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Seasonal variation of the population of two fruits flies in the cultivation of cucumber in Dabou, South of Côte d'Ivoire

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ABSTRACT

Bactrocera cucurbitae and *B. dorsalis* are two fruits flies which cause significant damage to cucumber in Côte d'Ivoire. In perspective control, a monitoring of their populations was conducted during two periods (from April 2014 to March 2015 and from April 2015 to March 2016). Cucumber orchards were carried out in Dabou, South of Cote d'Ivoire. The catches of flies were made at twice a week to different phenological stages in traps made of yellow bowl. *B. cucurbitae* and *B. dorsalis* were collected during the four seasons of the year. These flies are predominant in crops during the fruit maturation stage. During the two study periods, the numbers of flies caught the rainy seasons were 3906 individuals for *B. cucurbitae*, 519 individuals for *B. dorsalis* and the rainy seasons, the numbers of flies were 1129 individuals for *B. cucurbitae*, 427 individuals for *B. dorsalis*. *B. cucurbitae* was more abundant than *B. dorsalis* on cucumber crop. Cucumber is preferred host of *B. cucurbitae*. The rainy seasons seem to be favorable to the development of these two flies.

Introduction

Tephritidae are major pests of fruits, vegetables and other ornamental plants (Bharathi et al., 2004). They have a broad global distribution. They are widely distributed throughout the temperate, tropical and subtropical zones. Most of these flies are subject to quarantine measures because of highly invasive nature and the threat they pose to a country's export capabilities. *B. cucurbitae* and *B. dorsalis* are cause extensive damage to cucumber in Cote d'Ivoire. Indeed, the gravid females of these flies lay eggs in small groups under the epidermis of the fruits. The larvae develop in the pulp of the fruit making them unsuitable for feeding. This phenomenon reduces the yield of crops and the marketability of cucumber. Therefore, vegetable enterprise is rendered unprofitable for farmers. Control of these flies exclusively based on chemical insecticides has shown its limitations due to constant adaptation of pests. The necessity to think effective control, sustainable and environmentally friendly was therefore conceivable. Several field and laboratory studies have demonstrated that the distribution and abundance of Tephritidae depends on abiotic factors such as temperature, relative humidity and precipitation (Vargas et al., 1997; Brévault & Quillici, 2000; Duyck & Quilici, 2002) and biotic factors such as the phenological stages of the host plant (Brévault, 1999; Alyokhin et al., 2000; N'Depo et al., 2010; Kamala et al., 2012). These observations led us to study abundance of *B. cucurbitae* and *B. dorsalis*, the main pests of cucumber in Côte d'Ivoire during the four different seasons of the year in perspective of management these pests.

Materials and Methods

Study area

The study was conducted in Dabou (Lat. 5 ° 18'50, 55 '' N; Lon. 4 ° 14'27, 16 '' W) located in south of Cote d'Ivoire. The climate in this area is subequatorial characterized by two annual rainy seasons (from April to mid-July and September to November) and two dry seasons (mid-July to August and December to March). Average rainfall varied from 9.7 to 726.9 mm. Temperature averages ranged from 24.6 °C to 28.8 °C. The study period extended from April 2014 to March 2016.

Plant materials

The plant material used was the variety "Tokyo" of cucumber (*Cucumis sativus* L.). This variety is the best adapted to the climatic conditions and has a prolific yield. The animal material was composed of adults of *B. cucurbitae* and *B. dorsalis* captured on the experimental plot.

Experimental field and implementation of crops

The size experimental plot was 459 m² with 51 m at length and 9 m at wide. It was a randomized complete block design with three replications. It is divided into three blocks distant of three meters. The sizes of each block 15 m at length and 9 meters wide or 135 m^2. Each block was composed eight buttes of 1 meter of width separated from each other by 1 m. On each butte there were two lines of 10 plants spaced from each other by 1 m. One butte contains a total of 20 plants, i.e., 160 plants per subplot and a total of 480 plants on the experimental plot. Before each experiment, an application of poultry manure was carried out on the plot. The crops were carried out during two periods which have been April 2014 to March 2015 (first period) and from April 2015 to March 2016 (second period).

The cultures were made by direct semi. Two to three seeds were placed by bucket. The thinning to one plant by hole was realized 10 days after sowing. Two weeks after sowing, an NPK fertilizer was added and then tutors were placed around the plants to support the plants. No pesticides were applied in the plot during experimentation. During the dry seasons the plants were regularly watered in order to promote their growth. The crops were grown directly on raised planks to facilitate drainage during the rainy season and promote root development.

Trapping flies

The trapping method used was that of colored traps. It composed of yellow plastic bowl (22 cm at diameter and 8 cm at depth) arranged on a rack of 90 cm of height. The plates were filled up with soap water each two days. Each trap was placed at a distance of 3 m from the ends of the buttes. A total of 16 traps were placed per subplot. Every two days, the captured insects were removed from the plates, identified and counted by species and by sexes according to the phenological stages.

Statistical Analysis

All data processing was performed using statistical software version 7.1. An analysis of variance (ANOVA) revealed significant differences between the data; the test of Newman-Keuls at 5% was used for to separations the means.

