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Original Research

Effectiveness of IPM (Insect Pest Management) integrated control strategies in the control of fruit flies (Tephritidae) from three agro-ecological zones of Côte d'Ivoire

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ABSTRACT:

The mango is the top second fruit exported by Côte d'Ivoire. More than 95% of the exported volumes are destined for the European market. This production was confronted with many sanitary problems such as the damage of fruit flies which are formidable insect pests of mangoes and other fruits in Côte d'Ivoire. In order to effectively control fruit flies, a test to evaluate the effectiveness of combining different IPM methods was carried out in the three agro-ecological production zones of mango. In each zone, the four combinations were tested in comparison with a control orchard that did not receive any IPM technologies. Four fruit samples were taken: one at the beginning, two in the middle and one at the end of the experiment. A total of 100 mangoes were randomly collected from each orchard. Those that were pitted were counted and incubated in the laboratory. The results obtained from the three areas showed that the level of mango infestation was low in the orchards where the combinations were tested *viz:* sexual attractant trapping + Food bait (GF-120) + Sanitation (0.1 pupae/fruit); Sanitation + Food bait (0.25 pupae/fruit); Sexual attractant trapping + Sanitation (0.3 pupae/fruit); Sexual attractant trapping + Food bait (0.45 pupae/fruit) respectively. On the other hand, in the untreated plots, infestation levels were high (6 pupae/fruit). In addition, the protection percentages revealed that the sexual attractant trapping + food bait + sanitation system recorded the highest percentage of orchard protection (95%). Next came sanitation + GF-120 combination (92%), followed by sexual attractant trapping + sanitation" (90%) and sexual attractant trapping + GF-120 (88%) combinations. However, statistical treatments (P>0.05) showed that there was no significant difference between the percentages of protection.

Keywords:
Agro-ecosystem, Integrated pest management, Tephritidae, Cote d'Ivoire.

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INTRODUCTION

The mango is the second most important fruit exported from Côte d'Ivoire after the banana. On international markets, Côte d'Ivoire is the second largest supplier of mangoes after Brazil. More than 95% of the exported volumes are destined for the European market. The quantities exported over the last five years have increased from 10,179 tonnes in 2011 to more than 33,000 tonnes in 2017 (Beaudelaire, 2017). Unfortunately, the fruit sector in Côte d'Ivoire is facing heavy economic losses due to numerous attacks by insect pests (White and Elson-Harris, 1992). Health problems lead to a reduction in the quantity of mangoes exported, poor fruit quality and a shortening of the season. To reduce the impact of fruit flies, growers and exporters prefer to harvest mangoes before the start of the rainy season, which is a very favourable time for fruit fly outbreaks. Also, the requirements of international markets in terms of the quality of agricultural products, environmental concerns and consumer health are all factors that no longer favour the application of chemical control. The strategy is therefore to develop effective methods that are compatible with environmental concerns. For better fruit fly management, it is essential to promote a set of effective, efficient, compatible and economically viable control methods for transfer to growers (Vayssières *et al*., 2009a). Among the main IPM methods promoted (IPM-package) that can reduce fly population levels are: sanitary orchard harvests, treatments with success appat (GF-120), mass trapping using different products such as timaye and biological control using predators (*Oecophylla longinoda* Latreille) and parasitoids (*Fopius arisanu*s Sonan) (Vayssières *et al*., 2009a). This integrated pest management approach based on a combination of techniques could effectively reduce the mango fruit fly population. However, the effectiveness of the different combination possibilities as well as their cost-effectiveness has not been demonstrated. The aim of this study was to identify the best possible combinations for a good cost-effectiveness ratio.

MATERIALS AND METHODS

Experimentation sites

Integrated pest management tests were implemented in the three agro-ecological mango production zones viz: North-East, Center and North-West (Table 1). In each zone, five sites (orchards) were selected for the study, for a total of fifteen orchards. The distance between the orchards in each area was at least 500 m.

