss and severely affecting fruit yields. Damaged fruit cannot be sold even in local markets. It cannot be sold for export, because damage thresholds are extremely low, due to the quarantine regulations of importing countries (especially the USA, which is the main commercial partner of Nicaragua).

An important prerequisite for the development of new fruit fly control measures is basic information on fruit fly species composition, and on their flight periods and host plants range. The results of the study presented here contribute to the information needed for the development of an integrated fruit fly management programme in Nicaragua.

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Materials and methods

The soils of the Meseta de los Pueblos are of volcanic origin. The climate is subtropical-humid with an average annual temperature of 22–24°C and 1300–1600 mm of rain per year. Normally there is a dry season from November to April and a rainy season from May to October (INETER, 1995). The original vegetation cover of the area was semi-montane tropical forest. In the Meseta de los Pueblos the study area covered 350 km^2, including parts of the Departments of Masaya, Granada and Carazo. Within this area, 50 sites with an altitude range of 160–660 m above sea level (average 445 m), where fruit trees are grown, were visited weekly from mid June 1994 to mid March 1995.

Three types of trap were used, one of each hung in a fruiting tree at each of the 50 sites:

1. A Jackson pheromone trap (JTCM) baited with cuelure and methyl eugenol to detect any incipient outbreak or introduction of fruit flies of the genera *Bactrocera* or *Dacus*, for which the baits are specific attractants (Hentze *et al*., 1993).

2. A Jackson pheromone trap (JT) baited with trimedlure to attract male *Ceratitis capitata* (Wiedemann) (Hentze, 1993).

3. A McPhail trap baited with food attractant. The trap compises an approximately spherical bottle of glass (*c*. 1.5 l), with a concave base and central entrance hole through which the flies are attracted. The bottle is closed with a stopper and can be suspended by a wire wound round the neck of the bottle (McPhail, 1937). The bait per trap consisted of 25 g hydrolysed protein, 5 g borax and 220 ml water. Females of most tephritid flies need certain amino acids for nutrition and so are attracted by the bait (Aluja, 1985). This trap was used mainly to catch flies of the genus *Anastrepha*.

The baits in all three trap types were renewed weekly. The number of flies caught on the sticky cardboard inside trap types 1 and 2 were counted and the cardboard strips renewed. The catch in the McPhail traps was collected for study in the laboratory. If necessary, traps were hung in a new tree if it was considered to be at a more suitable fruiting stage. Identification of the fruit fly species followed the keys of Korytkowski (1993a,b), Hernández-Ortiz (1992) and Foote (1980). Voucher specimens were deposited at the Institute of Phytopathology and Applied Zoology, Justus-Liebig-University, Giessen.

The number of fruit flies per trap per day (FTD) was used as a measure of fly abundance. In order to relate the captured fruit flies to their host plants and to find potential host plant species, fruits were collected at each of the 50 sites during weekly visits. These were stored separately in the laboratory in experimental cages ($70 \times 25 \times 25$ cm) covered with fine gauze to prevent entry by other flies or ants. The fruits were placed on a wire grid and descending larvae allowed to pupate in moist sand at the bottom of the cages. Pupation mostly took place after 5 to 14 days, when the fruits started rotting. Pupae and full-grown larvae were then removed and stored in vials containing moist sand, covered with a fine gauze, until adult flies or parasitoids emerged. Parasitoid specimens were sent for identification to Dr R.A. Wharton, Texas A & M University, USA. For calculating the rate of parasitism the number of emerged parasitoids was divided by the sum of emerged fruit flies plus emerged parasitoids $\times$ 100.

Results

During the 40 week study period, a total of 47,532 tephritid flies was collected at the 50 study sites including 1001 reared from fruits. The numbers of flies caught in the different trap types are presented in table 1.

The fact that no *Bactrocera* specimen was trapped in Jackson traps means that no species of this genus has been detected in Nicaragua so far. This study deals with the other

Table 1. Subfamilies, genera and specimens of tephritid flies caught in three different trap types (50 each) in the Meseta de los Pueblos, Nicaragua, 1994/95.