Results

Evaluation of numbers of fruits flies according to phenological stages during the seasons

Long rainy season

During the period from April 2014 to March 2015, the mean numbers of *B. cucurbitae* and *B. dorsalis* captured per subplot increased progressively from the stage before flowering to reach their peaks (71.33 ± 1.45 for *B. cucurbitae* and 23 ± 1.15 for *B. dorsalis*) at the second week of maturation (Mat2) (Fig. 1a). These mean numbers decreased progressively to reach 36.66 ± 0.88 for *B. cucurbitae* and 12.33 ± 0.33 for *B. dorsalis* at the end of the crop.

During the period April 2015 to March 2016, the mean numbers of flies species captured increased progressively from the stage before flowering to reach their peaks at the second week of fruit maturity (Mat2) with 65.33 ± 1.76 individuals for *B. cucurbitae* and 27.66 ± 2.96 individuals for *B. dorsalis*. These mean numbers decreased gradually (36.0 ± 1.52 for *B. cucurbitae* and 13.33 ± 2.02 for *B. dorsalis*) to reach lower numbers at the end of the crop. Statistical analysis showed significant differences between the mean numbers recorded at different phenological stages during April 2014 to March 2015 (first period) ($F = 312.71$; ddl = 13; $P < 0.001$) and those recorded in the period April 2015 to March 2016 (second period) ($F = 125.32$; dd1 = 13; $P < 0.001$).

Small rainy season

During the first period (from April 2014 to March 2015), the mean numbers of *B. cucurbitae* and *B. dorsalis* captured per subplot increased progressively from the stage before flowering to reach their peaks with 60 ± 1.73 (*B. cucurbitae*) and 23.33 ± 0.66 (*B. dorsalis*) at the second week of maturation (Mat2) (Fig. 1b). These numbers decreased progressively to 23.33 ± 0.88 for *B. cucurbitae* and 6.66 ± 0.33 for *B. dorsalis* individuals per subplot at the end of the crop.

During the second period (from April 2015 to March 2016), the mean numbers of both flies captured increased progressively from the stage before flowering to reach their peaks at second week of fruit maturity (Mat2) with 63 ± 0.57 for *B. cucurbitae* and 28.33 ± 0.88 individuals per subplot for *B. dorsalis*. These numbers decreased gradually (36.33 ± 1.76 for *B. cucurbitae* and 11 ± 0.64 individuals per subplot for *B. dorsalis*) at the end of the crop. Statistical analysis showed significant differences between the mean numbers recorded at different phenological stages during first period ($F = 297.84$; ddl = 13; $P < 0.001$) and those recorded at the second period ($F = 132.82$; ddl = 13; $P < 0.001$).

Long dry season

The mean numbers of both flies increased progressively during the period from April 2014 to March 2015 (first period), reaching their peaks during the maturation stage (Mat2) with 51.66 ± 1.85 (*B. cucurbitae*) and 17.0 ± 1.27 (*B. dorsalis*) individuals per subplot (Fig. 1c). These numbers decreased to 17.0 ± 0.33 (*B. cucurbitae*) and 7.33 ± 0.88 (*B.dorsalis*) individuals per subplot at the end of the harvest.

During the period from April 2015 to March 2016 (second period), the mean numbers of both flies species reached their peaks during maturation stage (Mat2) with 40.33 ± 0.88 and 16.66 ± 2.40 individuals per subplot for *B. cucurbitae* and *B. dorsalis*, respectively. These mean numbers decreased to 17.0 ± 1.15 (*B. cucurbitae*) and 7.66 ± 1.33 (*B. dorsalis*) individuals per subplot at the end of the harvest. Statistical analysis showed significant differences between the mean numbers recorded at different phenological stages during first period ($F = 82.26$; ddl = 13; $P < 0.001$) and those recorded at second period ($F = 85.42$; ddl = 13; $P < 0.001$).

Small dry season

During first period, the mean numbers of the two fruits flies increased progressively to reach their peaks during maturation (Mat2) with 51.66 ± 1.2 (*B. cucurbitae*) and 12.33 ± 1.33 (*B. dorsalis*) individuals per subplot (Fig. 1d). These numbers decreased to 15.33 ± 0.33 individuals per subplot for *B. cucurbitae* and 4.66 ± 0.33 individuals per subplot for *B. dorsalis* at the end of the harvest.

During the second period, the mean numbers of both fly species reached their peaks during the maturation stage (Mat2) with 38.33 ± 0.33 and 20.66 ± 1.76 individuals per subplot for *B. cucurbitae* and *B. dorsalis*, respectively. These mean numbers decreased to 9.33 ± 0.33 (*B. cucurbitae*) and 6.66 ± 0.88 (*B. dorsalis*) individuals per subplot at the end of the harvest. Statistical analysis showed significant differences between the mean numbers recorded at different phenological stages during first period (F = 206.22; ddl = 13; P <0.001) and those recorded during second period (F = 206.58; ddl = 13; P <0.001).

Comparison of numbers of fruits flies caught during four various seasons

During the four seasons of the two periods (April 2014 to March 2015 and April 2015 to March 2016), *B. cucurbitae* was most abundant compared to *B. dorsalis* (Table 1). During the period from April 2014 to March 2015, in all four seasons, the total number of *B. cucurbitae* was 2543 flies and that of *B. dorsalis* was 725 flies.

During the period from April 2015 to March 2016, in all four seasons, the total number of *B. cucurbitae* was 2492 flies and the total number of *B. dorsalis* was 913 flies. The numbers of both fruits flies species during the rainy seasons were higher than those obtained during the dry seasons.

