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RESEARCH ARTICLE

OVIPOSITION PREFERENCE AND OFFSPRING PERFORMANCE OF THE ORIENTAL FRUIT FLY BACTROCERA DORSALIS (DIPTERA, TEPHRITIDAE) ON EIGHT HOST PLANTS

Ahamada Karihila Boinahadji^{1,2}, Emile Victor Coly², Cheikh Atab Diedhiou^{1,2} and Pape Mbacké Sembene¹

1. Université Cheikh Anta DIOP de Dakar, Département de Biologie Animale, BP 5005, Dakar, Sénégal.
2. Direction de la Protection des Végétaux-Sénégal, Km 15, Route de Rufisque. BP: 20054 Thiaroye, Dakar, Sénégal.

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Abstract

The oriental fruit fly, *Bactrocera dorsalis*, is one of the most destructive pests of tropical and subtropical fruit crops. The aim of this study was to assess the effect of 8 fruit species on oviposition preference and the offspring performance of *B. dorsalis*. Total soluble solids and pH of fruits were determined by using respectively a refractometer and pH meter. The oviposition preference was evaluated in choice and no-choice tests respectively inside 1 by 0.6 by 0.6 m and 30 by 30 by 30 cm cages at laboratory conditions. The offspring performance was assessed by infesting the fruits with freshly laid eggs and followed until the emergence of adults. The values of total soluble solids content were varied from 4.18 ± 0.99 (tomato) to 14.11 ± 0.99 (mango) ° Brix. The highest pH value was obtained on the papaya (5.61 ± 0.08) while the lemon was the most acidic fruit with a pH of 2.47 ± 0.08 . The oviposition preference results revealed that papaya and mango were the most preferred hosts by *B. dorsalis* among tested fruits in choice and no-choice tests. However lemon was the least preferred fruit in this study. Mango seems to be the most favorable fruit for the development of *B. dorsalis* with a shorter development time (18.68 ± 0.61 days) after the papaya (17.68 ± 0.61 days) and a higher percentage of eggs survival to puparia ($67.83 \pm 8.11\%$) as compared to other fruits. However lemon was the unfavorable fruit for offspring survival of *B. dorsalis*, with a longer development time (22.16 ± 0.61 days) and a lower percentage of eggs survival to puparia ($19.09 \pm 11\%$) as compared to other fruits.

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Introduction:-

The oriental fruit fly, *Bactrocera dorsalis*, is one of the most destructive pests of tropical and subtropical fruit crops. Originally from Asia, this fruit fly was reported for the first time in Africa in 2003 (Lux et al., 2003; Drew et al., 2005). After detection in Kenya, this pest was rapidly spreaded across several African countries where it was found on more than 40 host plants (Drew et al., 2005; Mwatawala et al., 2006; Rwomushana et al., 2008; Ndiaye et al., 2012). In Senegal, cultivated or wild fruit species such as *Mangifera indica*, *Psidium guajava*, *Carica papaya*, *Citrus* sp, *Capparis tomentosa*, *Anacardium occidentale*, *Kedrostis hirtella* and *Solanum lycopersicum* have been identified as host plants of *B. dorsalis* (Ndiaye et al., 2012; Boinahadji et al., 2019).

Corresponding Author:- Ahamada Karihila Boinahadji

Address:- Université Cheikh Anta DIOP de Dakar, Département de Biologie Animale, BP 5005, Dakar, Sénégal.

The best knowledge of the *B. dorsalis* behavior on its host plants is an essential element to develop an effective and sustainable control strategy against this pest. It has been shown that the physico-chemical characteristics of host fruits play an important role in the fecundity and development of *B. dorsalis* (Papachristos et al., 2008; Rattanapun et al., 2009). In Senegal, (Diatta et al., 2013) were studied the *B. dorsalis* preference on five (5) fruit species without evaluated the larval performance of this pest neither the fruit physicochemical parameters that were tested. Thus, this study was therefore undertaken to assess the effect of eight (8) fruit species on the fecundity and the development of the immature stages of *B. dorsalis* (Diptera, Tephritidae) in relation with the pH and Total soluble solids of those fruits.

Materials and Methods:-

The study was conducted in the agricultural zoology laboratory of the Direction de la protection des végétaux in Senegal. The temperature of this laboratory was $27^{\circ}\text{C} \pm 2$ and the photoperiod (light / dark) 12 hours / 12 hours.

