



Effective chemical control of fruit flies (Diptera: Tephritidae) pests in mango orchards in northern Côte-d'Ivoire

Ossey Robert N'DEPO^{1,2*}, N'klo HALA¹, Achille N'DA ADOPO¹, Felix COULIBALY¹,
Philippe Kouassi KOUASSI³, Jean-François VAYSSIERES⁴ et Marc DE MEYER⁵

¹Centre National de Recherche Agronomique (CNRA), 01 BP 1740 Abidjan 01, Côte d'Ivoire.

²Laboratoire de Biologie et Physiologie Animale, UFR Agroforesterie,
Université Jean-Lorougnon Guédé, Daloa, Côte d'Ivoire.

³Laboratoire de Zoologie-Biologie Animale, UFR Biosciences-22 BP 582 Abidjan 22, Côte d'Ivoire.

⁴Cirad, UPR Fruit Production, IITA Biological Control Center for Africa,
08 BP 0932, Tri Postal, Cotonou, Benin.

⁵Head Entomology Section Royal Museum for Central Africa Leuvensesteenweg 13 B-3080 Tervuren, Belgium.

* Corresponding author, E-mail: osseyndeporob@yahoo.fr

ABSTRACT

Fruit flies are major pest in West Africa. In Côte-d'Ivoire, they caused heavy losses. Thus, preventive measures are taken to reduce their damage. The objective was to evaluate the effectiveness of *Success Appat*[®] and *Proteus 170 O-TEQ* against fruit. Traps baited with sexual attractants were set in mango orchards and their contents were collected each week. Bait and insecticide were renewed each month. Three orchards were treated with *Success Appat*[®] and three with *Proteus 170 O-TEQ*, respectively and their untreated orchards were selected. Mangoes were collected in treated and untreated orchards to assess the attack and infestation rates of orchards. Eight species of fruit flies were recorded. *Bactrocera invadens* was highly captured in different orchards. Orchards treated with *Success Appat*[®] have a lower rates of attack ($11.7 \pm 3.52\%$) and infection (02.32 ± 1.6 pupae/ kg.f) than the untreated orchards, ($41.05 \pm 7.6\%$) and (34.4 ± 8.18 pupae/ kg.f), respectively. Equally, orchards treated with *Proteus 170 O-TEQ* showed lower rates of attack ($13.59 \pm 5.38\%$) and infection (05.86 ± 4.08 pupae/ kg.f) than untreated ($47.37 \pm 10.95\%$) and (44.72 ± 15.64 pupae/ kg.f), respectively. Insecticides *Success Appat*[®] and *Proteus 170 O-TEQ* significantly reduced the damage of fruit flies in orchards.

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INTRODUCTION

Fruit flies are major pest problem in West Africa, especially in Côte-d'Ivoire (Hala et al., 2006; N'dépo et al., 2009). These insects attack a wide range of fruit trees varieties, including citrus and berries (Mwatawala et al., 2004; Drew et al., 2005; Quilici et al., 2005 ;

Anonymous, 2006; Mwatawala et al., 2006; N'dépo, 2006; Quilici, 2007). These flies cause severe damage to fruit from 12 to 60% or even 80% of loss (Vayssières et al., 2005; N'dépo, 2010; N'dépo et al., 2010). Moreover, the economic loss is estimated to about \$100 million of \$ 850 million of an annual fruit

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production in Australia (White and Elson-Harris, 1992) and € 2.5 million per year by *Ceratitidis capitata* on fruit production in Madeira Island, South Africa (Dantas et al., 2002). Due to their enormous damage and their status of quarantine insects, fruit flies constitute major obstacle to the free movement of fresh vegetables in the world (Anon, 1994). Thus, preventive measures are developed and implemented to reduce the damage. Unfortunately, these measures are mostly out of reach of African farmers because of the expensive cost and lack of adequate infrastructure for their implementation. However, spot treatments with *Success Appat*[®], frequently made in Reunion in citrus orchards, are being implemented in mango orchards in West Africa. Thus, in the context of "regional project against fruit flies in West Africa", the spot treatments with *Success Appat*[®] in mango orchards by Vayssières et al. (2009a), gave satisfactory results. This study consequently aimed at evaluating the effectiveness of *Success Appat*[®] and *Proteus 170 O-TEQ* in mango orchards by using the method of chemical control, to the approval of these products and to advise producers of fruits, flowers and vegetables in Côte-d'Ivoire.

