Pest Management in Horticultural Ecosystems,
Vol. 14, No. 1 pp 1-8 (2008)

POPULATION DYNAMICS AND ON-FARM FRUIT FLY INTEGRATED PEST MANAGEMENT IN MANGO ORCHARDS IN THE NATURAL AREA OF NIAYES IN SENEGAL

MBAYE NDIAYE[1], ELHADJI OMAR DIENG[1] and GILLES DELHOVE[2]

[1]National Plant Protection Service ; Km 15, Route de Rufisque. Box: 20054 Thiaroye, Dakar. Republic of SENEGAL

E-mail : mbaye52@hotmail.com, elhadjidien@yahoo.fr

[2]PIP/COLEACP ; Rue du Trône, 98 1050 Bruxelles

E-mail : Gilles.Delhove@coleacp.org

ABSTRACT: The trend of the population of fruit flies follows the dynamic of the rains. This is more perceptible in *Bactrocera invadens* (Drew) than in *Ceratitis cosyra* (Walker). From 350 individuals captured per trap, *B. invadens* seemed to disrupt the presence of C. *cosyra* and the other related fruit fly species. Such behavior is probably due to an interspecific competition and could be the fact that *C. cosyra* dominated emergences from the incubated fruits of alternate host plants up to 87 % even though *B. invadens* was observed.

Integrated pest management (IPM) package was tested which included:

(1) male annihilation using wood blocks soaked in insecticide (malathion 50 EC) and lure (methyl eugenol and terpinyl acetate),(2) protein hydrolysate bait applications (Success Appat at 1 liter per ha) and (3) sanitation (weeding and destroying of the collected fallen fruits by the following practices: using black plastic bags, burying in holes, burning on the ground surface and incinerating with a barrel transformed into incinerator).

Aim was to control fruit flies in mango orchards. Results showed a control as an inferred improvement in fruit fly infestations in the treated plot up to 83% compared to the untreated. From all above particular method implemented to destroy collected fruits, a reinforced black plastic bag would be recommended for popular use.

When we compare methyl eugenol to the home-made baits of grinded or ground nutmeg and NET, a beauty cream, we found that methyl eugenol attracted significantly *B. invadens*. Methyl eugenol's half life is also significantly longer (5 weeks) than the grinded nutmeg (less than 1 week) ($P = 0.0109$; $t = 9.4935$; $df = 2$). No capture was recorded in the NET based trap. In case of lack of methyl eugenol, the grinded nutmeg might be recommended as an alternative product to renew every week.

Key Words: Fruit fly, IPM, alternate host plants, bait.

INTRODUCTION

Previously unknown as a pest in Senegal, the fruit flies in particular *Bactrocera invadens* (Drew) and *Ceratitis cosyra* (Walker), (Diptera, fam: Tephritidae), are seriously threatening the fruit production, particularly mangoes. Actually there is already a rearing record from Dakar dating back to 1912 for *C. cosyra*, a species widespread through western, Central, Eastern and Southern Africa (De Meyer personal communication). *B. invadens* was observed in Kenya for the first time by Lux and *al*. (2003). From Asia, it invaded very quickly the African continent, where the indigenous natural enemies present are inefficient for a consequent control. Thus, fruit flies constitute a serious threat because they are: - A plague due to their fast proliferation and the presence of important populations in all the main fruit growing areas - An agronomic problem by their polyphagy and quarantine insect pest status, among others -A socio-economic problem involving income and job, national and international market sharing losses, non profitable investments, etc. Losses are very important and are approximately 41,000 tones of mangoes and the national production is around 100,000 tones. The situation is further complicated by the fact that the fruit flies are regarded as quarantine pest in most of the countries of the world. The detection of only one larva in the countries of destination, will involve the destruction of the batch which will cost 30,000 Euros per container, supported by the exporter.

Within this scope, an IPM package is implemented in the Niayes, Senegal. It is aimed at studying the population dynamics of the fruit flies in relation to the rainfall, the effectiveness of an IPM package against the infestation of the fruit flies and to compare the conventional lure methyl eugenol, a *Bactrocera* attractant to the home-made baits of grinded nutmeg and NET (beauty cream). Wild fruits were also incubated for the identification of eventual alternative host plants. It is expected for producers that after a short training by the National Plant Protection Service (NPPS) researchers, to carry out the routine operations themselves.