Trap type	Tephritid subfamily	Genus, species	Numbers caught	Remarks
Jackson (JTCM)	Dacinae	*Bactrocera* spp.	0	see text
Jackson (JT)	Dacinae	*Ceratitis capitata*	13,775	100% males
McPhail	Dacinae	*Ceratitis capitata*	13,652	75% females
	Trypetinae	*Anastrepha* spp.	18,608	10 species
		Toxotrypana curvicauda	31	*T. curvicauda* is not well attracted to the hydrolysed proteins used
		Hexachaeta sp.	57	host plants unknown
		H. obscura Hendel	33	host plants unknown
		Blepharoneura sp.	5	host plants unknown
		Lezca sp.	2	host plants unknown
	Tephritinae	*Tetreuaresta* sp.	170	Larvae of Tephritinae live in flowers of Asteraceae (Fletcher, 1989)
		Dyseuaresta sp.	76	
		Baryplegma sp.	74	
		Xanthaciura insecta (Loew)	32	
		Neotaracia imox (Bates)	10	
		Dioxyna sp.	4	
		Euaresta sp.	1	
		Eutreta sp.	1	
Total	3	14 genera	46,531	

Table 2. Abundance of the five most common fruit fly species in the Meseta de los Pueblos, Nicaragua, and number of larvae and pupae, reared from collected fruits, 1994/95.

Tephritid species	Total no. caught in 50 McPhail traps	No. sites out of 50	Host plant (family)	Fruits		Larvae and pupae	
				no. collected	no. sites	no. reared	no. per fruit
Ceratitis capitata	13652	49	5 *Citrus* spp. (Rutaceae)	1295	35	556	0.4
			Coffea arabica (Rubiaceae)	136	2	36	0.3
Anastrepha obliqua	10396	48	*Mangifera indica*	127	10	87	0.7
			Spondias mombin (Anacardiaceae)	236	6	67	0.3
			Psidium guajava	8	2	8	1.0
			P. friedrichs-thalianum	25	3	141	5.6
A. straita	7756	45	*P. friedrichs-thalianum*	261	7	552	2.1
			P. guajava (Myrtaceae)	141	2	250	1.8
A. serpentina	352	31	*Calocarpum mammosum* (Sapotaceae)	8	3	0	0
Toxotrypana curvicauda	31	12	*Carica papaya* (Caricaceae)	10	3	116	11.6

three genera listed in table 1, *Ceratitis, Anastrepha* and *Toxotrypana*, which are the most abundant and of the highest economic importance.

Ceratitis capitata (Wiedemann)

The Mediterranean fruit fly (medfly), which appeared in Costa Rica in 1955 and in Nicaragua in 1960 (Arevalo, 1976), produces 12 or more generations per year in Central America, which is far more than the three to eight generations per year exhibited by known indigenous tephritid species (Aluja, 1985; Bloem *et al*., 1993). Table 2 shows that *C. capitata* was trapped at 49 out of the 50 sites. In the season studied, the medfly proved to be the most abundant tephritid species in Nicaragua, with more than 13,000 individuals trapped in each of the two trap types used. The flight period started at the end of November, when the rainy period ended and the last coffee berries were ripening (fig. 1). Peak densities were reached quickly in the dry season during February and March, when the last *Citrus* fruits were ripening. Males were trapped in Jackson traps more