MATERIALS AND METHODS

Sites of study

The study was conducted in the northern region of Côte-d'Ivoire; the main area of production of export mangoes. The climate is of Sudanese type, with an annual temperature of 25.5 °C and rainfall of 1100 mm. Three different mango orchards from 1 to 3 hectares were treated with *Success Appat*[®]. The treated orchards were located in Napié (09°17' N - 05°35' W), Karakoro (09°21' N - 05°32' W) and Waraniéré (09°32' N - 05°41' W). As well, three other mango orchards treated with *Proteus 170 O-TEQ* were located in Napié (09°16' N - 05°34' W), Téguré (09°20' N - 05°22' W) and Nagbanakaha (09°24' N - 05°36' W). For each treatment, one untreated mango orchard wider

than 3 hectares was selected in each area. The distance separating the treated from the untreated orchards was more than 500 m. This area was not covered by crop unsusceptible to chemical control such as cotton *Gossypium hirsutum* L.

Trapping of natural populations of fruit flies

The dry Tephri and McPhail traps containing specific sexual attractants (methyl eugénol and terpinyl acetate) and an insecticide dichlorvos (DDVP), were laid out in the selected orchards. Each trap was labelled with the first letters of each lure. Attached on a branch of mango tree with a wire, the traps were suspended at about 1.60 to 1.80 m above ground to maximize the capture, away from sunlight and foliage to facilitate entrance of flies in traps. The traps' density was 2 traps per orchard separated with an optimal distance of 50 m (Vayssières et al., 2005; N'dépo et al., 2010; 2013). A total of 22 dry traps were used to cover the six orchards. The sexual attractants and insecticide were renewed every month. The different captures of the traps were separately collected every week. The collected insects were identified in the laboratory by using an identification guide (De Meyer, 2000; Ekesi and Billah, 2007).

Insecticide application

Phytosanitary treatments were applied when one of the three conditions is satisfied: the fruit ripening stage was reached (sensitive stage to fruit fly attack); one of the invasive fruit fly *Bactrocera invadens* was captured; or twenty *Ceratitidis cosyra* were captured.

Spots treatments with the *Success Appat*[®]

One liter of formulated product "*Success Appat*[®]" or "*GF-120*" [a.m: spinosad (0.24 g/l)] was taken and dissolved in 5 l of water (1:5 dilution) for 1 ha (Dow AgroSciences, 2001; Anonymus, 2008). Partial coverage treatment (1 m² leaf area) was applied with a manual pressure sprayer SOLO 425 (capacity 15 l), rotationally around



the tree, inside the canopy sheets avoiding fruits. All the trees of the field were treated and the application was renewed every week or after a heavy rain until the end of the fruit harvest. Each treated orchard (100 trees treated averagely) was a repetition.

Total treatment with the Proteus 170 O-TEQ

Proteus 170 O-TEQ (a.m: 20 g/l deltamethrin and 150 g/l thiacloprid) was applied at rate of 5 ml per tree according to the recommendation of 500 ml ha⁻¹. 40 ml of the product were dissolved in 2 l of water. The mixed liquid was supplemented with 12 l of water and sprayed with the atomizer SOLO 423. The treatment was done by a homogeneous dispersion of the product in all parts of the tree with a high flow. The plots of large surface (≥ 1.5 ha) were subdivided into elementary fields. The trees of each elementary plot were treated with a frequency of 21 days. Each treated orchard (100 trees treated on average) was a repetition (N'Dépo, 2010).

Evaluation of the effectiveness of treatments

To evaluate the effectiveness of the products, the fruits were taken randomly from different treated and untreated plots separately. Infested fruits were identified and counted among picked fruit. The economic impact (ratio between the number of infested fruits and the total fruits collected per treatment), expressed as a percentage, was calculated using the formula below:

$$IE (\%) = (NFI \times 100) / NFT$$

IE= economic impact, NFI= number of infested fruits, NFT= total fruits

Statistical analysis

Weekly average capture of fruit flies per orchard was subjected to analysis of variance (ANOVA) at the 5% threshold. The

averages are classified according to Tukey's test.

The rate of attack and infestation of treated and untreated orchards and abundance of each species in treated and untreated orchard were compared with Fisher t-Test using the STATISTICA V.7.1 software.