Table 1. Numbers of fruits flies captured during the seasons of year.

Seasons of year	Number of fruits flies during the two periods			
	From April 2014 to March 2015		From April 2015 to March 2016	
	B. cucurbitae	*B. dorsalis*	*B. cucurbitae*	*B. dorsalis*
Long rainy season	1269	351	1194	497
Small rainy season	734	168	709	195
Long dry season	363	112	403	133
Small dry season	177	94	186	88
Total number	2543	725	2492	913

Fluctuation of males and females numbers of *B. cucurbitae* following to the phenological stages during the seasons

During the both periods (April 2014 to March 2015 and April 2015 to March 2016), the population of *B. cucurbitae* varied from the stage before flowering to the end of the harvest, with differences at male and female numbers (Fig. 2 a & 2 b and 3 a & 3 b). Thus, from the stage before flowering to beginning fructification, the mean numbers of flies varied between 9.66 ± 0.88 and 39 ± 3.38 individuals per subplot with male numbers (ranged from 8 ± 1.41 to 20.33 ± 2.35 individuals per subplot) most higher than females (ranged from 1.66 ± 0.47 to 19.33 ± 2.49 individuals per subplot). From the first week of maturation (Mat1) to the 4th week of maturation stage (Mat4), the mean numbers of flies ranged from 9.33 ± 0.33 to 71.33 ± 1.15 individuals per subplot with females numbers (ranged from 7.33 ± 0.47 to 49 ± 2.49 individuals) higher than those of males (ranged from 2.0 ± 0.18 to 24.66 ± 0.47 individuals).

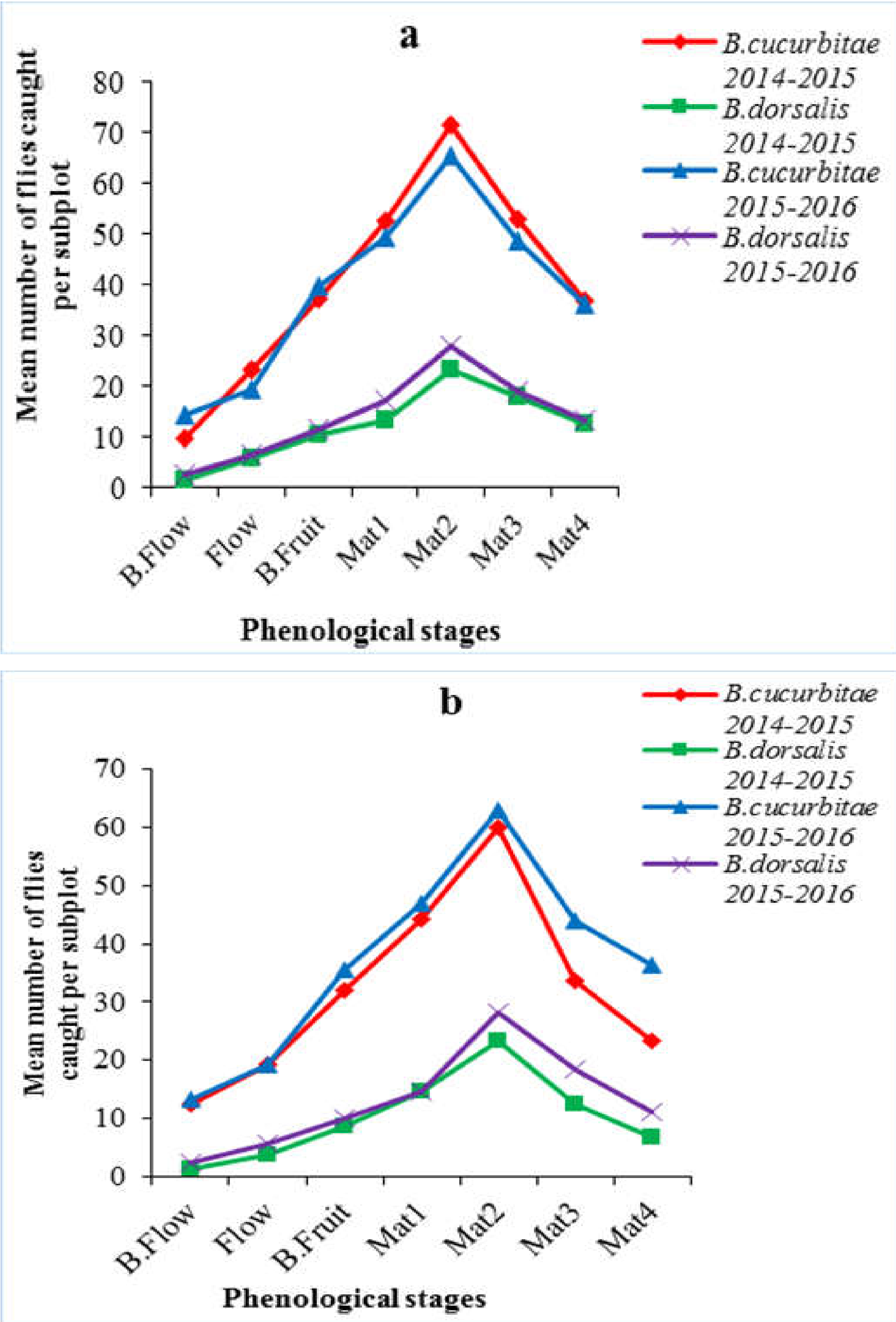
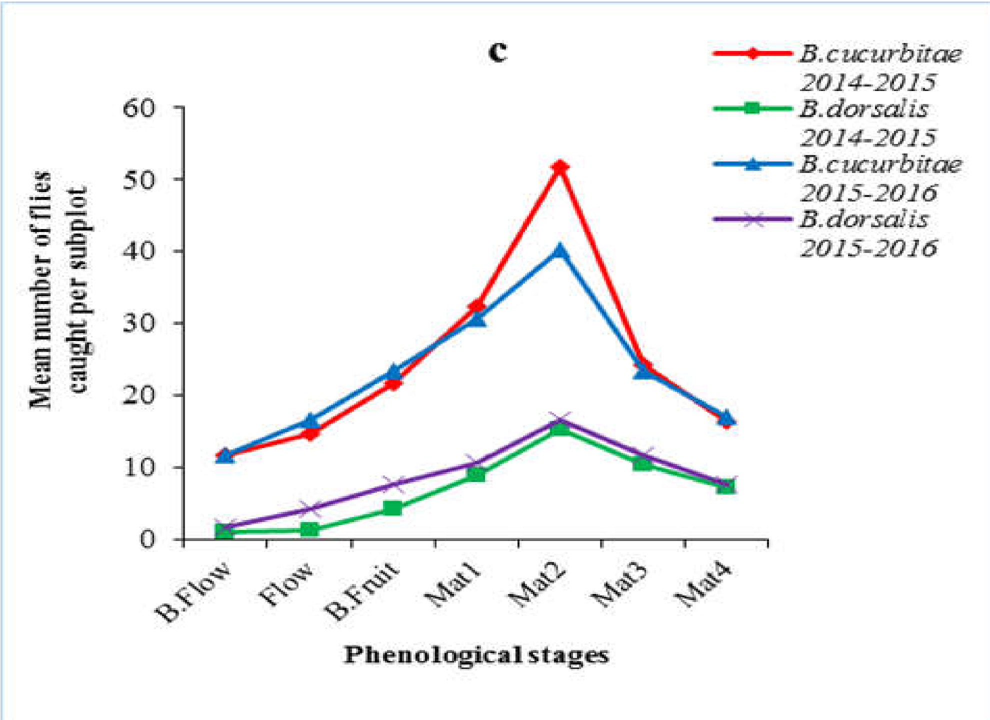