Experimental apparatus

IPM control trials have been implemented with the close collaboration of producers. The control trials used in this study are as follows: the collection of fallen fruit in the orchards concerned is done once a week. The fruits collected were put in "Augmentium" whose principle is to prevent the flight of flies but to let fly their natural enemies. In addition to the augmentium, black plastics have been used for the destruction of fallen fruit. TIMAYE sexual attractants were placed in local traps placed 2-4 m above the ground, in the canopy in the shade to prevent the sun from degrading the product. The attractants were renewed once a month. Forty-five traps were used to make a phytosanitary seat belt around

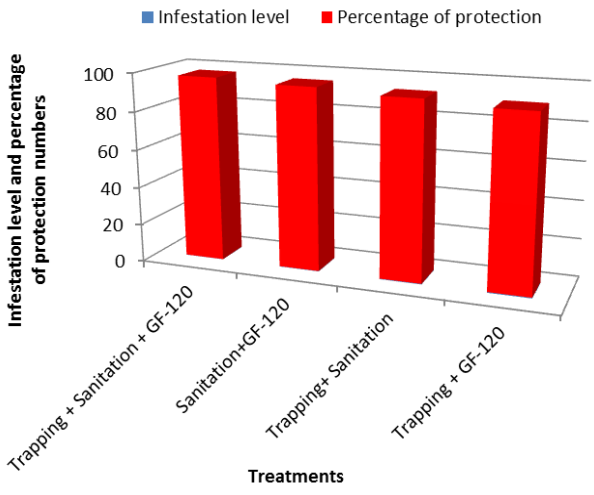

Figure 1. Fruit infestation level and the percentage of orchard protection

Table 1. Geographical location of the sites

Zones	Sites	Longitude	Latitude	Altitude
Northeast	1	09°40.135'N	005°45.911'W	402 m
	2	09°36.007'N	005°24.038'W	374 m
	3	09°35.265'N	005°13.182'W	385 m
	4	09°21.829'N	005°38. 620'W	412 m
	Witness	09°25.505'N	005°41.405'W	422 m
Center	1	08°50.394'N	005°10.988'W	380 M
	2	08°49.893'N	005°13.830'W	420 m
	3	09°07.214'N	005°13.421 W	441 m
	4	08°53.057'N	005°14.812'W	437 m
	Witness	08°39.975'N	005°12.506'W	340 m
North West	1	09°39.932' N	006°29.327'W	437 m
	2	09°38.339'N	006°29.875' W	355 m
	3	09°31.953'N	006°29.875 W	355 m
	4	09°32.377'N	006° 29.508' W	425 m
	Witness	09°32.033' N	006°.326' W	436

the orchard.

Success bait food bait (GF120) was used at a dose of one liter / ha by the spot treatment method once a week for two months. The treatments started a few weeks before the fruit ripened and were carried out until harvest. The spot treatment consisted in partially treating the foliage with a sprayer dispersing droplets of 4-6 mm in diameter on the leaves of the lower layer of each tree during production. The foliage was treated on an area of about 1 m^2 at breast height until the first drops drips. The Success Bait was diluted in water before spraying. A dilution of 1: 5 (GF-120 NF: water) was used. The study therefore consists in testing the effectiveness of four combinations in the fight against fruit flies. The combinations tested are: "trapping by sexual attractants + food bait GF120"; "Attractive sexual trapping + Pickup"; "Collection + food bait GF120"; "Sexual attractants trapping + food bait GF120 + Collection". In each area, the four treatments (due to an IPM combination per orchard) were tested in comparison with a control orchard that did not receive the technologies.

Evaluation of the effectiveness of combinations

To assess the effectiveness of the different combinations on fruit flies, fruits were collected from the treated orchards. During the experiment, four fruit samples were taken at the start, two in the middle and one at the end of the experiment. For each sampling, 10 fruits per tree were collected from 10 trees chosen at random from each orchard, for a total of 100 fruits per orchard. The sampled fruits were brought back to the laboratory, weighed and incubated individually in boxes. For each orchard, the infestation rate was evaluated in number of pupae/kilograms of fruit in comparison with the control orchard. The level of fruit infestation which is the ratio between the number of pulps collected and the total weight of the sample was determined. The formula used is as follows:

$$\text{Infestation level (Pulps / kg)} = \frac{\text{Number of pulps collected}}{\text{Total mango weight in kg}}$$

Statistical analyzes

The collected data were statistically processed by an analysis of variance to compare the different treatments using Statistical Package for the Social Sciences

