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# Infestation rate of *Mangifera indica* fruit fly in Sudanese zone of Mali

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**Mali has a potential for mango production across the country. However, this plant is facing phytosanitary problems mainly related to fruit flies. The study was conducted to evaluate the infestation rate of fruit flies on mango varieties in Sudanese zone of Mali (Kati). Stung mangoes were weekly collected from three sites. Fruits were weighted and placed inside plastic bags containing sand to the monitor larva infestation under semi-natural conditions within of the laboratory. *Bactrocera dorsalis* and *Ceratitis cosyra* were the two species identified from all sites with an average of 22.88 and 23.32 fruit flies, respectively. *C. cosyra* appreciated mango varieties such as Valencia, Amelie, Kent, Davis Haden and Keitt whilst *B. dorsalis* preferred Keitt, Brooks, Kent and Smith varieties. No correlation was found between mangoes weight and the number of emerged flies in addition to lack of sex predominance based on fruit' fly species. The infestation rate varies according to the variety of mangoes.**

**Keywords:** Mango, fruit fly, infestation, Sudanese zone, Mali.

## INTRODUCTION

Agrosylvopastoral sector contributes around 70% of export value providing about 80% of populations' income (Vayssières et al., 2004). Fruit and vegetable sector play very important role in Mali socio-economic development policy (Helvetas, 2003). Among this sector, more importance has been given to mangoes either from the professional sector, government or partners for the country's development. It occupied the first position in term of fruit exportation (Helvetas, 2003).

*Mangifera indica*, [Anacardiaceae] is one of the most planted fruit trees in the world especially in Asia and Africa, particularly in Mali (Vayssières et al., 2004). More than 49.9 million tons of mangos were produced over the world (FruiTrop, 2016). Asia, the continent of mangos origin, is the largest producer with 71% of world production followed by Africa (17%) and America (10%) (FruiTrop, 2016). Mango fruit, most consumed in Mali, is a source of vitamin C supplement and income for the rural population (Thiam et al., 2001). Mango is produced throughout Mali with a major production of this country from Sikasso, Ségou and Koulikoro regions in addition to Bamako district (Thiam et al., 2001).

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In 2015, Malian mango production reached 600 000 tons and raised USD 30 million in export earnings, nearly 15 666 634 CFA francs (IFM, 2016). During the last four years, the exported amount of mango was 66 049, 67315, and 64 730 tons, respectively in 2015, 2016 and 2017 (IFM, 2016, 2017).

Despite this high production from Mali, the country exportation is not significant (Diallo et al., 2016; IFM, 2017). In 2018, the quantity of fresh and dried mangoes was 22 276 tons of the treatement of orchards against fruit flies (PACAM, 2018). Even though 6 522 ha (2017) and 24 800 ha (2018) had been treated (PCDA, 2005; PACAM, 2018), several containers of Malian exported mango were intercepted due to phytosanitary problems related to fruit flies (IFM, 2017). The number of mango containers intercepted at the European borders over the years include 25 in 2014, 11 in 2015, 66 in 2016, 25 in 2017 and 26 in 2018 were among of mangoes containers intercepted at the European borders (European Commission, 2018; IFM, 2017).

These flies belong to the family of Tephritidae, or "fruit flies", including more than 4 000 species distributed among 500 genera. It is one of the most economically important Dipterans because of the damage they may cause in crops (fruits and vegetables) and their presence in many countries. For a century, Tephritidae has been one of the most studied pests (Passion Entomology, 2014). They cause considerable economic losses for farmers (Vayssières et al., 2014). The study has been carried out on the unspecified infestation rate of mango varieties in Benin (Vayssières et al., 2010) and Togo (Gomina, 2015). In Côte d'Ivoire, three varieties of mangoes (Kent, Keitt, Amelie) were recorded and most of them were infested with *Bactrocera invadens* (called *Bactrocera dorsalis* from 2014) according to N'dépo et al. (2009). In Mali, Vayssières et al. (2004) identified three varieties of mangoes (Keitt, Kent, and Brooks) most bitten by species of the genus *Ceratitis.* Keita (2015) observed pupae of *Ceratitis cosyra* and *B. dorsalis* in mango varieties (Personal communication). The main objective of this study was to identify mango varieties highly susceptible to fruit fly infestation in Mali in order to establish future strategies to reduce associated yield loss.