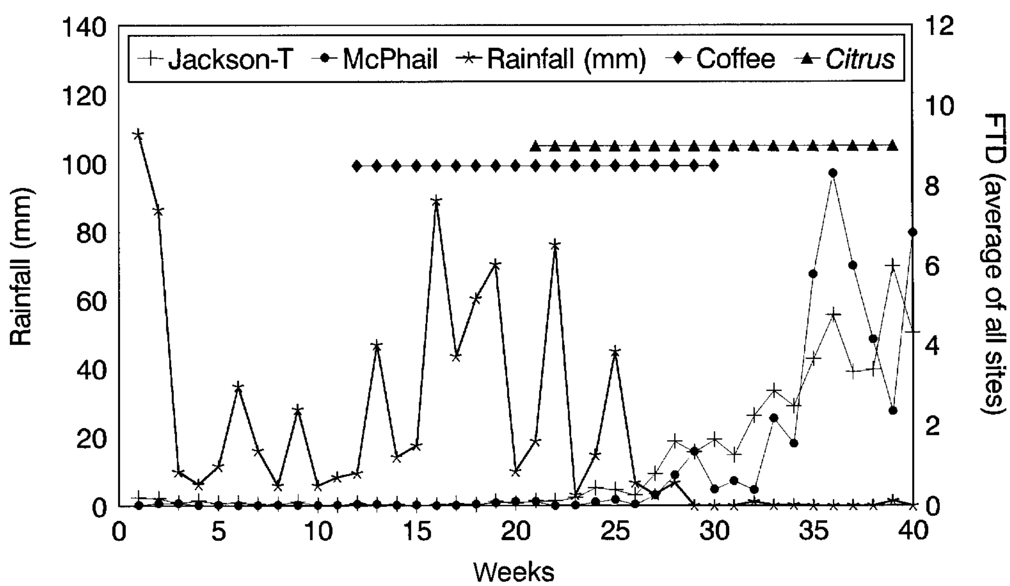

Fig. 1. Flight periods of male and female *Ceratitis capitata* in the Meseta de los Pueblos, Nicaragua, in relation to rainfall and the presence of ripening fruits of *Coffea arabica* and *Citrus* spp., June 1994–March 1995 (1995 starting with week no. 29). Horizontal lines indicate the fruiting period of the main host plants.

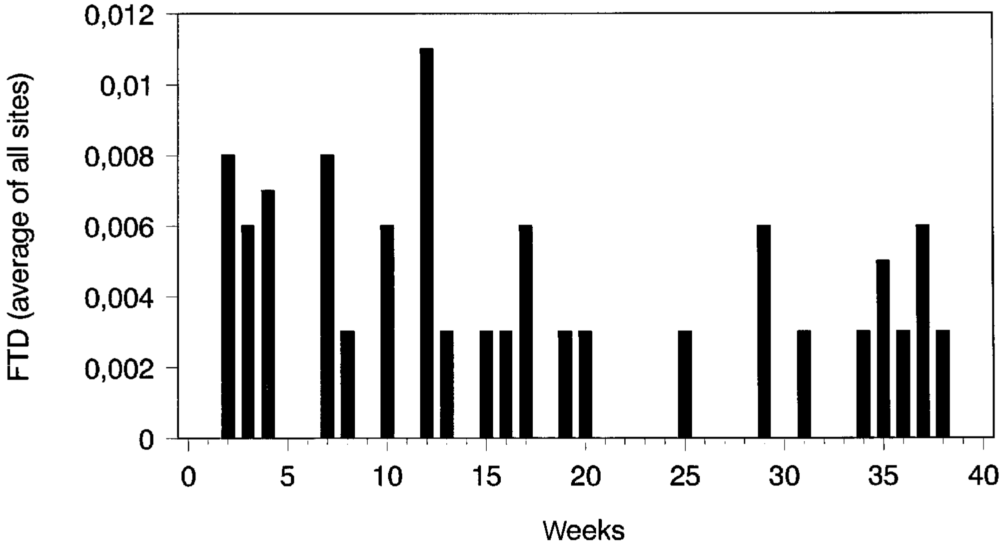

Fig. 2. Catches of *Toxotrypana curvicauda* in McPhail traps in the Meseta de los Pueblos, Nicaragua, June 1994–March 1995 (1995 starting with week no. 29).

regularly than females, which prevailed in McPhail traps. It can be seen from table 2 that five *Citrus* spp. proved to be the main host plants of the medfly, followed by *Coffea arabica*. The FTD (number of flies per trap per day) exceeded the critical value of 0.08 (Gutierrez *et al*., 1992) during the ripening and harvesting season of *Citrus* at 35 out of 49 sites. The maximum FTD value observed was 48 at one site, while the average maximum of all sites was 9 (fig. 1).

Toxotrypana curvicauda *Gerstaecker*

The papaya fruit fly is not only morphologically different from other Trypetinae, but also differs in larval feeding habits and chemical ecology (Landolt, 1993). For these reasons the species was not attracted in high numbers by the hydrolysed protein bait used in McPhail traps. Nevertheless, some females were trapped (table 2). Figure 2 shows that female *T. curvicauda* were flying throughout the year. In Central America, *T. curvicauda* has three to five generations per year (Aluja, 1985). The only host plant of the papaya fruit fly proved to be papaya, *Carica papaya*, as shown in table 2.