Fig. 1 a & b. Average numbers of *B. cucurbitae* and *B. dorsalis* captured during the four seasons (Period 2014-2015 and Period 2015-2016). B. Flow: Before flowering stage; Flow: Flowering stage; B. Fruit: Beginning fruiting; Mat1: first week of maturation; Mat2: second week of maturation; Mat3: Third week of maturation; Mat4: fourth week of maturation.



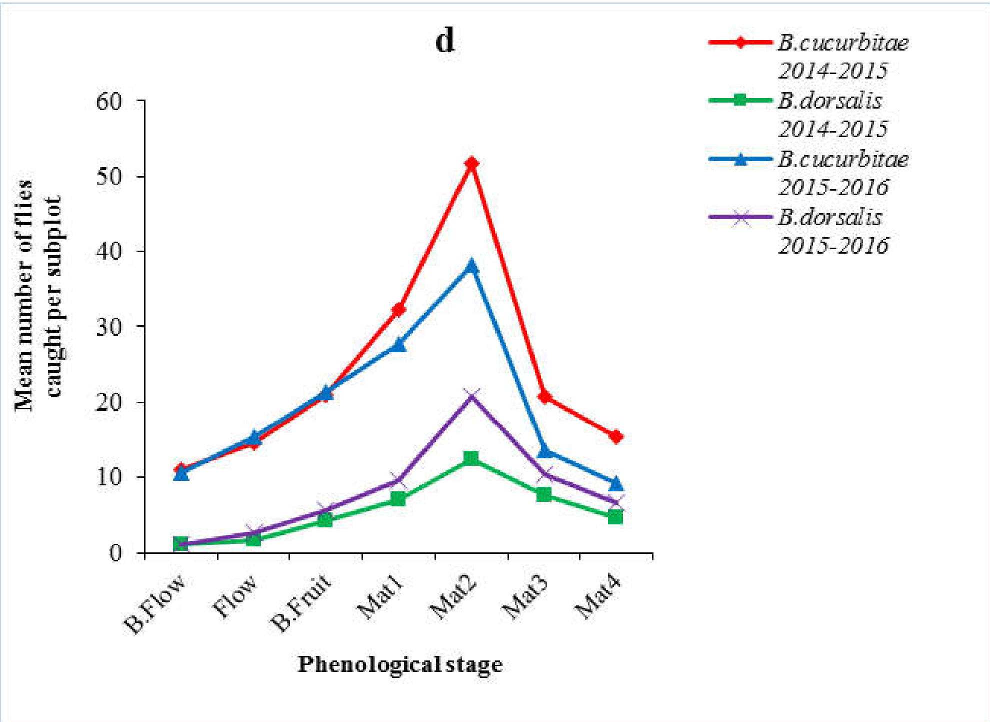


Fig. 1 c & d. Average numbers of *B. cucurbitae* and *B. dorsalis* captured during the four seasons (Period 2014-2015 and Period 2015-2016). B. Flow: Before flowering stage; Flow: Flowering stage; B. Fruit: Beginning fruiting; Mat1: first week of maturation; Mat2: second week of maturation; Mat3: Third week of maturation; Mat4: fourth week of maturation.