RESULTS

***Success Appat*[®] treatment and specific composition of fruit flies**

Eight species of fruit flies have been identified in treated orchards with *Success Appat*[®] and untreated orchards. These included *Bactrocera invadens*, *Ceratitis cosyra*, *Ceratitis breinii*, *Ceratitis punctata*, *Ceratitis anonae*, *Ceratitis rosa*, *Ceratitis ditissima* and *Trirhithrum coffeae*. The invasive fly *B. invadens* was the most abundant species caught. The average capture was 186.48 ± 37.95 flies per week, 186.9 ± 38.98 flies per week respectively in treated orchards and untreated orchards. The capture of other species fluctuates between 0.01 and 15.66 flies per week. The relative abundance of *C. cosyra* species with 7.35 ± 1.95 and 15.66 ± 4.90 individuals per week in treated and untreated orchards and *C. breinii* with 6.52 ± 2.05 and 4.43 ± 1.27 individuals per week in treated and untreated orchards was not statistically different. However, there was significant difference ($P < 0.05$) between the abundances of *C. rosa* in untreated and treated (Table 1). The analysis of variance revealed a highly significant difference ($P = 0.000$) between species abundance in the different orchards (Table 1). However, the comparison the abundance of flies in treated orchards with *Success Appat*[®] and untreated orchards is not statistically significant ($P = 0.95$) (Table 1).

Proteus O-TEQ 170 treatment and specific composition of fruit flies

Seven species of fruit flies have been identified in treated orchards with *Proteus 170 O-TEQ* and untreated orchards. These were *B. invadens*, *C. anonae*, *C. cosyra*, *C. breinii*, *C.*



rosa, *C. punctata* and *C. capitata*. Invasive species *B. invadens* was more abundant in orchards compared to other species. This average capture was 519.02 ± 77.06 individuals per week, 968.49 ± 127.33 individuals per week respectively in treated orchards and untreated orchards. The capture of other species fluctuates between 0.06 and 152.65 individuals per week. The analysis of variance revealed a highly significant difference between species abundance ($P = 0.000$) (Table 2).

At the treated and untreated orchards, statistical treatments reveal a significant difference in the abundance of *B. invadens* ($P=0.003$) (Table 2). It was the same for minority species *C. cosyra* and *C. punctata* whose abundance in untreated orchards and treated orchards was statistically different ($P < 0.01$). Overall, the comparative study of the abundance of species of flies in treated and untreated plots revealed a high significant difference ($P = 0.008$) (Table 2).

Attack and infestation level with *Success Appat*[®] treatment

An important attack rate (economic impact) of fruits was observed during 2009 and 2010 in unsprayed orchards. Application of *Success Appat*[®] dropped dramatically the rate of attack. In fact, it was estimated to $11.70 \pm 3.52\%$ in treated orchards against $41.05 \pm 7.60\%$ in untreated orchards; about 3.5 times lower than the one of untreated orchards. The t-test detects a highly significant ($P < 0.01$) difference between the attack rate in treated and untreated orchards (Table 3).

An important infestation rate also was recorded in treated orchards. In 2009, average of infestation rate was higher in untreated orchards with 25.68 ± 6.4 pupae/kg of fruits than the one in treated orchards (17.76 ± 5.06

pupae/kg of fruits). However, this difference was not statistically significant ($P > 0.05$). In opposite, in 2010, the difference between the averages of infestation rate in untreated and treated orchards was statistically significant ($P < 0.01$). Infestation rate was 2.33 ± 1.60 and 34.4 ± 8.18 pupae/kg of fruits respectively in treated and untreated orchards, representing about 14.7 times the infestation rate average of treated orchards (Table 3).

Attack and infestation level with *Proteus 170 O-TEQ* treatment

The attack level of treated orchards with *Proteus 170 O-TEQ* during 2009 and 2010 was significantly lower than the one in untreated orchards. In 2010, the average rate in untreated orchards was estimated to $47.37 \pm 10.95\%$ representing about 3.41 times the infestation rate in treated orchards which was $13.59 \pm 5.38\%$. Generally, the attack rate was estimated to $8.82 \pm 3.61\%$ in treated orchards and $33.28 \pm 7.88\%$ in untreated orchards. The statistical analysis gave a highly significant ($P < 0.01$) difference between the attack level in the orchards (Table IV). Important variation was observed on infestation rates of orchards. The infestation load of treated fruits with *Proteus 170 O-TEQ* was 13.92 ± 10.25 pupae/kg of fruits and 5.86 ± 4.08 pupae/kg of fruits respectively in 2009 and 2010. In untreated orchards, the infestation load was 98.67 ± 23.3 pupae/kg of fruits and 44.72 ± 15.64 pupae/kg of fruits in 2009 and 2010, respectively. Thus, the infestation load in untreated orchards was more than 7 times the one of treated orchards. Statistical analysis showed a highly significant ($P < 0.01$) difference between infestation loads in treated and untreated orchards (Table 4).