Bactrocera dorsalis rearing:

The adults of *B. dorsalis* used in this study were reared in cages at the agricultural zoology laboratory of the Direction de la protection des végétaux. Flies were fed on a mixture of sugar, peptone and yeast hydrolysate. Water was also provided regularly with cotton whose base was immersed in a small plastic bottle. Egg-laying devices made with perforated plastic containers and coated with fruit juice were regularly introduced inside the cages for 24 hours. Eggs were collected and placed on an artificial diet for the immature stages development. The composition of the diet was wheat bran, yeast hydrolysate, sugar, distilled water, benzoate Sodium and HCL.

Host plants:

Eight fruit hosts, viz. mango (*Mangifera indica*), guava (*Psidium guajava*), papaya (*Carica papaya*), tomato (*Solanum lycopersicum*), pomelo (*Citrus paradisi*), mandarin (*Citrus deliciosa*), lemon (*Citrus limon*) and sweet orange (*Citrus sinensis*), were chosen to evaluate the oviposition preference and offspring performance of *B. dorsalis*. Mango, papaya and citrus fruits are selected because are the most grown fruit hosts of *B. dorsalis* in the Niayes area. Guava was included on this list because it is a potential host of *B. dorsalis*. The tomato was chosen because of its recent identification as a host of *B. dorsalis* in Senegal (Boinahadji et al., 2019). All the fruits were fully ripe and harvested directly from trees in Niayes area Orchards. These orchards were situated in the villages of Keur Moussa ($14^{\circ}47'33.76''\text{N}/17^{\circ}07'18.04''\text{W}$), Sébikotane ($14^{\circ}45'10.43''\text{N}/17^{\circ}08'21.82''\text{W}$) and Seugueul ($14^{\circ}59'12.77''\text{N}/17^{\circ}00'41.24''\text{W}$).

Measurement of the total soluble solids and pH of fruits:

Six fruits from each species were selected to measure the total soluble solid and pH. Total soluble solid of fruits was determined by using a digital refractometer (HI 96801). The pH was measured with a pHmeter.

Oviposition preference:

Choice test:

The experiments were conducted inside 1 by 0.6 by 0.6 m cages at the laboratory. In total, 50 couples of *B. dorsalis*, sexually mature (12 to 15 days old) and virgin, were introduced into each cage one day before the experiment. For each fruit, a nail attached to a wire was pointed at its base to facilitate its suspension in the cage. Indeed, the fruits were suspended simultaneously in each cage as oviposition substrate to females and distant 25 cm. After 24 h, the fruits were removed from the cages and incubated individually in plastic containers with sand until the development of larvae into pupae. These pupae were extracted from the sand for each fruit and counted to determine the egg-laying preference of *B. dorsalis* for all the fruits. Three replicated cages were maintained and the experiment was repeated thrice.

No-choice test:

A fruit from each species was placed individually in a 30 by 30 by 30 cm plexiglass cage that containing 10 couples of *B. dorsalis* at 12 to 15 days old. There were 9 replicates of each species. After 24 hours, fruits were removed from cages and incubated individually in plastic containers containing sterilized sand until all larvae had pupated. The recovered pupae from each fruit were counted to determine the egg-laying preference of *B. dorsalis* for all the fruits.

Offspring performance:

To obtain newly laid eggs, an artificial eggging device made with perforated plastic container swabbed with fruit juice were introduced inside the rearing cages of *B. dorsalis* for 2 hours.

Bactrocera dorsalis eggs were collected by washing the artificial eggging device and placed in a container containing water to select viable eggs. Viable eggs sank to the bottom of the container, while non-viable ones floated on the surface (Balagawi et al., 2005).

Each fruit species was weighed, washed and slited before insert *B. dorsalis* eggs using a fine paintbrush at rate of 10 per 100g of fruit. The fruits were subsequently individually incubated over plastic container containing sterilized sand as pupation substrate. From the fifth day, the sand is sieved daily to collect newly formed pupae. The pupae recovered each day from each fruit were counted and placed in Petri dishes until adult emergence. Emerged flies were also sexed and counted daily. The biological parameters studied were the duration of the immature stages, rate of eggs that survived to pupae and sex ratio. There were six replicates of each fruit species.

Statistical analysis:

The data were processed using Microsoft Excel spreadsheet and Xlstat. Analysis of variance (one-way ANOVA) was generated for treatments and means were compared (LSD) by Fisher test at 0.05 probability.