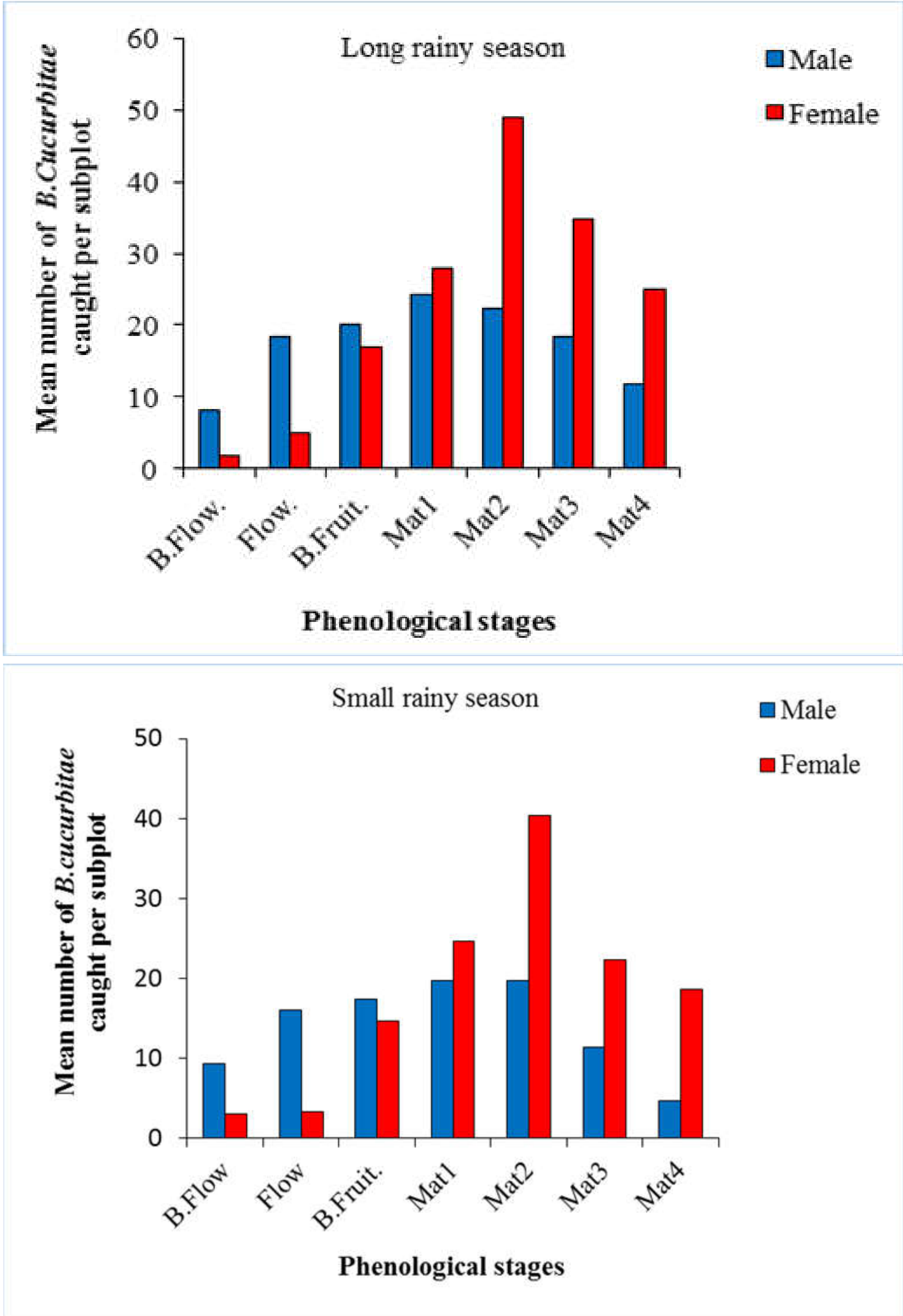


Fig. 2 a. Sexual distribution of *B. cucurbitae* during the four seasons of period 2014-2015 (Long rainy season and Small rainy season).