## METHODOLOGY

### The study sites

Sampling was carried out in Koulikoro region within Kati district from 3 locations: Dougourakoro (0.53 ha, 12° 64' 92' 'and 7 ° 85' 86''), Kati (1.24 ha, 12° 77 '31'' and 8° 12' 00'') and Farabana (1.17 ha, 12° 46' 64'' and 8° 11' 13'') (LET, 2017). This region is located in the Sudanese zone with an average annual rainfall of 980 mm. It is also one of the most important mango producing areas in Mali (MDR, 2002). The orchards were selected based on some criteria such as plot size (at least 0.5 hectares), age of the trees (at least 10 years old) and accessibility during seasons. At least, 4 commercial mangos' varieties must be in the orchard and homeowners must opt for non-use of pesticides during the study period.

### Material

The plant materials composed of commercial mango varieties: early varieties (Amelie), medium varieties (Kent, Davis Haden, Valencia, Smith, and Springfels) and late varieties (Keitt, Brooks). Mangoes were used to feed the larvae of fruit fly. The animal material composed of the fruit flies (Tephritidae) whilst technical equipment were containers (plastic cup), mosquito net tulle, gloves, binocular loupes, sand, vacuum cleaner, breeding cage, super weather station (I.T.Works, Model N°.: KW.9007, Kesa UK HU1 3AU, 433 MHZ), etc.

### Methods

#### *Collection of infested fruit samples*

Data collection was carried out between April and August 2017. Mangoes were collected once a week at the three sites randomly. In the field, there was no consistency in terms of the number of fruits collected by varieties. The number of fruits depended on the number of mango trees per varieties, the reproductive cycle, and the maturity period (early, medium, and late). The fruits falling under the trees bearing signs of spawning were collected by variety and transported to the laboratory to follow the evolution of the infestation in semi-natural conditions (a grill shed with thermo-hygrometer).

#### *Weighing and incubation of fruits*

Fruits were weighted, placed inside plastic bags containing sand, labeled with the name of mango variety, weight in grams, date and collection site. Sand allows the larvae to steal. The mangoes were weighed before the incubation, the weights of mangoes were between 100 and 5100 g depending on the variety according to the technique of Vayssières et al. (2009) modified. The containers were closed by lids with fine mesh, sometimes closed with tulle mosquito nets fixed with elastic band in order to prevent egg-laying from certain insects or to circumscribe the loss of larvae and pupae from predatory actions. This container also avoids larvae escape, but also to keep emerged adults which will be further used for breeding and identification. Insects dead after emergence were conserved inside the tube containing 70% alcohol for their identification.

#### *Species identification*

At the laboratory, emerged flies were collected using a vacuum cleaner and kept inside the refrigerator. The identification of emerged fly species in the laboratory was done using determination keys available at the Entomology-Parasitology Laboratory at the Faculty of Science and Technique or at the Laboratory of Arthropod Biology and Integrated Struggle, Institute Rural Polytechnic Training and Applied Research (IPR/IFRA) of Katibougou. Insects' observation was done using binocular loups. After identification, flies were counted based on species, sex and the date of emergence.

Data were collected from mangoes varieties based on the weight of mango and emerging adult fly. The temperatures (minimum, maximum), the relative humidity (RH %), the observation of pupae and the identification of emergence were scored every day. The software SAS (System of Statistical Analysis) was used to compute recorded data in addition to the sex difference of fruit flies; the preference of flies according to mango varieties was analyzed using R (RCRAN https: //cran.r -project.org/ Card). Excel sheet was used to establish a correlation between the weight of mangoes and the number of emerged flies.