Genus Anastrepha *Schiner*

According to Hernández-Ortiz & Aluja (1993), 29 species of *Anastrepha* are known to occur south of Mexico and north of Panama. Ten species were found during the present study in Nicaragua, but only three of these were common (table 2). These produce four to eight generations per year in Central America (Aluja, 1985).

A. obliqua *(Macquart)*

This species occurred nearly as abundantly as the medfly with 10,396 specimens caught in McPhail traps, but its host plants, two species each of Anacardiaceae and Myrtaceae were quite different (table 2), as was the flight period (fig. 3). The main flight of *A. obliqua* occurred in the rainy season, mainly during the fruiting period of *Mangifera indica* and *Spondias mombin* (June to September), which ended before a period of higher rainfall during October and November. Peak densities were observed very soon after the start of the study, in July. The critical FTD value of 0.08 was exceeded at 39 out of 48 sites where *A. obliqua* was recorded.

A. striata *Schiner*

Anastrepha striata also proved to be abundant in Nicaragua, with 7756 specimens trapped in McPhail traps at 45 of the 50 sites studied (table 2). Its main flight period lasted from June to November (i.e. nearly throughout the rainy season), but fly numbers trapped in the dry season were also reasonably high (fig. 4). Host plants in the study area proved to be *Psidium friedrichsthalianum* and *P. guajava* (Myrtaceae) (table 2). These had fruiting periods of several months, so that fruits for oviposition by *A. striata* were present during the whole period of study. The critical FTD value of 0.08 was exceeded at 27 out of 45 sites where *A. striata* was recorded.

Table 2 shows that two *Psidium* spp. were host plants of *A. obliqua* and *A. striata*, but mostly *Psidium* fruits were infested by *A. striata*. Mixed infestations of the same individual fruit by both *Anastrepha* species were very rare.

A. serpentina *(Wiedemann)*

352 specimens of this species were caught at 31 sites in McPhail traps. The critical threshold of 0.08 flies per trap per day was exceeded at five sites. The main flight period (fig. 5) was observed in the first half of the rainy season (June to September), with a reduced level of activity throughout October and coincided with the fruiting time of two species of Sapotaceae: *Manilkara zapota* and *Calocarpum mammosum*. These plant species are known to be the preferred hosts of *A. serpentina* (Norrbom & Kim, 1988). But of eight fruits of *C. mammosum* collected from three samples, only two were attacked by *Anastrepha* larvae, and these could not be reared to the adult stage. Thus no evidence was obtained during the