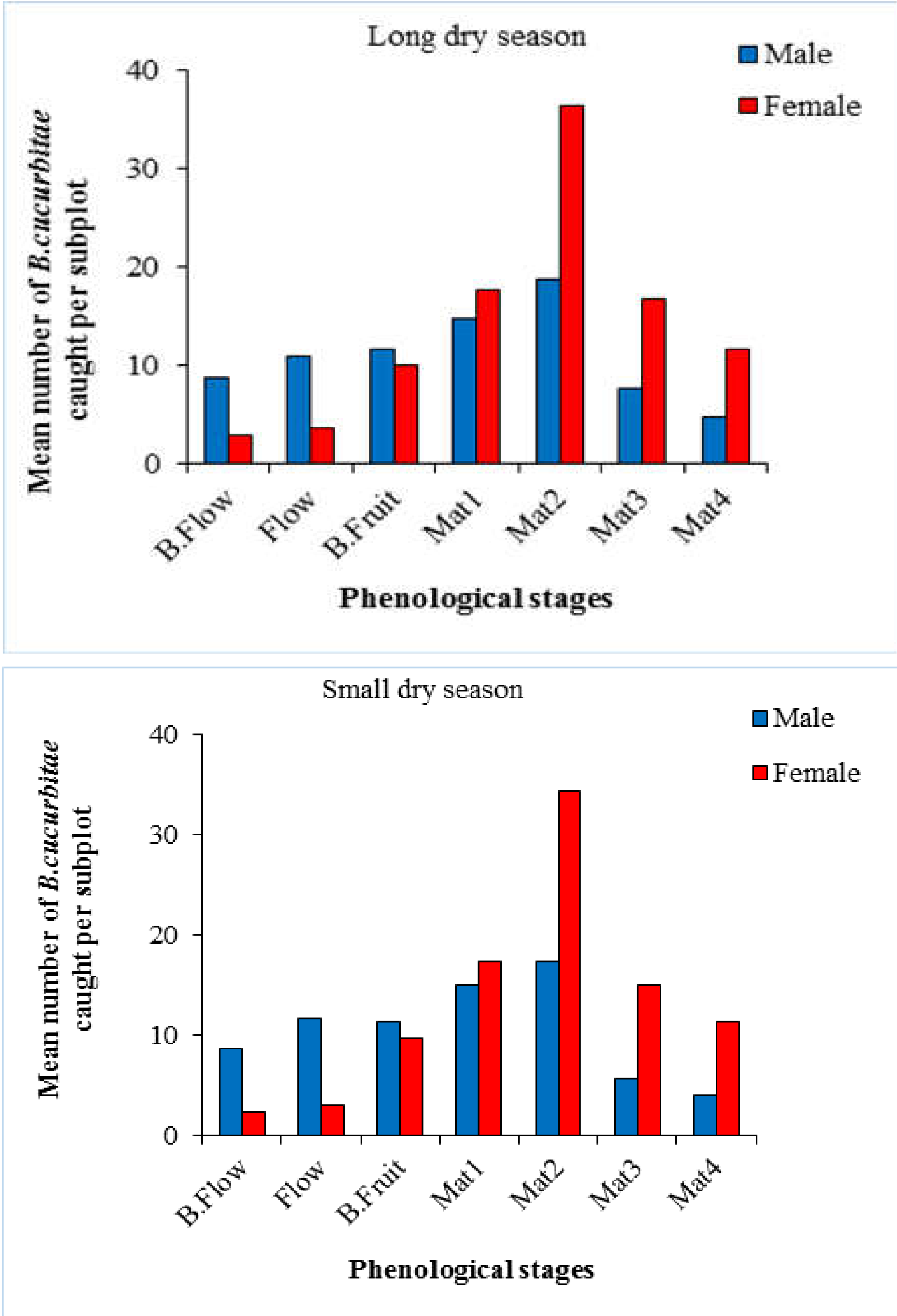


Fig. 2 b. Sexual distribution of *B. cucurbitae* during the four seasons of period 2014-2015 (Long dry season and small dry season).