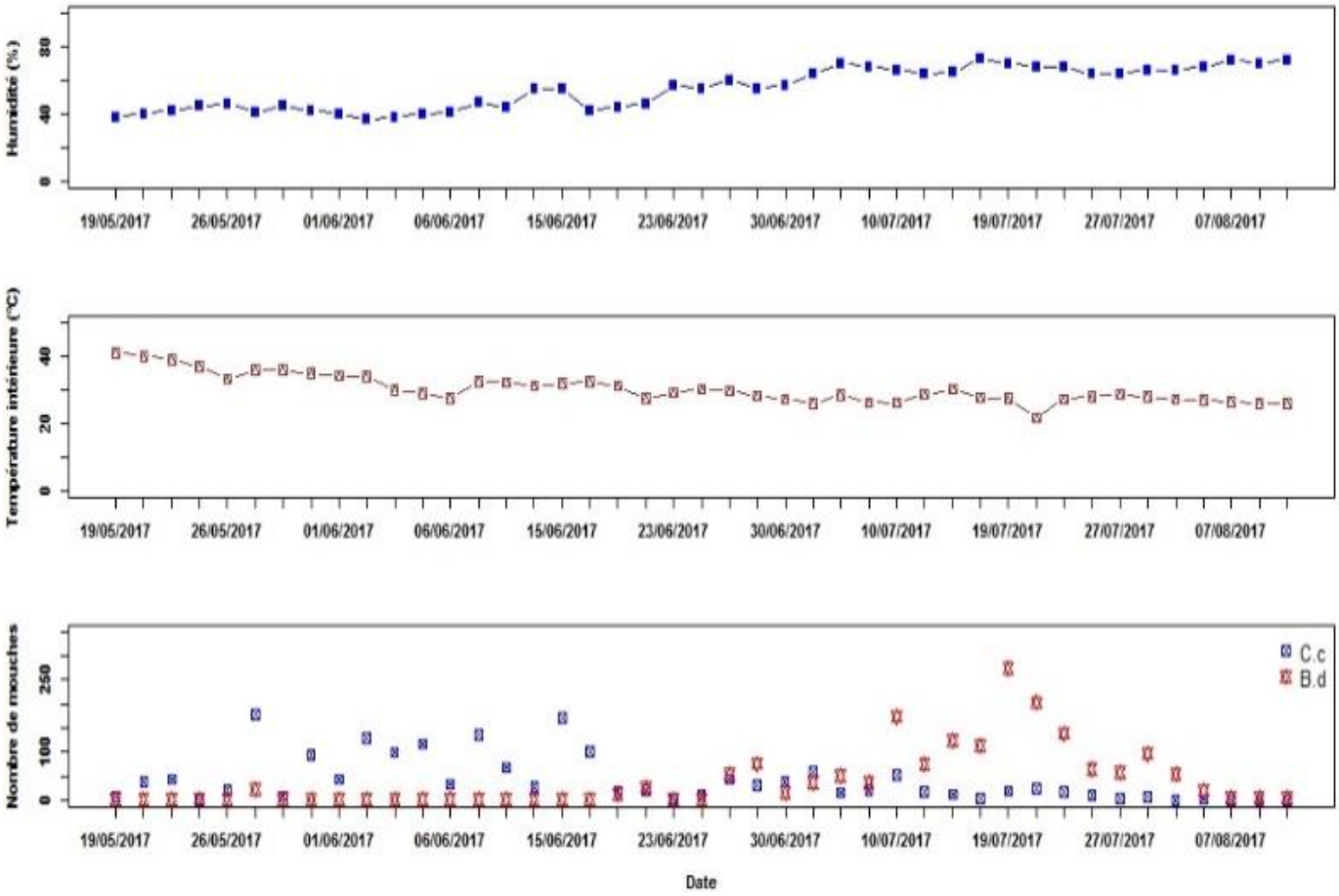


**Figure 1.** Evolution of the species according to the temperature, interior and humidity of the air. B.d = *Bactrocera dorsalis;* C.c = *Ceratitis cosyra*.

## RESULTS

### Number of fruit flies emerged at the laboratory

The results revealed the presence of three species: *B. invadens* (named *B. dorsalis* from 2014 onwards), *C. cosyra* and *Ceratitis ditissima* of the order Diptera and Tephritidae family (Table 1). *B. dorsalis* and *C. cosyra* were the two important species with an average of 22.88 and 23.32 flies, respectively. Moreover, there was predominance of *B. dorsalis* at all sites of Dougourakoro and *C. cosyra* in Farabana.