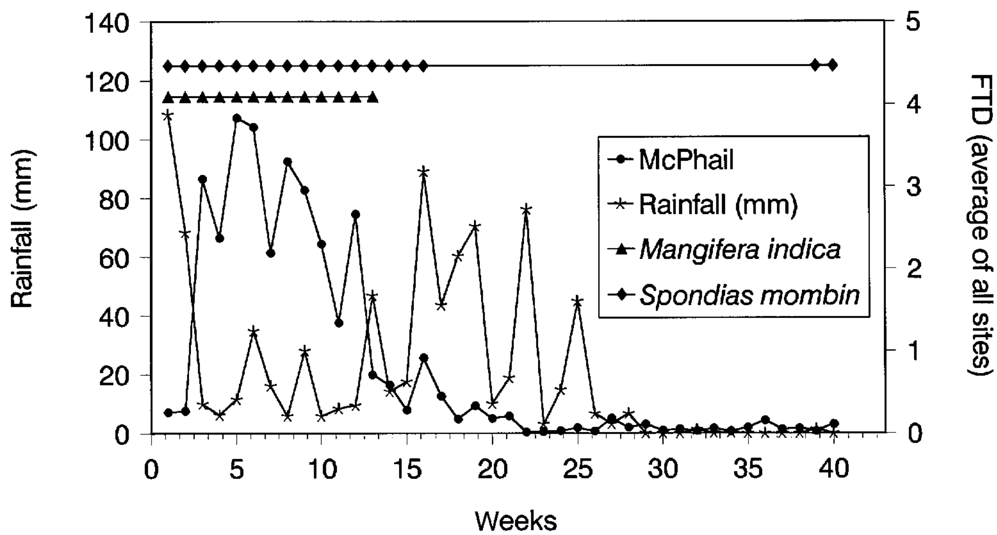

Fig. 3. Flight period of *Anastrepha obliqua* measured by McPhail traps in the Meseta de los Pueblos, Nicaragua, in relation to rainfall and to the fruiting season of *Mangifera indica* and *Spondias mombin* (Anacardiaceae), June 1994–March 1995 (1995 starting with week no. 29). Horizontal lines indicate the fruiting period of the main host plants.

current survey of the host plants utilized by *A. serpentina* in Nicaragua.

Levels of infestation

The average numbers of fruit fly larvae found per fruit for the above species are shown in table 2. There were no 'natural' levels of infestation, since most of the orchards studied (except most papaya plantations) had received insecticidal sprays against fruit flies prior to the dates of fruit sampling. No detailed observations were made by the authors on the frequency of and the preparations used for the spray applications. The infestation of *Citrus* fruits and coffee berries by the medfly and of mangoes and *Spondias mombin* fruits by *Anastrepha obliqua* proved to be low (<1 larvae per fruit, on average). The infestations of the two *Psidium* species by *A. obliqua* and *A. striata* were higher (1 to 5.6 larvae per fruit). The highest infestation was observed in papaya (11.6 larvae of *T. curvicauda* per fruit). As mentioned above, most papaya orchards remained unsprayed.

Other species of Anastrepha

A further seven species of *Anastrepha* were caught in McPhail traps in low numbers at a few sites. They are listed below (in brackets: total number / number of sites):

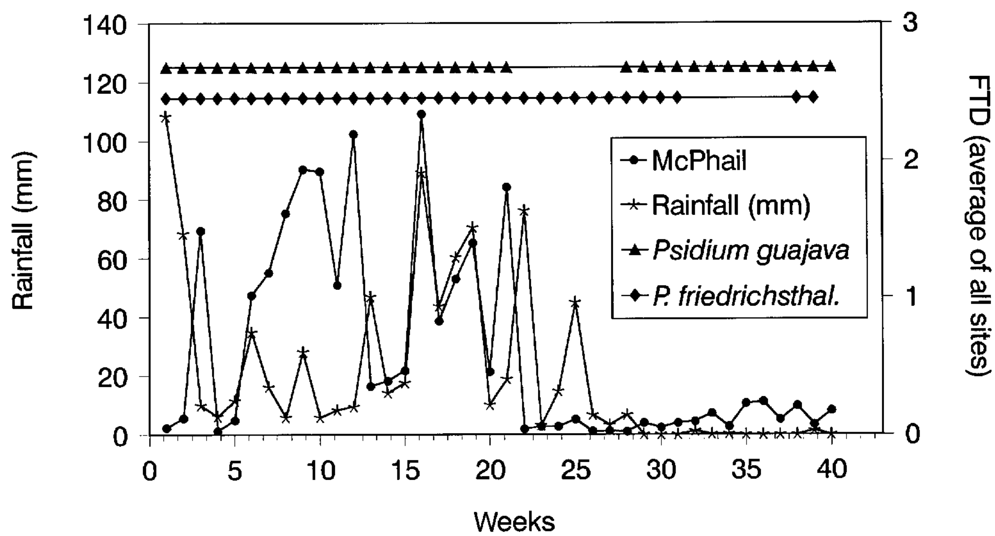

Fig. 4. Flight period of *Anastrepha striata* measured by McPhail traps in the Meseta de los Pueblos, Nicaragua, in relation to rainfall and to the fruiting season of two *Psidium* spp. (Myrtaceae), June 1994–March 1995 (1995 starting with week no. 29). Horizontal lines indicate the fruiting period of the main host plants.