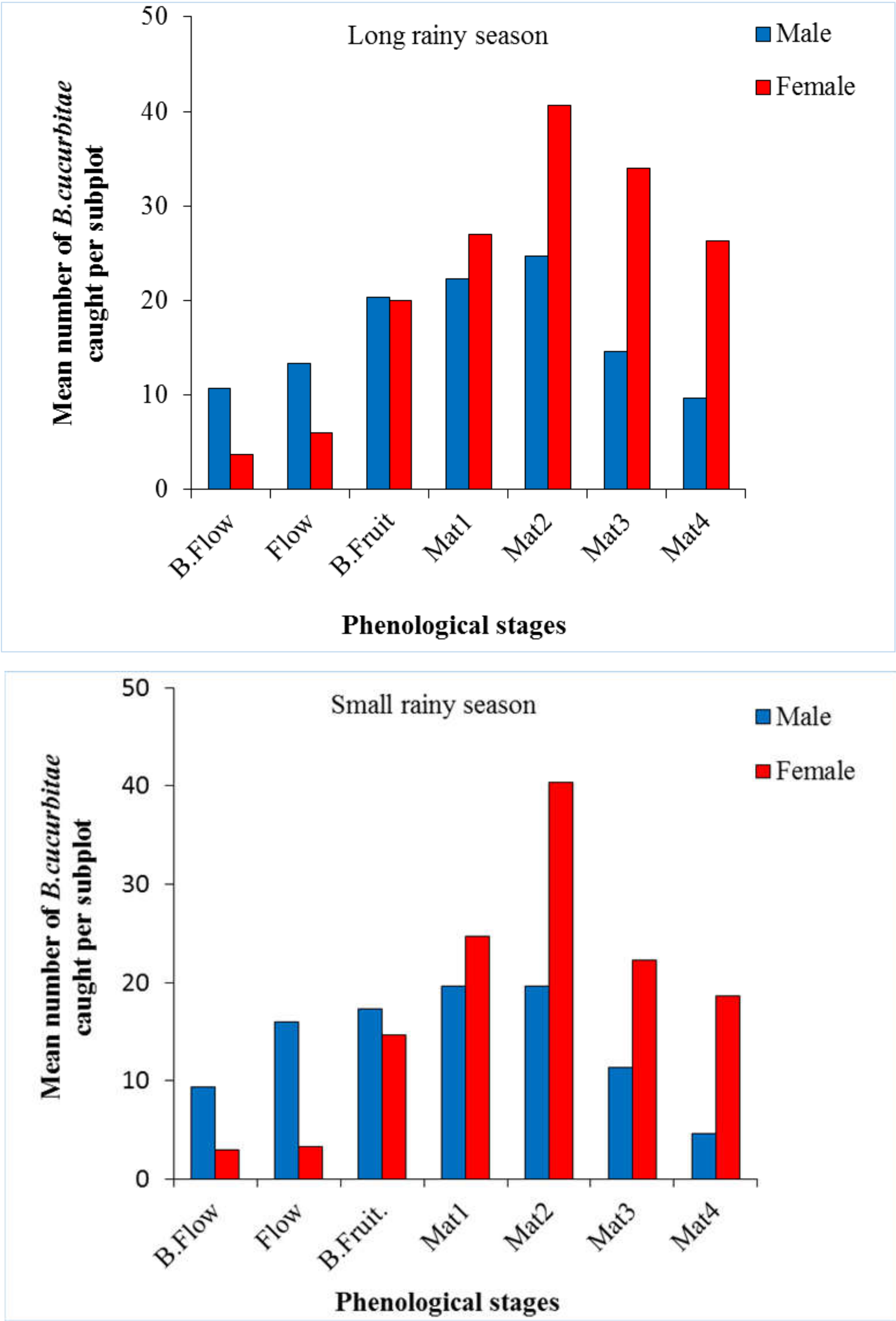


Fig. 3 a. Sexual distribution of *B. cucurbitae* during the four seasons of period 2015-2016 (Long rainy season and small rainy season).

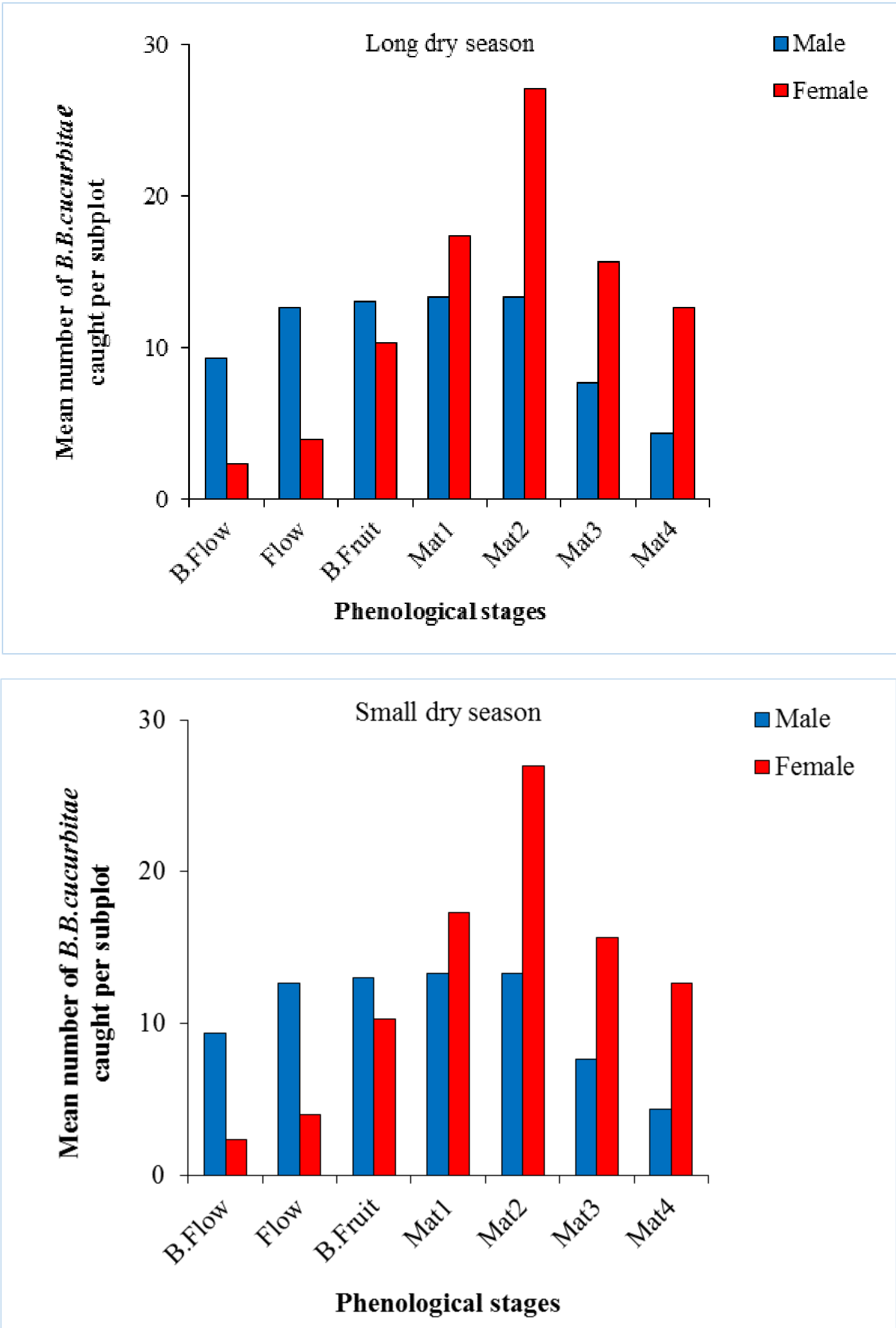


Fig. 3 b. Sexual distribution of *B. cucurbitae* during the four seasons of period 2015-2016 (Long dry season and Small dry season).