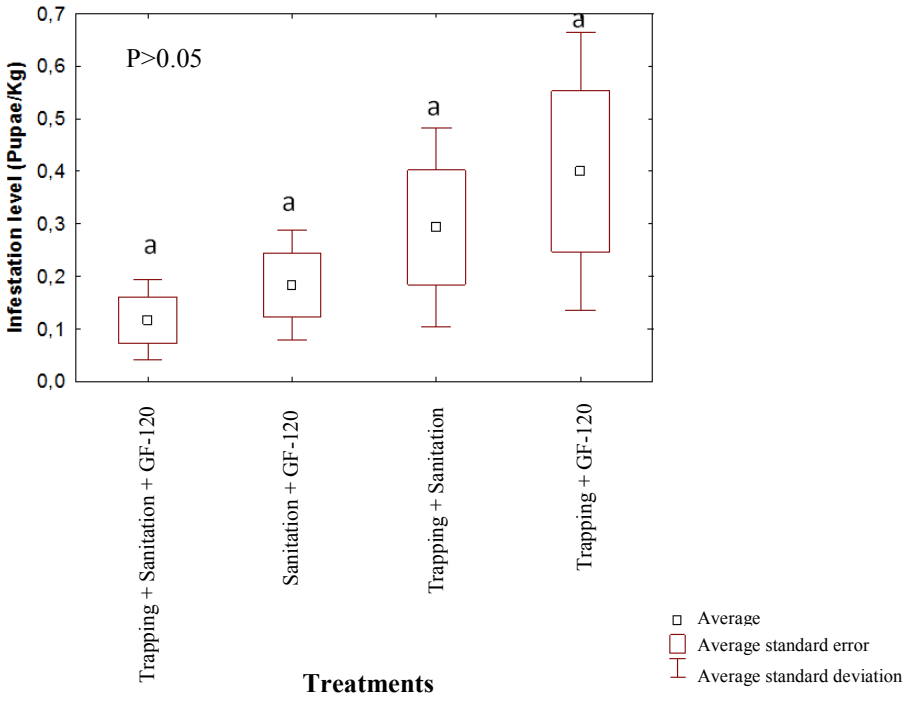

Figure 2. IPM infestation level

The means followed by the same letter are not significantly different (Newman Keuls test, α = 0.05).

(SPSS); version 16.0. Chicago: Polar Engineering and consulting. The Student Newman-Keuls test was used to separate the means at the 5% level.

RESULTS

Fruit infestation level and protection percentage

The four wrestling suits installed in the orchards, noted a variation in the levels of infestations and the percentages of protection according to the wrestling suits. Most of the different combinations provided high protection percentages and very low infestation levels (Figure 1).

Infestation level of the different integrated pest management combinations

Across all study sites, infestation levels varied very little. At all sites, the "trapping + GF120" control combination recorded a higher average infestation than the other combinations (0.4 pupae/fruit). The other IPM combinations recorded average infestations ranging from 0.1 to 0.3 pupae/fruit. However, the statistical treatments showed that there was no significant difference between the different levels of infestation of IPM combinations (P>0.05) (Figure 2).

Percentage of effectiveness of different IPM combinations

The orchard protection percentages also varied according to the different combinations. The "Trapping + Collection + GF120" system recorded the highest percentage of protection (95%) of the orchards in all the test areas. Then come the combination "Pickup + GF120" (92%) and then the combinations "Trapping + Pickup" (90%) and "Trapping + GF120" (88%). However, statistical analyzes (P<0.05) showed that there is a significant difference between the protection percentages (Figure 3). Finally, it should be noted that all the integrated pest management combinations in which prophylactic methods have been associated (collection) have given a very good percentage of protection.