Results:-

Total soluble solids and pH of fruits:

Table I:- Mean values of total soluble solids and pH of fruits.

Fruit species	Total soluble solids (°Brix)	pH
Lemon	8.78±0.99 ^c	2.47±0.08 ^g
Guava	6.00±0.99 ^d	3.88±0.08 ^c
Mango	14.11±0.99 ^a	4.10±0.08 ^b
Mandarin	11.46±0.99 ^b	3.70±0.08 ^d
Orange	12.10±0.70 ^{ab}	2.99±0.06 ^f
Pomelo	11.51±0.99 ^b	3.28±0.08 ^e
Papaya	11.33±0.99 ^b	5.61±0.08 ^a
Tomato	4.18±0.99 ^d	4.18±0.08 ^b
p-values	< 0.0001	< 0.0001

Table I shows the total soluble solids and pH of the eight fruit species. There were significant differences ($P < 0.05$) in the total soluble solids and pH between the fruit species. Total soluble solids values were varied between 4.18 ± 0.99 (Tomato) and 14.11 ± 0.99 (mango) °Brix depending on the fruit species (Table I). Papaya had the highest mean pH (5.61 ± 0.08), while lemon had the lowest (2.47 ± 0.08).

Oviposition preference:

There was a significant difference in the number of puparia recovered from the eight fruit species exposed to *Bactrocera dorsalis* in choice ($F= 4.774$; $P= 0.000$) and no-choice tests ($F= 12.003$; $P < 0.0001$). In the no-choice test, highest number of puparia was recovered from papaya (101.56 puparia per fruit) and mango (69.89 puparia per fruit), whereas the lowest recovery was observed in tomato and lemon (0.22 puparia per fruit).

In the no-choice test, among the eight fruit species tested, papaya (172.67 puparia per fruit) and mango (85.55 puparia per fruit) recorded the highest number of puparia, whereas the lowest were occurred on the lemon (0.22 puparia per fruit) and sweet orange (0.57 puparia per fruit).

Table II:- Oviposition preference of *B. dorsalis* on eight fruit species in choice test

Fruit species	Mean numbers of pupae recovery from eight fruit species	
	Choice test	No-choice test
Guaava	22.00 ^{bc}	16.33 ^{bc}
Lemon	1.67 ^c	0.22 ^c
Mango	69.89 ^{ab}	85.55 ^b
Mandarin	5.56 ^c	3.77 ^c

Orange	5.78 ^c	0.55 ^c
Papaya	101.56 ^a	172.67 ^a
Pomelo	43.33 ^{bc}	7.33 ^{bc}
Tomato	2.78 ^c	7.88 ^{bc}
p-values	0.000	< 0.0001

Offspring performance

Table III shows the development periods and rates survival of *B. dorsalis* immature stages in all the test fruits. Statistical analysis showed that there were significant differences in development period from egg to adult and the rates of eggs that survived to pupae in overall the test fruits. The shortest development times were recorded in papaya and mango with respectively 17.68 ± 0.61 and 18.68 ± 0.61 days (Table III). Mango and pomelo were recorded highest rates of eggs that survived to pupae with respectively $67.83 \pm 8.11\%$ and $51.28 \pm 11.48\%$ (Table III). However, lemon was the unfavorable fruit for offspring survival of *B. dorsalis*, with a longer development time (22.16 ± 0.61 days) and a lower percentage of eggs survival to puparia ($19.09 \pm 11\%$) as compared to other fruits.

Consistent with the results of sex ratio, Mandarin, lemon, guava, orange and tomato favors females than males. Whereas in the papaya, pomelo and mango the males were higher than the females.

Table III:- Effect of host fruit on the development of *B. Dorsalis*.

