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Influence of Different Mango Phenological Stages on Fruit Fly Populations in Mango Orchards in Northern Côte d'Ivoire

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Abstract

Côte d'Ivoire is the third largest supplier of mangoes to the European market, after Brazil and Peru, and the leading exporter of mangoes to the African market. However, mango production is faced with the problem of fruit flies, which cause yields to fall. In order to combat fruit flies, a study was launched into the early detection of fruit flies at different phenological stages of the mango tree. The overall aim of the study is to help improve mango productivity through early detection of fruit flies at different phenological stages. Accordingly, a trapping system containing sexual attractants and insecticides was set up in the four cardinal directions of the mango orchard. Insects were collected once a week during the vegetative, flowering, mango development and mango ripening stages. Twelve fruit fly species in four genera and seven species were identified, with a high abundance of *Bactrocera dorsalis* ((265.64 ± 132.82) individuals) and *Ceratitis cosyra* ((171.87 ± 85.94) individuals). Fruit flies were most abundant at the maturity stage, with a high abundance of *Bactrocera dorsalis* species ((129.20 ± 46.15) individuals) and at the vegetative stage ((597.80 ± 214.07) individuals), and a high abundance of *Ceratitis cosyra* species at the flowering (111.26 ± 33.71) and mango development ((187.47 ± 62.64) individuals) stages. In conclusion, the phenological stages of mango influence the population of fruit flies in mango orchards.

Keywords

Trapping Device, Detection, Vegetative, Flowering, Mango Development,

Maturity

1. Introduction

The mango (*Mangifera indica* L.) is a very important tropical fruit in the world. It represents the sixth most produced fruit in the world, with an estimated production of over 50 million tons in 2017 in an area of over 5 million hectares [1]. Currently, Côte d'Ivoire is the third-largest supplier of mangoes to the European market, after Brazil (100,000 t) and Peru (80,000 t), and Africa's leading mango exporter [2] [3]. However, although mango production is flourishing, it faces a number of problems, of which fruit flies are the most damaging. Damage caused by these flies is estimated at 17% at the start of the season, 69% in the mid-season, and over 80% at the end of the rainy season, if control strategies are not deployed [3]. Overall, fly infestation keeps mango yields extremely low, in the order of 3 to 7 $t \cdot ha^{-1}$, in contrast to expected real yields of around 10 to 15 $t \cdot ha^{-1}$ for the Kent variety and 15 to 20 $t \cdot ha^{-1}$ for the Keitt and Palmer varieties [3]. Indeed, there is no tolerance threshold on the European market, as the discovery of a single fruit fly larva in a batch of fruit results in the systematic rejection and destruction of the shipment at the exporter's expense. As a result, many containers of mangoes destined for Europe are destroyed every year [4] [6]. To combat fruit flies, several studies have been initiated, including early detection of fruit flies using a trapping system based on the four cardinal directions in the mango orchard [3]. However, few studies have been initiated on the early detection of fruit flies according to the phenological stages of the mango tree. It is in this context that the present study was initiated to investigate the relationship between mango phenological stages and fruit fly population for better pest management in mango orchards.

2. Materials and Methods

2.1. Study Site

This study was conducted in three mango orchards in northern Côte d'Ivoire. These mango orchards are located in Korhogo (09˚40'151"N; 05˚45'861"W), Sinématiali (09˚35'982"N; 05˚24'126"W) and Ferkessédougou (09˚44'803"N; 05˚15'668"W). These are major mango-producing areas in the country, characterized by a Sudanese-type climate with a dry season from November to April and a rainy season from May to October. The average annual rainfall is 1400 mm in the wet season and 1000 mm in the dry season. The natural vegetation is wooded savannah; soils are ferralitic, moderately to strongly drained [7]. Temperatures are marked by a maximum of 41˚C in March and a minimum of (16.5˚C) in January.