### Influences of meteorological parameters (temperature and humidity) on flies' emergence

For all sites and throughout the monitoring period, fly species moved in the opposite directions. On the other hand, as the temperature dropped (below 30°) in increase the humidity (greater than 70%), the population of *C. cosyra* decreased whilst that of *B. dorsalis* increased (Figure 1).

### Preference of fly species in relation to mango varieties

Eight mango varieties were incubated at the laboratory. At Dougourakoro site, *B. dorsalis* preferred firstly the Keitt mango variety followed by Brooks and Kent, with a maximum of 244, 196 and 141 fruit flies, respectively. Valencia was the only variety which is not appreciated by *Bactrocera dorsalis* (Figure 2a). Few *B. dorsalis* emerged with varieties from Kati location, 26 fruit flies were scored from Amelie, 25 from Kent and 19 from Davis Haden (Figure 2b). At Farabana, Keitt variety was the most infested by *B. dorsalis* species (169 fruits flies) followed by Kent (69 fruits flies) and Brooks (66) (Figure 2c). Out of the five mango varieties from Dougourakoro, Smith (50 flies) and Valencia (47 flies) varieties were little appreciated by *C. cosyra* followed by Keitt variety. The Brooks variety did not record any emerging flies (Figure 3a). In Kati, Amélie and Kent varieties recorded the maximum C*. cosyra* emergence with 108 and 161 flies, respectively (Figure 3b). In Farabana, the three most appreciated varieties by *C. cosyra* were Valencia (147 flies), Kent (147 fruit flies) and Amelie (144 fruit flies)

**Table 1**. Difference between averages of emerged fly species in the laboratory.

| Site | Dougourakoro | Kati | Farabana | Total |
|---|---|---|---|---|
| Species | Effective | Effective | Effective | - |
| *B. dorsalis* | 12.50[a] | 3.15[b] | 7.23[c] | 23.32[a] |
| *C. cosyra* | 5.84[d] | 6.86[e] | 10.62[f] | 22.88[a] |
| *C. ditissima* | 2.5[g] | 0[h] | 0[h] | 2.5[b] |

The averages with different letters are very different at the threshold α = 0.05.