Fruit species	Egg-pupae period (days± SE)	Pupae-adult period (days± SE)	Egg –adult period (days± SE)	Embryo-larval survival rates (% ± SE)	Sex-ratio (males/females)
Mangue	8.80±0.36 ^a	9.83±0.25 ^{ab}	18.68±0.61 ^{ab}	67.83±8.11 ^a	1.01±0.29 ^{abc}
Mandarin	9.21±0.51 ^{ab}	10.62±0.31 ^{bc}	19.83±0.61 ^{bc}	38.16±11.48 ^{bcd}	0.40±0.42 ^c
Orange	9.58±0.51 ^{ab}	11.01±0.31 ^c	20.59±0.61 ^{bc}	46.14±11.48 ^{abc}	0.56±0.42 ^{bc}
Pomelo	10.21±0.51 ^a	10.62±0.31 ^{bc}	19.69±0.61 ^{bc}	51.28±11.48 ^{ab}	1.30±0.42 ^{ab}
Lemon	11.07±0.51 ^c	11.08±0.31 ^c	22.16±0.61 ^d	19.09±11.48 ^c	0.19±0.42 ^c
Papaya	8.85±0.51 ^a	8.830±0.31 ^a	17.68±0.61 ^a	35.56±11.48 ^{bcd}	1.47±0.42 ^a
Guava	9.99±0.51 ^b	9.68±0.31 ^{ab}	19.67±0.61 ^{bc}	25.06±11.48 ^{cd}	0.42±0.42 ^c
Tomato	10.00±0.51 ^b	9.11±0.31 ^a	19.11±0.61 ^b	40.62±11.48 ^{bcd}	0.16±0.42 ^c
p-values	0.001	< 0.0001	< 0.0001	0.005	0.016

Discussion:-

Oviposition and imature development of fruit flies are influenced by several factors, the most important of which are the physico-chemical parameters of the fruit hosts (Gomez et al., 2019; Aluja and Mangan, 2008). This study shows that there were significant differences ($P < 0.05$) in the total soluble solids and pH between the fruit species. Total soluble solids values were varied between 4.18 ± 0.99 (Tomato) and 14.11 ± 0.99 (mango) °Brix depending on the fruit species. These values found in our study are similar to those obtained by Hipólito et al., (2015) in Portugal which vary between 9.1 and 14.8; 11.9 to 15; 11.4 to 12.8 and 6.5 to 6.9 ° Brix respectively on mango, mandarin, orange and lemon depending on the variety. However, the value found on tomato in the present study is lower (4.18 ± 0.99 ° Brix) than that obtained by Srivalli et al., (2016) in India (6.53 ± 0.06 to 6.93 ± 0.06 ° Brix) and Jorge et al., (2017) in Brazil (7.20 ± 0.50 ° Brix). This variation can be explained mainly by the different cultural practices, including fertilization as well as soil and climate conditions. Papaya had the highest mean pH (5.61 ± 0.08), while lemon had the lowest (2.47 ± 0.08). This agrees with the work of Hipolito et al., (2015), who recorded the highest pH on the lemon among six fruits analysed. The pH values of the fruits obtained in our study are similar to those found by Ovendo-martinez et al., (2018) on the papaya (5.54 ± 0.09 to 5.99 ± 0.06), Diakabana et al., (2013) on mango (4.3), Hipolito et al., (2015) on mandarin (4.2 ± 0.0 to 3.7 ± 0.0), Falguera et al., (2012) on guava (3.96 ± 0.02), Srivalli et al., (2016) on tomato (3.90 ± 0.10 to 4.13 ± 0.10), Sicari et al., (2018) on pomelo (3.01 ± 0.14 to 3.12 ± 0.07), Kubar et al., (2018) on orange (3.2 to 3.59) and lemon (2.62).

Our results were also showed that oviposition preference of *B. dorsalis* varied significantly with fruit species in choice and no-choice conditions. In the two experiment conditions, the highest number of puparia was recovered from papaya and mango. These agree with results obtained by Rwomushana et al., (2008) in Kenya and

Koswanudin et al., (2018) in Indonesia who showed that *B. dorsalis* which showed prefers papaya and mango over other fruits tested under laboratory conditions. However, our results are not totally agree with those of (Diatta et al., 2013) who showed that in laboratory conditions *B. dorsalis* prefers more papaya and citrus followed mango. The higher numbers of pupae that recorded in papaya and mango can be explained by the pericarp (soft) and the volatile compounds of these fruits which play an important role in the *B. dorsalis* egg-laying. In fact, fruit flies favour favour laying their eggs on fruits with soft pericarp than those with harder pericarp (Balagawi et al., 2005; Rattanapun et al., 2009). In addition, Kamala et al., (2014) identified four volatile compounds on mango (γ octalactone, 1-octen-3-ol, ethyl tiglate and benzothiazole) that stimulate *B. dorsalis* oviposition.