The mango tree is very hardy and can be grown under a wide range of environmental conditions. It thrives in warm climates with well-defined wet and dry seasons. It adapts to sandy soils with good drainage, neutral pH and average fertility. Good fruiting requires an average temperature of 25˚C - 30˚C during flowering

and fruit development. Mango trees should be grown in regions where annual rainfall is between 500 and 2000 mm. Abundant, uniform flowering requires a dormant period of 2 to 3 months, induced by lower temperatures (8˚C - 10˚C) and/or drought conditions. In addition, a sunny climate is necessary for good fruit set and ripening [8]. Mango grows in a wide variety of soils. Above all, it requires healthy, sandy-loam, well-drained soils with a pH between 5.5 and 7.5 [8].

2.2. Study Material

2.2.1. Fruit Flies

Fruit flies are insects belonging to the order Diptera and the family Tephritidae. They consume a wide variety of fruits, and also carry out their entire life cycle (eggs, larva) on them.

2.2.2. Mango Variety

The present study was carried out in mango orchards of the Kent variety of the *Mangifera indica* species. The *Kent* variety is the most widely exported on the international market, due to its high sugar content, beautiful color and long shelf life [3] [8]. The selected orchards covered an area of 5 ha (500 trees per orchard) with a regular spacing of 10 m between mango trees. The trees were between 15 and 20 years old.

The targeted orchards had not undergone any chemical treatments by the growers during the experimental period. The orchards were located far from crop sites requiring chemical treatments, such as cotton growing. The orchards were easily accessible, well-maintained and secure.

With regard to plant material, the different phenological stages were used in this study. These include the vegetative stage from mid-June to the end of December [9], the flowering stage from December (25% of flowers open) to the end of March with 75% of flowers open [10], and the fruiting stage, which includes the development and ripening of mangoes. This stage extends from early April to mid-June [10].

2.2.3. Traps and Trapping Equipment

Trapping equipment consisted of TephriTraps. This is a cylindrical plastic box-shaped trap, 11 cm high and 12.4 cm in diameter. It is yellow in color, with a colorless lid, which is pierced on the inside by four holes in four directions [11]. The trapping material used consisted of sex attractants specific to male fruit flies and an insecticide. The sexual attractants were composed of: 1) terpinyl acetate and 2) trimedlure specific to the *Ceratitis genus*, cue-lure specific to the *Dacus* and *Zeugodacus* genera, and methyl eugenol specific to the *Bactrocera genus* [11]. The insecticide is a 2,2-Dicholoro Vinyl Dimethyl Phosphate (DDVP) tablet, which acts by inhalation after the flies have been attracted to the TephriTraps by parapheromones.

2.2.4. Trap Installation Method

Insecticide and parapheromone are placed in TephriTraps, which are installed in mango orchards during the flowering, mango development, ripening and vegetative

seasons.

Traps containing sex attractants and insecticides were suspended from a mango tree carpenter branch, about 1.80 m above the ground, and sheltered from sunlight under a mango leaf to protect the traps and attractants exposed to the sun [3] [11]. The suspension wires were covered with a grease barrier to prevent the predatory action of ants on the dead flies in the traps. Sex attractants and insecticides were renewed every 30 days during the study. Flies were collected once a week and transported to the laboratory for identification [3] [11].

Traps were set up by selecting the four ends of the orchard according to the four cardinal directions and placing a trapping device. At each cardinal direction, a trapping device consisting of four different traps, each containing a sexual attractant and an insecticide, was placed under different trees spaced 10 meters apart. This system remained unchanged at all test sites.

In each orchard, Tephri trap (**Figure 1**) traps containing sexual attractants and solid insecticides were hung on a branch of the host plant with a wire at a height of around 1.60 to 1.80 m from the ground to allow maximum capture [9]. The traps were placed under foliage, sheltered from sunlight to facilitate entry of the flies into the traps containing the sexual attractant and insecticide [9]. The branch supporting the trap was covered with a solid barrier of grease to prevent the predatory activity of oecophyll ants on the flies caught in the traps. The traps installed in the orchards were checked and emptied once a week. Flies were collected weekly from the traps using flexible entomological forceps and preserved in pillboxes containing 70˚ alcohol before being sent to the laboratory for identification [9].

Figure 1. Tephri trap.

2.3. Collection and Storage of Fruit Flies

The collection equipment consisted of flexible entomological forceps, which were used to collect the flies from the traps while preserving their various characteristics.