MATERIAL AND METHODS

Study site: The study was conducted from June 10 to October 1st in the rural community of Noto in the natural area of Niayes, the most important area of exportable horticultural products in Senegal (40 % of the mango orchards of Senegal and 60 % of exported mangos) For this study, three (3) orchards of late varieties, "Kent" and "Keit" are concerned. – (1) CADA limited Co., is a modern 70 ha of mango trees in which only one piece of 6 ha were used. This orchard is not supposed to receive any treatments. - (2) The orchard of Abdoulaye Diéne, a small producer of the village of Noto; it is isolated and belongs to an environment which is not more than 15 ha of mango trees. The various treatments were carried out in this orchard. Both orchards (CADA and Ablaye's) are 6 kms distant and located oppositely from the village of Noto. In the experiment, the orchard of Ablaye is called Noto. (3) In the last orchard (56 ha) selected in the village of Niague, the methyl eugenol were compare to the home-made baits of grinded nutmeg and NET.

Population dynamics of *B. invadens* and *C. cosyra:(1)* Trapping *B. invadens* males by methyl eugenol (ME): In one central hectare, 3 traps ("Tephri-trap") are laid out. And at the bottom of each of the trap, a ME dispenser is deposited and a strip of insecticide dichlorvos (DDVP) suspended on the nacelle adhering under the lid of the trap. Traps are suspended in mango trees on a branch of the lower third of the foliage at the Northern side to avoid a long exposure to the sun rays. The openings are well hung in order to facilitate the access of flies into traps. The branch being used as support has been coated with solid

grease, on 10 cm length on both sides of the string which suspends the trap, in order to prevent any predatory activity of ants on trapped adults of flies (died at the bottom of the trap). The ME dispensers and strips of insecticide are renewed every month by recovering residues in plastic bags and left out the field. ***(2)*** **Trapping male *Ceratitis* by terpenyl acetate (TA):** The same as above protocol with ME, has been used. ***(3)*** **Trapping Tephritidae females and males by food Traps Torula:** In one central hectare, 10 traps have been laid out on line, at rate of 1 trap/10 trees (70 m distant) for the follow-up of female populations. Four (04) pellets of hydrolyzed protein "Torula" are plunged in each trap filled with water at the three lower quarters to avoid the dryness of the pellets. The installation scheme of traps is identical to those with parapheromone. The renewal of the water-soluble pellets of Torula was done every 10 days. The FT is neither selective for one sex nor specific to a species. The different captures of the traps are individually collected every 10 days in small plastic bags for TA and ME while for FT, they were collected in tubes using flexible grips. Collected samples were identified by mentioning the date and the trap identification number. Captures are then sorted out at the laboratory to be counted and specified.

Incubation of fruits of potential host plants: Fruits of wild or cultivated plants are collected and incubated in small dishes filled with sandy soil obtained from dunes, humidified with water and then placed in wood cages (50x30x30cm). Daily observations are made to collect and identify the emerged adults.

I**ntegrated pest management (IPM) package: (1) Male Annihilation Technique (MAT)** using killer blocks that are wood blocks (5x5x1,25cm) soaked in insecticide (malathion 500 EC dose 4ml/block) and lures (methyl eugenol 1,25ml/blocks and terpinyl acetate 1,25ml/block)). Twenty (20) blocks were used for one (1) ha. Blocks were nailed on the trees but not deeply. A container was also fixed under some blocks to visualize captures. Every 30 days, the insecticide/lure mixture was applied with a brush on the exposed face of the block in the respect of the proportions of the above mixtures. **(2) Sanitation**: fallen fruits are supposed containing larvae and are consequently collected and destroyed by the following procedures: - **a)** putting fruits in black plastic bags (0,8X0.5 m) and leaving them under the sun light for 3 days - **b)** digging (1.5X1.5X1 m) and burying the fallen fruits in holes covered with minimum 30cm soil layer to avoid an emergence of adults - **c)** collecting fruits in heap and burning on the ground surface - **d)** weeding to eliminate eventual host plants - **e)** burning fruits in a transformed metal barrel (200 dm^3) used as incinerator. **(3) Bait Application Technique (BAT)**: these operations are carried out with "SUCCESS APPAT" at 0,24 g/l SC (new generation of pesticide has "spinosad", organic origin as active ingredient prepared with protein bait to create a synergy). One liter (1) of the formulation is diluted in 5 l of water for one ha. This volume is applied to the part of the lower layer of the foliage (1 m^2 approximately) with rotation around the tree while penetrating a little bite inside the foliage and avoiding to treat fruits. Treatments are renewed every 10 days and in case of a rain of 10 mm or more. *B. dorsalis* another species, was shown to be susceptible to spinosad (Stark et. al. 2004).