The low number of *B. dorsalis* pupae obtained on lemon agrees with results of Boinahadji et al., (2019) in Senegal and Mwatawala et al., (2009) in Tanzania under natural conditions. This low infestation of lemon was also observed by Staub et al., (2008) and Rizket al., (2013) on *Ceratitis capitata* and *Bactrocera zonata* respectively under laboratory conditions. This observation can be due to the presence of toxic substances on the zest and the high acidity in the pulp of this fruit which is a limiting factor for the development of immature stages of fruit flies (Salvatore et al., 2004; Papachristos et al., 2008).

Statistical analysis showed that there were significant differences in development period from egg to adult and the rates of eggs that survived to pupae in overall the test fruits. Similarly, variation was reported in this fruit fly, *B. dorsalis* reared on different fruit hosts namely sweet orange, mango, guava, jujube, waxapple, pomelo, pitaya, papaya, sapote and banana (N'guessan et al., 2011 ; Huang and Chi, 2014 ; Kalia and Yadav, 2015). In this study, papaya and mango recorded the shortest development times of *B. dorsalis* from egg to adult. The development times of *B. dorsalis* immature stages obtained in this study are close to those found by (Kalia and Yadav, 2015) on mango (18.00 ± 0.80 days) and by (Huang and Chi, 2014) on guava (19.66 ± 0.09 days) and on the orange (21.85 ± 0.17 days). However, the time of *B. dorsalis* development cycle found on papaya in this study is lower (17.68 ± 0.61 days) than that obtained by (Kalia and Yadav, 2015) (20.2 ± 0.77 days). This variation can be explained mainly by the differentiation of the experimental conditions and biochemical composition of the papaya varieties that were tested. The highest rate of eggs that survived to pupae was recorded on the mango. This is explained by the fact that mango has the necessary nutrients for the development of *B. dorsalis* larvae. Moreover, it was the most sugary in all fruit species, which provided the favorable medium of development to the larvae. According Lorscheiter et al., (2012), fruits with high sugar content (total soluble solids content) are considered ideal for the fruit flies development (*A. Fraterculus*).

Oviposition preference results showed that *B. dorsalis* prefers papaya and mango more than the other fruits tested in choice and no-choice conditions. These oviposition preference results agree with those obtained from larval performance study on mango with a shorter development time after the papaya and a higher egg-pupae survival rate compared to other fruits. Although papaya recorded the shortest immature development time, a very low rate of eggs that survived to pupae was observed on this fruit. This low survival rate is due to microbiological contamination that influenced by the high pH (5.61 ± 0.08) recorded in this fruit. This hypothesis was supported by Dias et al., (2019) who showed that on diet with pH 6.0, no larval hatching occurred for *Anastrepha fraterculus* and *Ceratitis capitata*, possibly due to the rapid microbiological contamination of the diet. However, lemon was the unfavorable fruit for offspring survival of *B. dorsalis*, with a longer development time (22.16 ± 0.61 days) and a lower percentage of eggs survival to puparia ($19.09 \pm 11\%$) as compared to other fruits. This is in accordance with oviposition preference results obtained on this fruit. Our results agree the work of Papachristos et al., (2008) who found the longest larval development time of *C. capitata* on the lemon (*C. limon*) among 4 citrus species tested. These results can be explained by the fact that lemon has a lower pH compared to other fruits. Several authors were reported that diet with a pH very acid cause an increase of the development time and reduction of immature stages viability of fruit flies (Papachristos et al., 2008; Vera et al., 2014; Dias et al., 2019). However, pH is not the only factor influencing the fruit flies development. Salvatore et al., (2004) found that coumarin and linalool presents in lemon were toxic to *C. capitata* larvae.

Conclusion:-

This study showed that *B. dorsalis* prefers lay eggs on papaya and mango, whereas lemon was the least preferred fruit for this pest at laboratory conditions.

The study showed also that the physico-chemical parameters of fruits and the development of immature stages of *B. dorsalis* vary significantly depending the fruit species. On overall fruits tested, mango was recorded the highest total

soluble solid and seems to be the most favorable fruit for the development of *B. dorsalis* with a shorter development time after the papaya and a higher percentage of eggs survival to puparia as compared to other fruits. However, the lemon with the most acidic pH proved to be the unfavorable fruit for offspring survival of *B. dorsalis*, with a longer development time and a lower percentage of eggs survival to puparia as compared to other fruits.

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