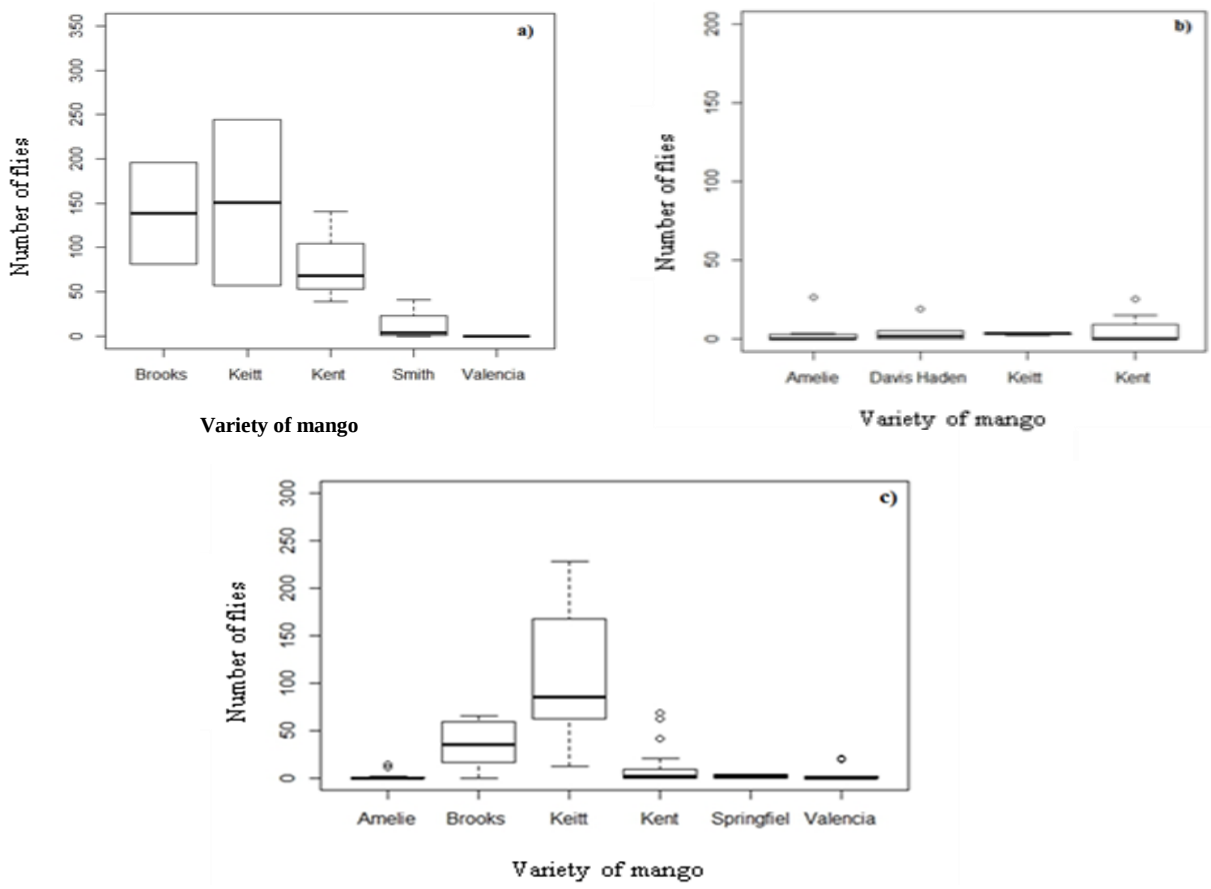


**Figure 2.** The preference of *Bactrocera dorsalis* on different varieties of mangoes: (a) Dougourakoro; (b) Kati; (c) Farabana in 2017.

(Figure 3c). *C. ditissima* was recorded only on the Valencia variety in Dougourakoro site (Figure 4).

## Relationship between infestation rate and weight of mangoes

The lines of equation (linear regression lines) were not closed to the set of points of the cloud for each species. The numbers of the species (*B. dorsalis* n = 1 577), (*C. cosyra* n = 1754), (*C. ditissima* n= 5) with the respective coefficients of determination, $R^2$ = 0.0168 for *B. dorsalis* and $R^2$ = 0.002 for *C. cosyra*. Therefore, the number of flies emerged by incubation from the collected fruits do not appear to be related to the weight of the mangoes, regardless of the site, the mango varieties and the fly species (Figure 5).

## Sex predominance of emerged fly species from all varieties of mangoes at the laboratory

Table 2 shows that there is not a significant difference between the male and female numbers of each fly