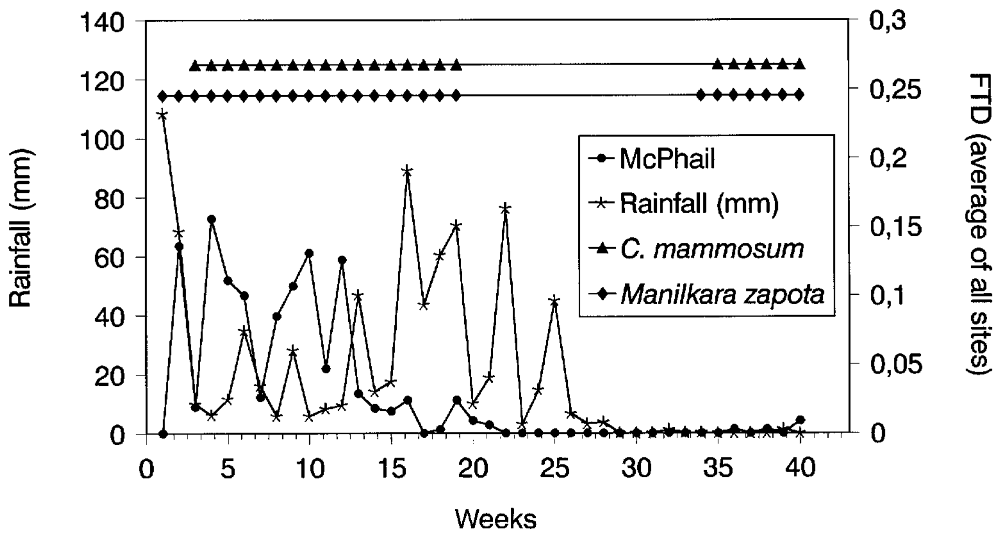

Fig. 5. Flight period of *Anastrepha serpentina* measured by McPhail traps in the Meseta de los Pueblos, Nicaragua, in relation to precipitation and to the fruiting period of *Manilkara zapota* and *Calocarpum mammosum* (Sapotaceae), June 1994–March 1995 (1995 starting with week no. 29). Horizontal lines indicate the fruiting period of the suspected main host plants.

Anastrepha distincta Greene (69/20), *A. limae* Stone (15/10), *A. bezzii* Costa Lima (6/6), *A. tumida* Stone (6/3), *A. ludens* (Loew) (4/4), *A. montei* Costa Lima (3/3) and *A. fraterculus* (Wiedemannn) (1/1).

Thus ten out of 29 *Anastrepha* species known to occur in Central America were found during the present study in south-west Nicaragua, of which only two can be considered of high economic importance due to their high frequency and wide distribution.

Other fruit flies (Trypetinae) suspected to be frugivorous that are of potential economic importance

Among the remaining Trypetinae (table 1), only one unidentified *Hexachaeta* sp. reached the FTD threshold of 0.08. The host plants of the two *Hexachaeta* species were not discovered during the present study.

Plant species not attacked by fruit flies

In addition to the 2239 fruits of eleven plant species belonging to six families from which fruit flies emerged (table 2), a further 470 fruits of eight plant species from seven families were collected during the study (19 to 120 fruits per plant species) which were not infested by fruit flies (table 3).

Braconid parasitoids (Hymenoptera)

One thousand and one adult flies of the four dominant tephritid species were reared from fruit in the laboratory. An additional 39 pupae gave rise to parasitoids. Eighteen specimens of these were sent for identification, and all belonged to the species *Diachasmimorpha longicaudata* (Ashmead) (Hymenoptera, Braconidae). Another braconid species *Doryctobracon areolatus* (Szepligeti) (det. R.A. Wharton) was observed in the field while ovipositing into fruits of *Psidium friedrichsthalianum*.

Diachasmimorpha longicaudata was released in large numbers in Nicaragua *c*. 1970 (Hentze *et al*., 1993). From table 4 it can be seen that the parasitoid is now established in the Meseta de los Pueblos, but the levels of parasitism achieved by this braconid were very low in 1994/95 for medfly and two *Anastrepha* species, and no parasitism was observed for *T. curvicauda*.