Collected fruit flies were preserved in pillboxes containing 70% alcohol. They were then labelled with the name of the site, the date of collection and the trap number.

2.4. Fruit Fly Identification Method

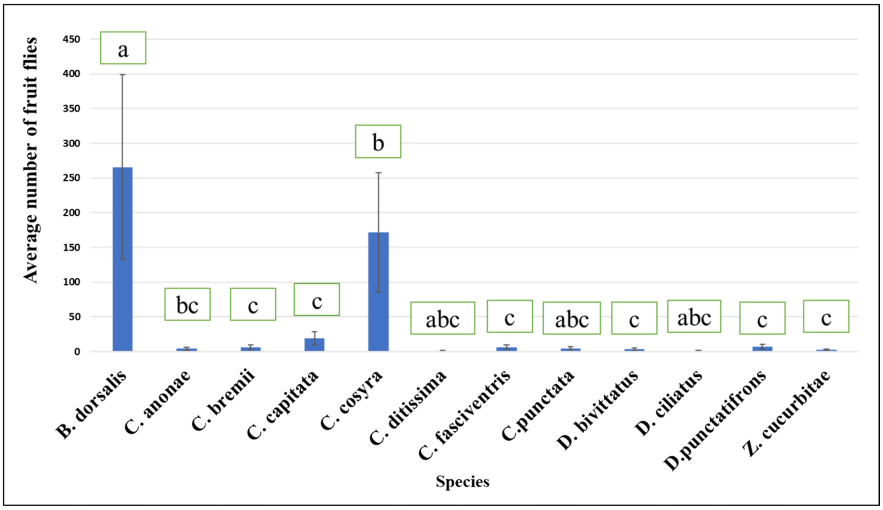
Fruit flies were observed in the laboratory using a Motic binocular loupe at magnification (10 × 20). Fruit flies were then identified using the DE Meyer Guides, versions 1996, 1998, 2000, and 2001 [12].

2.5. Statistical Analysis of Data

The data collected were processed using Microsoft Office Excel version 2010 and analyzed using STATISTICA version 7.1. Prior to statistical analysis, the Shapiro and Wilk test was used to verify normality between variables. Thus, when a significant difference was observed at the 5% threshold. The Tukey test was used to classify the variables.

3. Results

3.1. Abundance of Fruit Flies in Mango Orchards



Anova 1, Means assigned the same letters do not differ significantly at the 5% threshold.

Figure 2. Fly species abundance in mango orchards.

Traps containing sexual attractants and insecticides identified twelve (12) species of fruit flies divided into 4 genera (**Figure 2**). These included one (1) species of the *Bactrocera genus*, namely *Bactrocera dorsalis* Schultz *et al.*, and seven (7) species of the Ceratitis genus, namely *Ceratitis anonae* Graham, *Ceratitis bremii* Guérin-Méneville, *Ceratitis capitata* (Wiedemann) and *Ceratitis cosyra* (Walker), *Ceratitis ditissima* (Munro), *Ceratitis fasciventris* (Bezzi), *Ceratitis punctata* (Wiedemann), three (3) species of the genus *Dacus* including *Dacus bivittatus* (Bigot), *Dacus ciliatus* (Loew) and *Dacus punctatifrons* (Karsch) and finally, one (1) species of the genus *Zeugodacus* which is *Zeugodacus cucurbitae* (Coquillet).

With regard to the abundance of fruit flies in mango orchards, the results show that there is a highly significant difference between the two species (Tukey test; $p < 0.001$) according to species in all mango orchards. Of all the species caught in traps containing sexual attractants, *Bactrocera dorsalis* ((265.64 ± 132.82) individuals) was the most abundant. It was followed by *Ceratitis cosyra* ((171.87 ± 85.94) individuals). Next came *C. capitata* ((19.36 ± 9.68) individuals), *Dacus punctatifrons* ((7.09 ± 3.54) individuals), *C. fasciventris* ((6.47 ± 3.24) individuals), *C. bremii* ((6.23 ± 3.12) individuals), *C. punctata* ((4.75 ± 2.38) individuals), *C. anonae* ((4.30 ± 2.15) individuals), *Dacus bivittatus* ((3.37 ± 1.66) individuals), *Zeugodacus cucurbitae* ((2.63 ± 1.32) individuals), *C. ditissima* (1.00 ± 0.5), and *D. ciliatus* (1.00 ± 0.50) which were poorly represented (Figure 2).