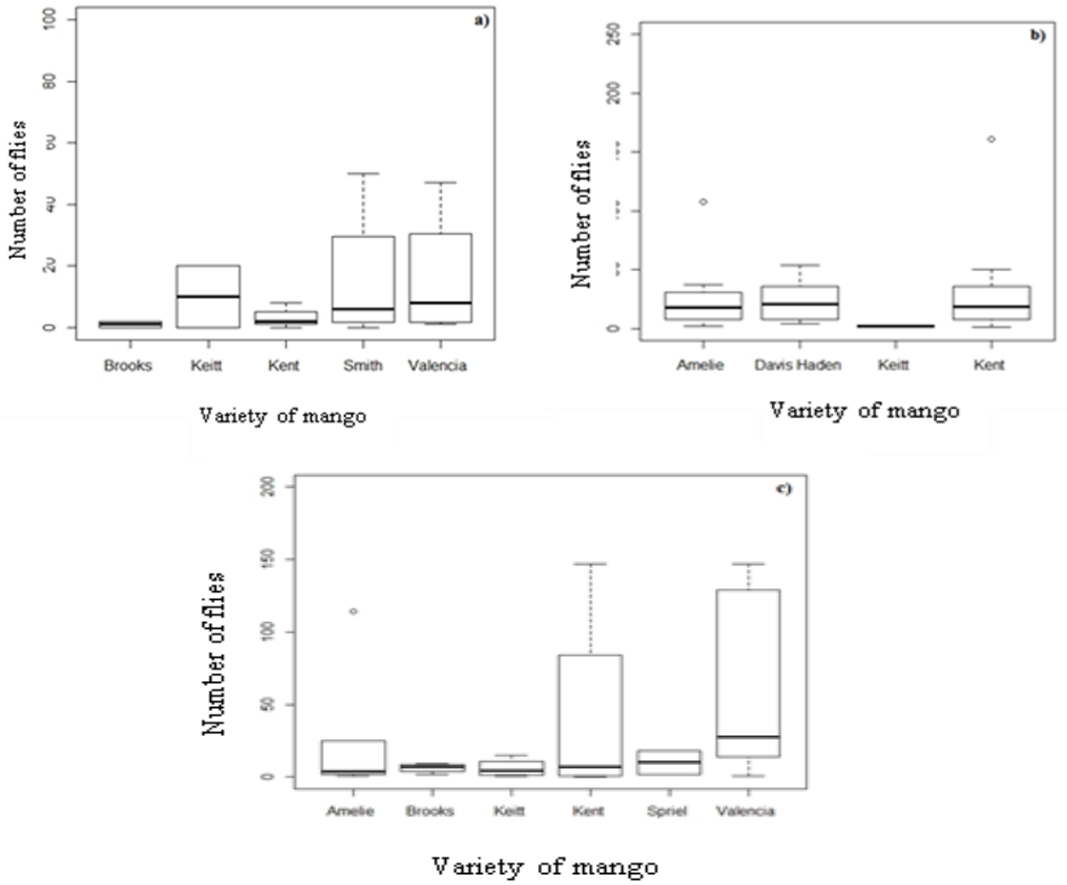


**Figure 3.** The preference of *Ceratitis cosyra* on different varieties of mangoes: (a) Dougourakoro; (b) Kati; (c) Farabana in 2017.