Discussion

Specimens of *Ceratitis capitata* (regardless of whether male or female) appeared to be trapped more regularly by Jackson traps than by McPhail traps (fig. 1). Nevertheless the overall results obtained by both traps were essentially similar (Bloem *et al*., 1993). Although the McPhail trap is expensive and laborious to use it is a necessity at present in fruit fly studies in Central America, if *Anastrepha* species are to be included (Aluja, 1994; Celedonio-Hurtado *et al.*, 1995).

The flight period of *C. capitata*, which is determined by rain and temperature in areas of more temperate climate, e.g.

Table 3. Fruits from plant species not attacked by fruit flies, collected from Meseta de los Pueblos, Nicaragua, 1994/95.

Family, species	No. fruits collected	No. sites sampled/ No. sampling dates
Clusiaceae		
Mammea americana	19	2/2
Malpighiaceae		
Byrsonima crassifolia	79	1/2
Myrtaceae		
Syzygium malaccense	37	1/3
Oxalidaceae		
Averrhoa carambola	120	4/8
Passifloraceae		
Passiflora edulis f. *flavicarpa*	36	3/5
Rutaceae		
Citrus latifolia	43	3/5
C. limetta	39	1/3
Sapindaceae		
Melicocca bijuga	97	4/5

Table 4. Numbers of fruit flies and braconid parasitoids reared from collected fruits (cumulative from all sites, dates and host plants), and percentage of parasitism, Meseta de los Pueblos, Nicaragua, 1994/95.

Tephritid species	No. flies reared	No. parasitoids reared	% parasitism
Ceratitis capitata	449	17	3.7
Anastrepha obliqua	143	4	2.7
Anastrepha striata	324	18	5.3
Toxotrypana curvicauda	85	0	0

Uruguay (Vadora *et al*., 1993), is influenced under Central American conditions by rainfall only. The phenology of *C. capitata*, as shown in fig. 1, seems to be typical of the medfly in Central America (Bloem *et al*., 1993).

Concerning the host plant range of the most common tephritid species studied, a wide range of host plants is indicated by White & Elson-Harris (1992) for *C. capitata* and by Norrbom & Kim (1988) for *Anastrepha* species. In spite of this, the present study and an earlier one conducted in Nicaragua (Daxl, 1978), plus four studies from South Mexico (quoted below), indicate that *C. capitata, A. obliqua* and *A. striata* develop in a rather narrow range of host plants in Central America, with differences in the host plant range for two *Anastrepha* species between the published literature and the present study.

None of the five reviewed references (Norrbom & Kim 1988; Aluja *et al*., 1987, 1990, Toledo, 1993 and Hernandez-Ortiz & Pérez-Alonso, 1993) lists the two *Psidium* species as host plants for *A. obliqua*. Our study also showed *P. friedrichsthalianum* as a good and *P. guajava* as a rather poor host plant for this fruit fly species (table 2).

Although Aluja *et al*., 1987, 1990; Toledo, 1993 and Hernandez-Ortiz & Pérez-Alonso, 1993 do not refer to *P. friedrichsthalianum* as a host plant of *A. striata*, the present study confirms the statement of Norrbom & Kim (1988): *P. friedrichsthalinanum* seems to be a good host for this species (table 2).

The number of species of *Anastrepha* recorded in Nicaragua increased from five to ten as a result of the current study, but the additional five species found were too uncommon to have any economic importance during the study period.

Although the level of parasitism by braconids was expected to be fairly high, following the successful introduction of *D. longicaudata* in a mass release programme in Nicaragua in 1970 (Hentze *et al*., 1993), this study showed that *D. longicaudata* was uncommon throughout southwest Nicaragua (table 4). The collapse of parasitoid populations following inundative release seems to be typical for *D. longicaudata* (Wharton, 1989). It is interesting, however, that Aluja *et al*. (1990) found relatively high rates of parasitism of fruit flies by *D. longicaudata* (average 19%) in an area of South Mexico where fruit trees grew wild and it is tempting to conclude that these large parasitoid populations resulted from the absence of the effects of insecticides.

It is important, therefore, in integrated fruit fly control programmes, that effects of insecticides on the rate of parasitization of tephritids are also studied so that the effects of both chemical and biological control can be maximized. From the findings presented here, it is hoped that some progress may be made towards an integrated fruit fly management system in Nicaragua and Central America.

Acknowledgements

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