Discussion

During the four seasons, the species of Tephritidae which have collected in the cucumber crops were *B. cucurbitae* and *B. dorsalis*. The mean numbers of *B. cucurbitae* were significantly higher than *B. dorsalis* at each season of the year. Similar results were reported in India by Ganie et al. (2013) who also identified the both species of flies in cucurbitaceous crops with a high number of *B. cucurbitae* than *B. dorsalis*. The low number of *B. dorsalis* is the fact that cucumber is not a very attractive host fruit its. Cucumber would be a secondary host for *B. dorsalis*. The high number of *B. cucurbitae* would be due to the fact that cucumber is the original host for *B. cucurbitae*. Cucumber contains all the conditions for the optimal development of the insect (Cassier et al., 1997).

During phenological stages of cucumber, the numbers of flies captured in the different traps have varied. At the stage before flowering, lower numbers of *B. cucurbitae* and *B. dorsalis* were captured. This would be due to the absence of egg-laying sites that can provide an available food source and shelter for the development of their offspring (Robert, 1986). At the flowering and beginning fruiting stages, the mean numbers of *B. cucurbitae* and *B. dorsalis* began to increase progressively. This would be due to the presence of many flowers and small fruits which would emit larger odors which would attract a large number of feeding and egg-laying. At the maturation stage, the numbers of flies increased and reached their peaks in the second week of maturation (Mat2).

The fruits have reached their maximum sizes and their smell is better perceived at long distance, making them easily detectable by fruits flies. Mature fruits are true chemical messengers compared to young fruits. Similar results were reported that the fruits fly population increases with the maturation of cucurbit fruit (Shukla & Prasad, 1985; Tariq et al., 2002; Ganie et al., 2013). This observation was also made by N'Depo et al. (2010) for *B. dorsalis* on mango. Similar results have been demonstrated for *Ceratitis capitata*, where a strong attraction of females to drupes has been observed (Prokopy & Vargas, 1996, Prokopy et al., 1997). Other studies on the Tephritidae have shown that the smells of ripe fruits are more attractive than those of immature fruits (Brévault, 1999; Alyokhin et al., 2000; Kamala et al*.,* 2012). From the third week of maturation (Mat3), the number of flies decreased until the end of the crop. This could be explained by the fruit harvest and the senescence of the cucumber plants. This argument is consistent with that of Douan et al. (2013), who reported a decrease of *Plutella sylostella, Hellula undalis* and *Spodoptera littoralis*, cabbage pests during the senescence of the plants which made them less attractive. Similar results were obtained by Obodji et al. (2015), who reported a considerable decrease in the number of *Leucinodes orbonalis* at the end of the eggplant cycle.

Different numbers of *B. curcubitae* and *B. dorsalis* were present each season. During rainy seasons, there was strong outbreak of Tephritidae population, while in dry periods the populations was very low. This observation is consistent with the results obtained in Togo by (Amevoin et al., 2009; Vayssières et al., 2014) and several other authors (Mwatawala et al., 2006; Vayssières et al., 2009; N'Depo et al., 2010; Ouedraogo, 2011). Indeed, Vayssières et al. (2009) and Ouedraogo (2011) have shown a significant and positive correlation between precipitation, relative humidity and *B. dorsalis* catches in mango orchards in Benin and Burkina Faso. According to Bateman (1972), low relative humidity of environment in dry periods causes a high mortality of adult flies that should provide a lot effort before leaving the dry soil.

From the stage before flowering to beginning fruiting, males of *B. curcubitae* were more abundant in traps than females. From the stage of maturation to the end of the crop, the trend has changed to that of females with a peak of females in maturation stage (Mat2). This observation was also made by Séri-Kouassi (2004) for *Callosobruchus maculatus* when setting up its second cowpea crop. Indeed, it would seem that the male individuals would come first in the cultures to wait females for a possible mating. Also, according to Bateman (1972), Fay and Meats (1983), males can mate frequently but become unresponsive for several weeks after coupling. This would certainly explain the decrease of male individual in our traps from the stage of maturation of fruits.

The female insects being more attracted by the effluviums of fruits will therefore overabundant during periods of fruiting and maturation in order to lay eggs. According to Quilici (2004), mature females tend to stay on to fructification plants, as long as the fruits are at a stage favorable to spawning and therefore do not need to locate them at long distances. Females in search of a nesting site visit the habitat until they find a fruit at the favorable stage. In the case of *B. cucurbitae*, Nishida and Bess (1957) showed that the gravid females move in the morning from their shelters to the plots containing fruiting host plants and then return to their shelters before dusk. On the other hand, when the host fruits are in small numbers or of lesser quality, the females migrate rather quickly.

Conclusion

This study allowed us to determine the periods of low and high abundances of *B. cucurbitae* and *B. dorsalis* in cucumber orchards. These pests were more abundant during the rainy seasons than dry seasons. The maturation stages of cucumber registered high numbers of flies. This study would allow for better monitoring of the fly population and the timing of treatment.

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