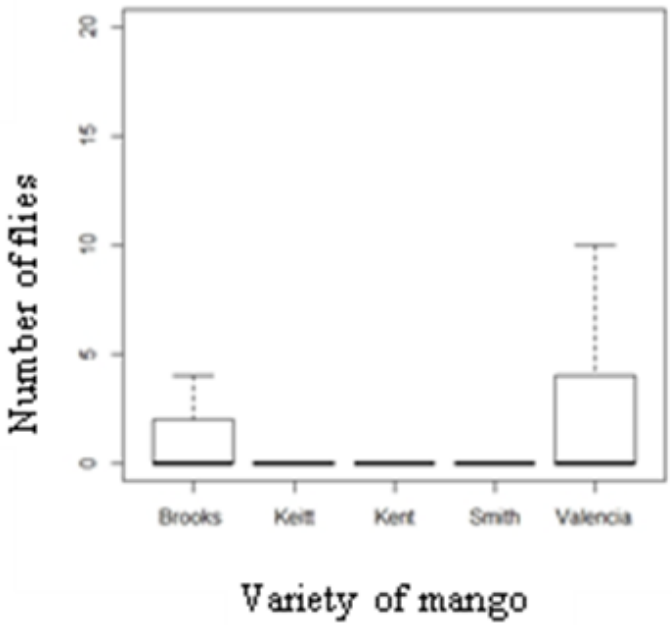


**Figure 4.** The preference of *Ceratitis ditissima* on the differents varieties of mango in Dougourakoro.

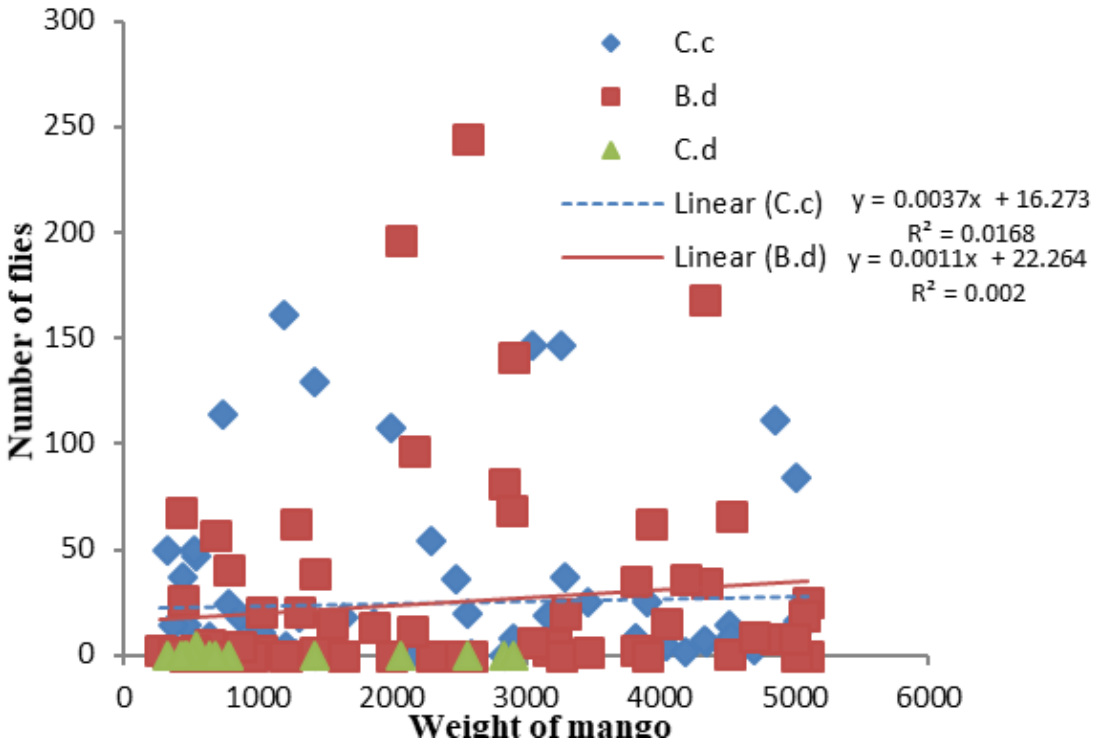


**Figure 5.** The correlation between the weight of mangoes and the number of emerging fly species at the sites. B.d = *Bactrocera dorsalis*; C.c = *Ceratitis cosyra*; C.d = *Ceratitis ditissima.*

**Table 2.** Difference between sex averages of fly species

| Species | B.b | C.c | C.d |
|---|---|---|---|
| **Sex** | | | |
| ♀ | $3.5^{a}$ | $3.45^{b}$ | $2.5^{c}$ |
| ♂ | $3.75^{a}$ | $3.42^{b}$ | - |

Meanings of the same letters are not very different for the same species at the threshold α = 0.05. B.d = *Bactrocera dorsalis*; C.c = *Ceratitis cosyra*, C.d = *Ceratitis ditissima*.

species in general at all sites except that of *C. ditissima* where the average of the females is higher than that of the males which corresponded to zero.

## DISCUSSION

### Number of fruit flies emerged at the laboratory

Results revealed no significant differences between the average of species (*C. cosyra* and *B. dorsalis*). On the other hand, some authors (N'dépo et al., 2009, 2010; N'diaye, 2009; Vayssière et al., 2010) from Ivory Coast (Azaguié, Abidjan and in the center of Yamoussoukro), Senegal (the Niayes and Thies Plateau area), and Benin (Guinean-Sudanian areas) showed a predominance of *B. dorsalis* species compared to other species such as *C. cosyra*. According to the results reported by Ouédraogo et al. (2010) in Burkina Faso and Keita (2015) in Mali, the emergence rate of *C. cosyra* is significantly higher than that of *B. dorsalis* in mangoes.