The impact of the IPM package is evaluated by comparing the orchards in Noto and CADA following the approach of Stonehouse and Verghese (2005) referring to the improvement of infestation level between both orchards, where I = U - T/U (I = improvement; U = untreated; T = treatment).

Comparison of effectiveness and duration of methyl eugenol, the nutmeg and the NET: With the increasing threat of the fruit flies in particular the *B. invadens*, and the lack of parapheromones in the national market, various initiatives were undertaken by the producers among which the uses of the dermal cream "NET" and the nutmeg (*Myristica fragrans*; fam: Myristicacea). The ME was used as reference to test the effectiveness

and the duration of both substances for comparison in a scoop of an IPM recommendation program for the extension agents. Three (3) traps are placed in the orchard of Niague following the principle above described to follow-up the importance of captures. The distance between traps was 50 m and each trap was allotted with a type of substance such as ME, NET, or crushed nutmeg; these three (3) substances attracting only *Bactrocera*. Traps are followed during 3 decades and at each decade, captures are reported. The half-life of substances are given according to the formula LN(0,5)/slope (Stonehouse and Verghese, 2005) and the *t* test used for a significant difference to separate means.

RESULTS AND DISCUSSION

Population dynamics of *B. invadens* and *C. cosyra*. The curve (Figure 1) represents the overall individuals trapped with parapheromone and food baits in CADA and Noto (Ablaye Diène). The rainfall seems to have an influence on the population dynamics of *B. invadens*. At the beginning of rainy season, it was noted that the populations of the fruit flies have increased by the first rain (20 mm). Following the curve trend, it was noted that during the last fortnight of July the population has decreased. This drop was attenuated by the important rainfall recorded at the end of July making possible the curve to reach the first peak. Thus, the reduction of populations has evolved from the second decade of August to the first decade of September following the rains intensity and frequency. After the 25 mm of the second decade of September, a new increase in the captures was re observed (Figure 1). This figure shows the variation of *B. invadens* outbreak following the trend of the rains.

As for *C. cosyra*, a slight peak of the curve was perceptible during the second decade of July, followed by a decreasing trend in the first decade of August despite the intensity of the rain (Figure 3).

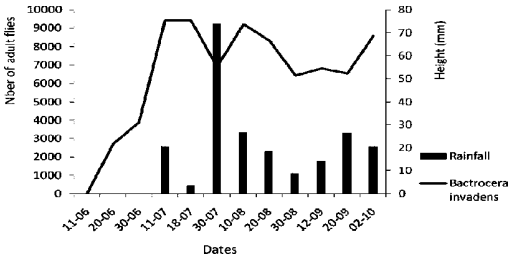

Figure 1: Population dynamics of *B. invadens* according to rainfall within the rural community of Noto (mango production season, 2007).

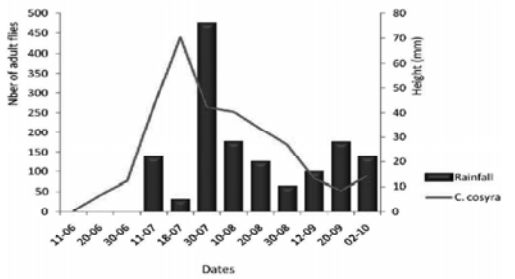

Figure 2: Population dynamics of *C. cosyra* according to rainfall within the rural community of Noto (mango production season, 2007).

The development of populations has been related to rainfall. Therefore, the number of individuals captured was higher from July 9 to August 20, the rainiest period (Figure 1 and 2) especially for *B. invadens,* the largely dominant species (Figure 3). The dependency on the rainfall conditions for *C. cosyra* was more obvious in the study carried out in 2004, period in which *B. invadens* was not yet invading. *C. cosyra* was found as the single fly pest recorded from the beginning to the end of the experiment. According to Vayssières (2004), the temperature and moisture have a direct effect on demography of the species but also an indirect effect by their incidence on the availability of plants hosts and the presence of natural enemies.