Table 1: Effect of *Success Appat*[®] treatment on average capture of fruit flies in mango's orchards.

Species	Treated orchards (SA)	Untreated orchards	Probability
<i>B. invadens</i>	186.48 ± 37.95 ^b	187.9 ± 38.98 ^b	P= 0.98
<i>C. anonae</i>	0 ± 0.0 ^a	0.03 ± 0.02 ^a	P= 0.16
<i>C. breinii</i>	6.52 ± 0.4 ^a	4.43 ± 1.27 ^a	P= 0.39
<i>C. cosyra</i>	7.35 ± 1.95 ^a	15.66 ± 4.9 ^a	P= 0.12
<i>C. ditissima</i>	0.01 ± 0.01 ^a	0.01 ± 0.01 ^a	P= 1
<i>C. punctata</i>	0.03 ± 0.02 ^a	0.03 ± 0.02 ^a	P= 1
<i>C. rosa</i>	0.03 ± 0.02 ^{a*}	0.22 ± 0.07 ^{b*}	P= 0.02
<i>T. coffeae</i>	0.01 ± 0.01 ^a	0 ± 0.0 ^a	P= 0.31
Probability (P)	P=0.0000	P=0.0000	
Fisher t-Test		P= 0.95	

SA: *Success Appat*[®], (*): P < 0.05.

ANOVA at 5%, means in column followed by the same letter are not significantly different.

Fisher t-Test 5%, means in row followed by the asterisk are significantly different.

Table 2: Effect of *Proteus 170 O-TEQ* treatment on average capture of fruit flies in mango's orchards.

Species	Treated orchards (PRO)	Untreated orchards	Probability
<i>B. invadens</i>	514.02 ± 77.06 ^{a***}	968.49 ± 127.3 ^{b***}	P= 0.003
<i>C. anonae</i>	0 ± 0.0 ^a	0.1 ± 0.07 ^a	P= 0.16
<i>C. breinii</i>	4.14 ± 1.31 ^a	4.83 ± 1.14 ^a	P= 0.69
<i>C. cosyra</i>	29.12 ± 6.09 ^{a***}	152.65 ± 35.01 ^{b***}	P= 0.001
<i>C. capitata</i>	0 ± 0.0 ^a	0.06 ± 0.06 ^a	P= 0.33
<i>C. punctata</i>	0 ± 0.0 ^{a*}	0.64 ± 0.27 ^{b*}	P= 0.02
<i>C. rosa</i>	0.06 ± 0.06 ^a	0.1 ± 0.07 ^a	P= 0.66
Probability	P=0.0000	P=0.0000	
Fisher t-Test		P= 0.008	

PRO: *Proteus 170 O-TEQ*; (**): P < 0.01; (*): P < 0.05; ANOVA at 5%, means in column followed by the same letter are not significantly different; Fisher t-Test at 5%, means in row followed by the asterisk are significantly different.**Table 3:** Attack and infestation rates of mango's orchards treated with with *Success Appat*[®].

Treatment	Attack rate (%)			Infestation rate (pupae/kg fruits)		
	Years					
	2009	2010	Average	2009	2010	Average
PSA	16.01 ± 6.69 ^a	8 ± 3.03 ^a	11.7 ± 3.52 ^a	17.76 ± 5.06 ^a	2.33 ± 1.6 ^a	9.45 ± 3.25 ^a
Control plots	24.92 ± 10.05 ^a	54.87 ± 8.35 ^b	41.05 ± 7.6 ^b	25.68 ± 6.4 ^a	34.4 ± 8.18 ^b	30.38 ± 5.25 ^b
Probability	P= 0.48	P= 0.000	P= 0.002	P= 0.36	P= 0.002	P= 0.002

PSA : Treated plots with *Success Appat*[®]; Means affected by the same letter in column are not significantly different.