3.2. Abundance of Fruit Fly Species According to Phenological Stage in Mango Orchards

Concerning the abundance of flies according to the phenological stage, statistical analyses reveal a significant difference (Tukey test; $p < 0.001$) in fruit fly species according to the phenological stage in mango orchards. At the mango flowering and development stages, *C. cosyra* was the most abundant species, with (111.26 ± 33.71) individuals and (187.47 ± 62.64) individuals, respectively. On the other hand, at the vegetative and ripening stages of mango, *B. dorsalis* was the most abundant species, with respectively (129.20 ± 46.15) and (597.80 ± 214.07) individuals. Other species were in the minority (Table 1).

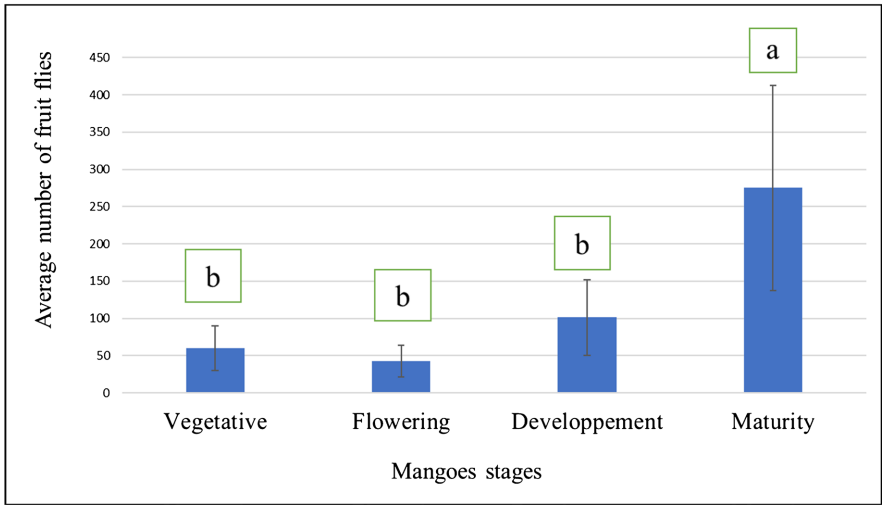
Table 1. Fruit fly species abundance according to mango phenological stages.

Species	Flowering	Mangoes development	Mangoes maturity	Vegetative
B. dorsalis	17.03 ± 6.09 a	41.17 ± 26.10 a	597.80 ± 214.07 a	129.20 ± 46.15 a
C. bremii	1.00 ± 0.00 ab	-	9.55 ± 2.29 bc	3.53 ± 1.31 b
C. anonae	-	1.50 ± 0.17 ab	4.50 ± 1.31 bc	-
C. capitata	4.31 ± 0.81 a	-	3.23 ± 0.67 bc	30.01 ± 22.32 b
C. cosyra	111.26 ± 33.71 b	187.47 ± 62.64 b	236.10 ± 78.1 b	5.54 ± 1.61 b
C. ditissima	1.00 ± 0.00 ab	-	-	-
C. fascibentrii	2.26 ± 0.45 a	2.20 ± 0.0 a	8.44 ± 2.54 c	2.44 ± 0.53 b
C. puntata	2.00 ± 0.35 ab	-	7.50 ± 1.23 abc	-
D. ciliatus	-	1.00 ± 0.00 ab	1.00 ± 0.0 abc	-
D. bivittatus	1.25 ± 0.12 ab	1.00 ± 0.00 ab	5.37± 1.05 c	1.93 ± 0.38 b
D. punctatifrons	1.48 ± 0.16 a	1.33 ± 0.22a	8.52 ± 3.14 c	7.30 ± 2.04 b
Z. cucurbitae	2.26 ± 0.43 a	1.45 ± 0.17 a	1.61 ± 0.36 bc	3.02 ± 0.87 b

Anova 1 means assigned the same letters in the same column do not differ significantly at the 5% threshold.