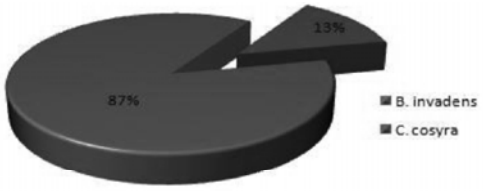

Figure 3 : Relative importance of the populations between B. *invadens* and *C. cosyra* in the rural community of Noto (mango production season, 2007).

Incubation of potential plant host fruits

Incubations of fruits of potential plant host fruits, as a source of infestation were made to observe emergences of flies. Results showed that most of emerged flies were *C. cosyra*. Thus, during the experiment, the low level of *C. cosyra* populations noted in both orchards and reported as the result of an interspecific competition might be confirmed by migrations of individuals towards other alternate host plants. Rearing results showed mango, loquat (Eriobotrya japonica), guava and grapefruit (Citrus · paradisi) to be the favored commercial host fruits for *B. invadens* (Mwatawala *et al*. (2006b). Such behavior could explain the fact that *C. cosyra* dominated emergences from the incubated fruits of alternate host plants up to 87 % even though *B. invadens* was observed (7.4%) then followed by *Dacus longistylus*, with 5.5%. *Dacus longistylus* is a specialized species in *Calotropus procera* (White, 2006) Where polyphagous tephritid species have been introduced in areas already occupied by a polyphagous tephritid, interspecific competition has resulted in a decrease in number and niche shift of the pre-established species (Duyck *et al*. (2006). The genus *Capparis* seems to be a preferential alternate host for these flies, compared to Cucurbitaceae. Complementary study is necessary to conduct a more complete inventory of the various host plants and to confirm the prevalence of the genus *Ceratitis* (Table 1).

Integrated pest management (IPM) package

At the beginning of the experiment, exceptional captures of 48 individuals were achieved in Noto with the ME in the first decade of June while in CADA, there were 19 individuals. In Noto, from July to October 10, the

Table 1: Results of emergences from incubated fruits

Types of incubated fruits		
Scientific name	**Number of incubated fruits**	**Number of Emerged flies**
Cucurbita pepo var. melopepo	2	5 *B. invadens*
Capparis corymbosa	20	53 *C. cosyra* - 2 *B. invadens*
Capparis decidua	20	19 *C. cosyra* - 2 *B. invadens*
Capparis tomentosa	20	43 *C. cosyra* - 1 *B. invadens*
Momordica balsamina	10	3 *C. cosyra* - 6 *B. invadens*
Cactus sp.	8	5 *C. cosyra*
Calotropis procera	13	12 *Dacus longistylus*
Psidium gayava	10	4 *B. invadens*
Citrullus lanatus	1	1 *B. invadens*
Cordyla pinata	14	65 *C. cosyra*

following captures were much less important (Figures 4 and 5). This low level may be due to applied methods of control to drop the fruit fly infestations, compared to the untreated orchard in CADA. The total captures of *B.invadens* and *C. cosyra* from the different trapping methods was 83.180 individuals in CADA and 14.009 in Noto, illustrating an improvement achieved in controlling up to 83% of the flies in Noto. It was also concluded that the combination of home-made-bait BAT with soaked-wood-block MAT, used cooperatively at village level, and in particular when combined with cultural methods, may reduce fruit fly losses by 90% or more under most conditions (Verghese *et al.* 2005). Thus, this result might be improved if the IPM was implemented as an area-wide control approach. The various methods used for destruction of the collected fallen fruits were effective but they have some constraints. The burying of fruits was time consuming and labor intensive. Burning fruits on the ground surface required large quantities of dry wood in this semi arid area, which leads to exclude this practice. Incinerators had the advantage to last but required paper or brushwood of dry grass and fuel to consume. Black plastic bags seemed more practical but tear very easily. Therefore, they need to be reinforced to resist and to enable an economical use. Similar studies were conducted on fruit infestations by *B. zonata* and *B. dorsalis* in India. Patel *et al.* (2005) found reductions in fruit infestations, relative to a low base infestation rate of 1%, of 80% by soil raking, 90% by field sanitation (fruit collection), 100% by MAT, 60% by BAT, 50% by cover sprays and 100% by MAT and by cultural controls and others in combination. Protection by cover and BAT sprays was not significant. The relationship between the orchard infestation level and its impact on the fruit infestation can be valuable information and might be an easy way to determine the damage involved. It has curiously been found that the total individuals of *C. cosyra* captured were more important in Noto than in CADA, where the ecosystem was more favorable to its swarming, similarly as *B. invadens* (Figure 4 and 5). Based on the average of 350 individuals captured per decade and per trap, the proliferation of *C. cosyra* seemed to be stopped by *B. invadens* through an interspecific competition. This particular situation has been illustrated by the populations' peaks in CADA recorded during the early 3rd decade of July and the mid-third decade of September in Noto and has confirmed the predominance of the newly introduced species, *B. invadens*. Apart *C. cosyra*, any other Ceratitidinae among those identified by Vayssieres (2004) has not been observed. According to Duyck *et al*. (2004), the data on tephritid invasions seem to support a hierarchical mode of competition; however, complete exclusion usually did not occur. Indeed, tephritid distribution and abundance are markedly structured by various abiotic (mostly climatic) and biotic (host plants) factors. No reciprocal invasions have been observed. Studies carried out in Kenya by Ekesi *et al*. (2006) mentioned that at most of the locations and especially at low elevations, *B. invadens* frequently shared the same fruit with the indigenous fruit fly species *C. cosyra* but often occurred at higher numbers than *C. cosyra*. The authors and Mwatawala et al. (2006a, b.) suggested that *B. invadens* is a predominantly lowland pest just like the Niayes area where the coastal sandy plain never reaches 50 m.