Table 4: Attacks and infestation Rates of mango's orchards treated with *Proteus 170 O-TEQ*.

Treatment	Attack rate (%)			Infestation rate (pupae/kg fruits)		
	Years					
	2009	2010	Average	2009	2010	Average
PPRO	4.83± 4.64a	13.59± 5.38a	8.82± 3.61a	13.92± 10.25a	5.86± 4.08a	10.26± 5.77a
Control plots	21.53± 9.33b	47.37± 10.95b	33.28± 7.88b	98.67± 23.3b	44.72± 15.64b	74.15± 16.27b
Probability	P= 0.14	P= 0.02	P= 0.01	P= 0.008	P= 0.04	P= 0.001

PPRO : Treated plots to *Proteus 170 O-TEQ*;

Means affected by the same letter in column are not significantly different.

DISCUSSION

Fruit flies associated with mango such as *Bactrocera invadens*, *Ceratitits cosyra*, *Ceratitits breinii* were present in varied proportions in orchards under insecticide control (*Proteus 170 O-TEQ* and *Success Appat*[®]) and unsprayed orchards. The early appearance of *C. cosyra* species from mid-March corresponds to the period of full maturity of mango variety *Amelie* (Vayssières et al., 2005, 2008, 2009b,c). Its appearance is shortly followed by the emergence and proliferation of the semi-late species *B. invadens* (N'dépo et al., 2009, 2013). The latter species exert a strong parasite pressure on other native species, which could be the reason of its important presence in mango orchards, particularly in mangoes. In treated and untreated orchards, the species *Bactrocera invadens* remained the major species with significantly higher population than that of others species, especially that of *Ceratitits cosyra*, formerly major in orchards (Hala, 2001). The high proportion of *Bactrocera invadens* in treated orchards, can be explained on one hand, by a high invasion of orchards, followed by a high emergence rate of flies from pupae and, on other hand, by the late application of insecticides (early April) in too infested orchards by fruit flies. The low proportion of other species (minor species) in treated orchards could be due in addition to the intense interspecific competition between *B. invadens* and those latest (Duyck et al., 2004, 2006 and 2007),

their sensitivity to insecticides. In fact, according Evdoxia et al. (2009), Spinosad is a new insecticide derived from a soil bacterium *Saccharopolyspora spinosa* Mertz & Yao, which is effective against a wide range of insects, including the olive fly *Bactrocera oleae* Rossi. According to these authors, this new generation of insecticides acts by ingestion or contact with insects, specifically at a site of nicotinic acetylcholine receptor firstly and secondly in the Gamma-Aminobutyric acid (GABA). Thus, it greatly reduces the attack rate of mangoes and consequently, the infestation rate of fruits in treated orchards through the death of poisoned fruit flies (Dow AgroSciences, 2008). Although the level attack and infestation of orchards treated with *Success Appat*[®] was low in 2009, this was not statistically significant. These results are close to those of Vayssières et al. (2009a) who applied *Success Appat*[®] and revealed a highly significant difference between the damage reduction rate of untreated and treated orchards in 2006 and 2007 in Benin. It is explained by a wrong manipulation of insecticide produced during the test plots. In terms of productivity, the treated orchards with *Success Appat*[®] were higher than that of untreated orchards yield (N'dépo, 2010). Application of *Proteus 170 O-TEQ* significantly reduces the attack and fruit infestation rate in mango orchards. This new generation of insecticide with two complementary active ingredients deltamethrin (20 g/l) and thiacloprid (150 g/l)

is recognized for its effectiveness in the control of a large number of pests (Anonymous, 2009a). It reduces the rate of damage caused to the mango just like *Success Appat*[®]. As demonstrated, both products reduced the damage caused by fruit flies in orchards and are effective against fruit flies (Anonymous, 2009b).

Conclusion

Eight species of fruit flies have been identified in mango orchards. Among these pests, the species *B. invadens* and *C. cosyra* are most abundant in northern of Côte-d'Ivoire with a large proportion of invasive fly. The attack and infestation rate in orchards sprayed with *Success Appat*[®] and *Proteus 170 O-TEQ* were significantly lower than those of untreated orchards. These products have significantly reduced the attacks rate in treated orchards. Products *Proteus 170 O-TEQ* (dose: 0.5 l ha⁻¹) and *Success Appat*[®] (dose: 1 l ha⁻¹) were effective in the control of fruit flies and improved production yield.

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