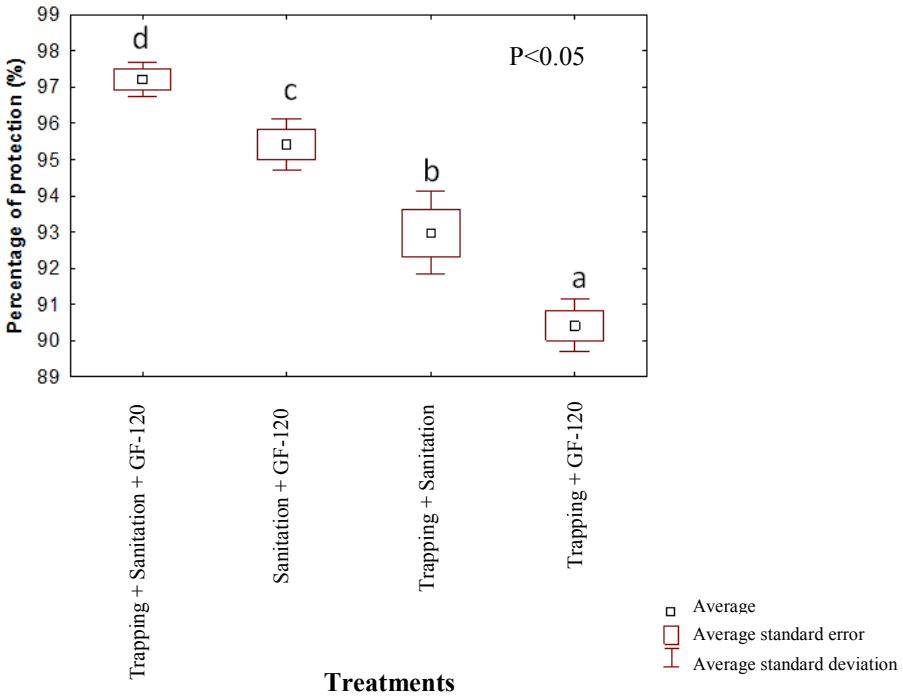

Figure 3. Percentage protection of IPM combinations.The means followed by the same letter are not significantly different (Newman Keuls test, α = 0.05)

DISCUSSION

Integrated pest management devices (Trapping + GF 120, Trapping + Collection, Collection + GF 120 and Trapping + GF 120 + Collection) implemented in orchards have given certain levels of infestations and percentages of protection that differ from device to another. It should also be noted that all the devices recorded high percentages of protection and low level of infestations. This has reduced pest infestations in mango orchards. This resulted in the small amount of pupae found in the fruits. However, the fact that there is no significant difference in orchard protection between the different combinations reveals the effectiveness of integrated pest management regardless of the integrated pest management device used in orchards. However, it should be noted that the device (Trapping + Collection + GF120) gave the highest protection rate and the lowest level of infestation. This could be explained by the fact that the wrestling combination (Trapping + Collection + GF120) contains the three wrestling methods used. Thus, by collecting and plowing, the pupae and larvae buried in the ground or in the fallen fruits are destroyed. This will reduce the amount of flies in the orchards. Pickup called prophylactic control plays a big role in interrupting the development cycle of fruit flies. In fact, by picking up the fallen fruit, the larvae from the fruit can no longer continue to pupate in the soil, hence the interruption of the development cycle takes place largely in the soil. De Larousille (1980) stated that regular tillage (plowing and weeding) can destroy the larvae and pupae in the soil and allow the sanitation of orchards. Previous work by Minhibo *et al*. (2018) has shown that prophylactic control is able to contribute to the protection of orchards by up to 70%. Some flies which could not be destroyed by the prophylactic method, were captured and killed by the TIMAYE trapping device put in place. The traps contain sexual attractants which helps in attracting and killing male fruit flies.

TIMAYE has the same effect as methyl eugenol which provides information on the abundance of *Bactrocera dorsalis* over a large distance around the trap (Mwatawala *et al*., 2006; Vayssieres *et al*., 2009;

N'Dépo, 2010a). In addition Minhibo *et al*. (2017) demonstrated that the use of TIMAYE in mango orchards resulted in high catches of fruit flies, with very high daily catch indices. Flies having crossed the barrier of traps, fell into the "meshes" of food bait GF 120 which was very effective in the protection of mango orchards according to the work of N'Dépo *et al.* (2010b). This work demonstrated that the application of GF 120 gave a high protection rate and a low level of orchard infestation. Vayssières *et al*. (2009b) applied the Success Appat® in mango orchards and revealed a highly significant difference between untreated orchards and treated orchards (16.97±1.96 pupae/kg of fruit for untreated plots, 3.17±0.61 pupae/kg of fruit for plots treated with success Appat® in 2006 and 34.5±3.53 pupae/kg of fruit for untreated plots against 3,67±0.67 pupae/kg of fruit for the plots treated in 2007), in Benin. Ultimately, Chouibani *et al*. (2001) affirmed that the integrated pest management strategy contributed in reducing the whole population of flies in a well-defined cultivation area where the fruit flies cause economic damage. Control strategy must involve the combined and judicious use of all available control methods. Spearman's correlation index revealed that there was a negative correlation between the two variables. This means that when the orchard protection percentages increases the level of fruit infestation decreases.

CONCLUSION

Different control methods have shown different effectiveness. However, none of them can individually control flies. The combination of two or three methods in the same orchard can significantly improve the protection of orchards. The best combination was the one using "Pickup + Trapping + Food Bait". The collection lowers the fly population to 70%; if we add the trapping that lowers parasite pressure and food bait, the orchard could be more than 98% protected. In the outlook, a socioeconomic study must be conducted on the different combinations and finally to assess their cost. Which will allow producers to adopt the combination that may be affordable.

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