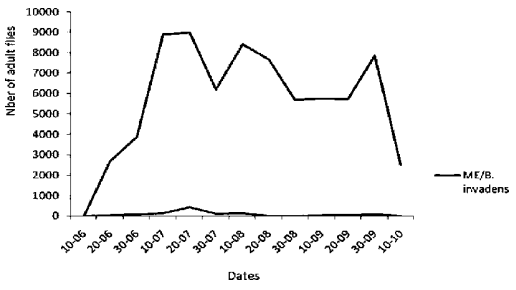

Figure 4 : Evolution of captures from ME and TA traps in CADA (2007)

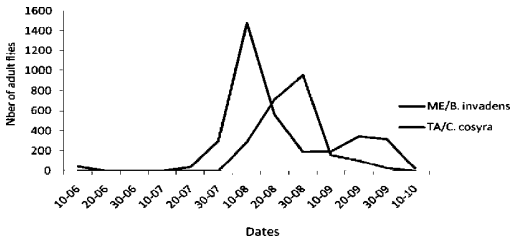

Figure 5: Evolution of captures from ME and TA traps in Noto (2007)

Comparison of the effectiveness and duration of methyl eugenol, nutmeg and NET

The ME presented a half life of 5 weeks (3,78 decades) compared to the grinded Nutmeg which is around one (1) week (0,66 decade). Because of the absence of captures, from the NET traps, its effectiveness and duration have not been included in the analysis. Decadal captures were 4639 made from ME and 56 from Nutmeg. Statistical analysis has shown a highly significant difference in effectiveness and duration of ME and Nutmeg ($P = 0.0109$; $t = 9.4935$; $df = 2$). The ME appeared as the more efficient substance in *B. invadens* males' annihilation technique. As well, the attractiveness of ME was longer than the Nutmeg's. However, in case of a lack of methyl eugenol, the grinded nutmeg might be recommended as an alternative product to be renewed every week. There were no captures recorded in the NET based trap (Table 2).

Conclusion and recommendations

B. invadens and *C. cosyra* populations followed the dynamics of the rains, since the number of the captures was more important during the rainiest period from July 9th to August 20th. This tendency is more perceptible on *B. invadens* than on *C. cosyra*. *B. invadens* seemed to displace *C. cosyra*. ME appeared as the best substance in the capture of the males of *B. invadens* compared with the NET, a beauty cream and the grinded Nutmeg. The nutmeg can be recommended as an alternative solution where there is a lack of ME or when the price makes it inaccessible for the small producers. In case that the nutmeg is used, it must be renewed every week. The IPM package results illustrate improvement achieved in controlling fruit flies infestation level to 83 % in Noto (treated plot) compared to CADA's orchard (untreated plot). Thus, if measures were taken on time in an area-wide approach, the level of control could be improved. Related to the processes used to destroy fallen fruits, the black plastic bag might gain to be popularized only after improvement of its resistance. Following the results obtained, this demonstration opens prospects and need to be pursued. The study of the relationships between the orchard infestation level and its impact on the fruit infestation need to be investigate to find an easy way for damage evaluation. This work allowed a beginning of the identification of some of the alternate hosts of *B. invadens* and *C. cosyra* but also to observe a specialized *Dacus*

Table 2: Results of three (3) decades trapping of *B. invadens* from ME, nutmeg and NET

Decadal period	Number of captures by types of substances		
	ME	NUTMEG	NET
1	1750	24	0
2	1677	29	0
3	1212	3	0
TOTAL	4639	56	

longistylus in *Calotropus procera*. It needs to be pursued with the estimates of the economic losses due to the fruit flies.