3.3. Abundance of Fruit Flies according to Mango Phenology

The results showed a highly significant difference ($p < 0.001$) in fruit fly abundance according to phenological stage (Figure 3). Fruit flies were more abundant in mango orchards at the mango maturity stage ((275.38 ± 137.69) flies) than at the mango development stage ((101.32 ± 50.66) flies), the vegetative stage ((59.73 ± 29.87) flies) and the flowering stage ((42.53 ± 21.27) flies).



Anova 1 means assigned the same letters do not differ significantly at the 5% threshold.

Figure 3. Abundance of fruit flies according to phenological stage in mango orchards.

4. Discussion

The Tephri trap containing sexual attractants and insecticides captured several species of fruit fly. The presence of fruit flies in traps containing sexual attractants would be due in part to the yellow color of the traps. According to [13] [14], the yellow color of the traps attracts the insects. On the other hand, the presence of fruit flies in traps containing sexual attractants would be due to the broad action spectra of sexual attractants. Indeed, according to [14] [15], sexual attractants attract fruit flies over long distances, unlike food attractants, which spread over short distances. The high abundance of *Bactrocera dorsalis* and *Ceratitis cosyra* in traps containing sex attractants compared with other sex attractants is thought to be due to the presence of mangoes in mango orchards and the presence of alternative host plants in and around the orchards. According to [16], *Bactrocera dorsalis* and *Ceratitis cosyra* are polyphagous species that attack a wide variety of fruits, particularly mangoes. The high abundance of *Ceratitis cosyra* in traps containing sexual attractants during the flowering and development stages of mango is due, on the one hand, to the presence of early mango varieties in and around mango orchards. On the other hand, during the mango development stage, mangoes at the "small fruit" stage are more exposed to the stings of *Ceratitis cosyra*. According to [9], in mango orchards in northern Côte d'Ivoire, *C. cosyra* peaks before *B. dorsalis*. The first species reaches a population peak during the dry season,

coinciding with the full flowering of *Kent* mangoes and the presence of early varieties such as *Amelie*. Indeed, *C. cosyra* is an early species compared with the invasive *B. dorsalis* [17]. The high abundance of *B. dorsalis* during the vegetative and ripening stages of mango is due to the fact that the vegetative stage of mango coincides with the ripening period of certain host plants. According to Ouédraogo (2011), the extent of Tephritidae damage to mango increases with the number of woody host plants around the orchard. The high abundance of *B. dorsalis* at the ripening stage of the mango would be due to the fact that at the ripening stage, the mango has reached physiological maturity and is therefore exposed to the flies' bites. Moreover, the ripening stage of the mango coincides with the rainy season. According to [15] [18], *Ceratite* species are better adapted to dry conditions, whereas *B. dorsalis* prefers wetter conditions. In addition, the adult of *B. dorsalis* is more aggressive than the adult of *C. cosyra*. According to [12], *Bactrocera dorsalis* is in competition with *Ceratitis cosyra* for food. In Côte d'Ivoire, studies by Coulibaly [9] have shown that *Bactrocera dorsalis* is the most devastating species in mango orchards. The low abundance of other species could be explained by the low presence of cucurbit flies around the sites. *Z. cucurbitae* and *D. punctatifrons* are species of this plant family [19]. However, several methods are deployed to fight against fruit flies in Côte d'Ivoire. These methods are prophylactic control methods, Trapping methods, bait methods, and Integrated Pest Management (IPM) methods [20].

5. Conclusion

The study on the influence of different mango phenological stages on the fruit fly population showed that mango phenological stages influence the fruit fly population. In fact, the ripening stage of mango recorded a higher fruit fly population than the other phenological stages of mango. In addition, certain species of flies were more abundant than others, depending on the phenological stage. In this respect, *Ceratitis cosyra* was more abundant during the mango flowering and development period than *Bactrocera dorsalis*. At the mango maturity and vegetative stages, *Bactrocera dorsalis* was more abundant than *Ceratitis cosyra*. This study is of vital interest for the early detection and deployment of methods to control fruit flies at the vegetative stage, even before the first mango flowers appear.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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