### Influences of meteorological parameters (temperature and humidity) on emerged flies

The meteorological parameters influenced the reproduction of each fly species which moved in the opposite direction with respect to temperature and humidity. The meteorological parameters taken at the

incubation site (in the shed) of stung fruits can confirm the dynamics of fruit fly species in orchards. The early onset (in the dry season) of *C. cosyra* compared with *B. dorsalis* was consistent with the results obtained by Vayssières et al. (2009) and Tinkeu et al. (2011). The population of *B. dorsalis* in the rainy season was greater than that of dry season (Vayssières et al., 2009; Ouédraogo, 2011; Tinkeu et al., 2011; Konta et al., 2015; Keita et al., 2016). According to Duyck (2005), Tephritidae are generally very sensitive to environmental condition variations, particularly that of relative humidity.

**Preference of fly species in relation to mango varieties**

Farabana and Dougourakoro sites recorded more *B. dorsalis*. This is due to the high density of the Keitt and Brooks (late-maturing) varieties in orchards in addition to the appearance of species at the time of heavy rainfall (July-August). On the other hand, the Farabana and Kati sites recorded more *C. cosyra* due to the presence of early (Amélie) and medium (Kent, Davis Haden, Valencia) mango varieties which maturity coincide with the appearance of *C. cosyra* (March - mid-July). Moreover, there was difference between fly species based on mango varieties. Whatever, the site *C. cosyra* appreciated Valencia, Amelie, Kent, Davis Haden and Keitt varieties, whereas *B. dorsalis* preferred Keitt, Brooks, Kent and Smith. In Mali, the report from Vayssières et al. (2004) and Vayssières (2002) showed the preference of *C. cosyra* for the following mango varieties: Smith, Keitt, Amélie, Brooks and Kent.

The species *C. cosyra* was significantly important in the fruits of the first waves of flowering especially with early varieties while *B. dorsalis* was present in all the varieties at all fruit development stages, its color, the wave of flowering and location (N'diaye et al., 2012). Ouédraogo et al. (2010) noted a total preference of *C. cosyra* for Amelie, Kent, Saber and Springfels varieties and more attacks of *B. dorsalis* were observed with Brooks and Keitt varieties. The results of N'diaye (2009) and Lo (2017) showed strong presence of *B. dorsalis* in medium and late varieties. Factors contributing to flies multiplication were high density of certain varieties in the sites, stage of maturity (early, medium and late), size and age of the plot, fruit characteristics (thin, tender, hard or thick skin) and starting date of variety flowering (N'diaye, 2009; Jayanthi et al., 2012; Diatta et al., 2013; Nordey, 2014).

**Relationship between infestation rate and weight of mangoes**

The analysis of the results showed low correlation coefficients ($R^2$ = 0.0168 for *C. cosyra*, $R^2$ = 0.002 for *B. dorsalis*) between the number of emerged flies and the weight of mangoes. Similarly, Gomina (2015), Vayssières et al. (2010) and N'diaye (2009) found a variation between the number of emerged flies and the weight of mangoes, respectively in Togo, Benin and Senegal.

**Sex predominance of emerged fly species from all varieties of mangoes in the laboratory**

There is no significant difference between the number of males and females of each fly species in general at all sites. The climatic parameters and the type of mango variety do not have an influence on sex. These results are in agreement with those observed by N'dépo et al. (2009), N'diaye (2009) and Gomina (2015) who showed that there is no highly significant difference in relation to sex ratio.

Moreover, results from current study were negatively affected by the loss of larvae during fruit stung transportation at the laboratory due to the heat and predator attacks (ants and spiders) at the place of incubation.

**Conclusion**

The study revealed two major flies' species (*B. dorsalis* and *C. cosyra*) a total of 3 511 flies emerged from the sample incubated and no significant difference was recorded in the set. Valencia, Amelie, Kent, Davis Haden and Keitt were preferred by *C. cosyra* whereas *B. dorsalis* species preferred more Keitt, Brooks, Kent and Smith varieties. The infestation rate depended on the varieties of mangoes and collection sites. No correlation was recorded between the weight of the incubated fruits and the emerging fly species and the same with the sex.

This study will lead us, on one hand, to the use of the parasitoids *Fopuis arinasus* in the biological control of the species *B. dorsalis* and on the other hand, to the popularization of the least pricked mango varieties according to the different periods of maturity. To limit losses, fruits should be harvested just after physiological maturity.

**CONFLICT OF INTERESTS**

The authors have not declared any conflict of interests.

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