ACKNOWLEDGEMENTS

We thank Mame Ndéne Lo, Director of the NPPS for logistic. Assane Diop, Maxime Diatta and Mody Gaye for field assistance. This research was supported in part by PIP/CLEACP with participation of the agrochemical industries SPIA, and Polychimie (Dow AgroSciences) Senegal. I acknowledge the suggestions made by Marc De Meyer on an earlier draft and Mahécor Diouf and Dr. Abraham Verghese (India) for critical review of the manuscript.

REFERENCE

Duyck, P.F., David, P. And Quilici, S., 2006. A review of relationships between interspecific competition and invasions in fruit flies (Diptera: Tephritidae). La Reunion island, France and [2]Centre d'Ecologie Fonctionnelle et Evolutive, CNRS UMR 5175, Montpellier, France.

Ekesi, S., Nderitu, P. W., Rwomushana, I., 2006. Field infestation, life history and demographic parameters of the fruit fly Bactrocera invadens (Diptera: Tephritidae) in Africa. *Bulletin of Entomological Research*. 2006 Aug;96(4):379-86. PMID: 16923206 [PubMed - indexed for MEDLINE]

Lux S. A., Copeland R. S, White I. M., Manrakhan A., and Billah M. K., 2003. A new invasive fruit fly species from the *Bactrocera dorsalis* (Hendel) group detected in East Africa. Insect Science and its Application, 23(4), 355-361.

Mwatawala, M. W., De Meyer, M., Makundi, R. H., and Maerere A. P., 2006a. Biodiversity of fruit flies (Diptera, Tephritidae) in orchards in different agroecological zones of the Morogoro region, Tanzania. *Fruits,* vol. 61, p. 321–332 (2006).

Mwatawala, M. W., De Meyer, M., Makundi, R. H., and Maerere A. P., 2006b. Seasonality and host utilization of the invasive fruit fly, Bactrocera invadens (Dipt., Tephritidae) in central Tanzania. *Journal of Applied Entomology*. 130(9-10), 530–537.

Patel, R.K., Verghese, A., Patel, V.M. , Joshi, B.K. Stonehouse, J.M., and Mumford, J.D., 2005. Bait, lure and cultural IPM of fruit flies in mangoes un Gujarat. *Pest Management in Horticultural Ecosystems*, Vol. 11, No. 2 pp 155-158 (2005)

Stark, J. D., Vargas, R. and Miller N., 2004. Toxicity of spinosad in protein bait to three economically important tephritid fruit fly species (Diptera: Tephritidae) and their parasitoids (Hymenoptera: Braconidae). *Journal of Economic Entomology*. 2004 Jun; 97(3) : 911-5.

Stonehouse, J. M. and Verghese, A.; 2005. The selection and Presentation of Variables in fruit fly IPM research. Pp 83-87. In AAPMHE. *Pest Management in Horticultural Ecosystems*. Vol. 11 N°2 Special issue on fruit fly. AAPM, Bangalore, India.

Vayssières, J. F., 2004. Rapport de mission sur une formation générale sur les Tephritidae du manguier au Sénégal. COLEACP/PIP, CERES/DPV, Dakar, Sénégal, 31p.

Verghese, A., Mumford, J.D., Stonehouse, J.M., Patel, R.K., Jhala, R.C., Patel, Z.P., Thomas, J., Jiji, T., Singh, H.S., Satpathy and S., Shukla, R.P. 2006. Integrated management of fruit flies in India : 7th International Symposium on Fruit Flies of Economic Importance, September 10-15, 2006, Salvador, Bahia, Brazil.

White I.M., 2006. Taxonomy of the Dacina (Diptera: Tephritidae) of Africa and the Middle *East African Entomological Memoirs*. 2 (2006) 7–156.