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Research Article
Potential of Fruit Extracts as Attractants of Female Oriental Fruit Flies

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Abstract
Background and Objective: The oriental fruit fly *Bactrocera dorsalis* (Hendel) is one of the most important insect pest species of fruit and vegetable crops in the tropical and subtropical regions. This study aimed to determine the attraction of female and male *B. dorsalis* fruit flies to the aroma of fruit juice from the host plants as well as their attraction to methanol extract, ethyl acetate extract and distillate water of selected host fruits. **Materials and Methods:** The attractiveness of the juice and extract/distillate water of the host fruits to *B. dorsalis* fruit flies was carried out in an experimental cage measuring 200×200×200 cm that was placed in the laboratory. The volatile compounds in the juice, methanol extract, ethyl acetate extract and distillate water of the selected fruits were analyzed using GCMS-Pyrolysis. **Results:** The results show that among the eight fruit juice aromas tested, the ones that significantly affected the number of trapped female *B. dorsalis* were the aromas of banana juice, papaya juice and chilli juice. The results of the analysis by GCMS-Pyrolysis showed that the methanol extract of banana fruit contains one volatile compound that was previously reported to have the ability to attract female *B. dorsalis* fruit flies. Two volatile compounds in the banana distillate water were also reported to have the ability to attract female *B. dorsalis* and other fruit flies. **Conclusion:** From the results of this study, it can be concluded that the methanol extract and distillate water of the green *Ambon lumut* banana fruit of *Musa acuminata* Colla has the potential to be developed as an attractant of female *B. dorsalis*.

Key words: Banana juice, banana extract, banana distillate water, fruit fly traps

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The oriental fruit fly, *Bactrocera dorsalis* (Hendel) is one of the most important insect pest species of fruit and vegetable crops in both the tropical and subtropical regions[1-3]. This insect is a polyphagous pest capable of attacking more than 300 species of host plants from 40 families[4], including chilies[5,6]. Yield losses due to attacks by *B. dorsalis* on fruit trees can reach 80%[7]. The most common methods of controlling *B. dorsalis* include the application of synthetic pesticides, poisonous baits, traps containing methyl eugenol attractant, fruit bagging and the release of sterile males[8,9].

Synthetic pesticides, especially systemic ones, are usually quite effective at controlling fruit flies[10,11] but these types of pesticides can be harmful to the environment and leave residues in the fruit that have the potential to harm consumers if they exceed the limit[12,13]. Traps containing methyl eugenol can effectively attract *B. dorsalis*[14-16], but only male[8,17]. Previously, no female fruit fly attractant has been proven to be effective and commercially available. Research on the development of the attractants of female fruit flies is still limited to the use of pheromone baits, both in the form of living male flies and pheromone extracts from male flies, with inconsistent results[18].

Female *B. dorsalis* are known to be attracted to the aroma of fruits, such as citrus[19], papaya[20] and mango[21]. According to Cornelius *et al.*[19], both mated and unmated (aged 10-12 days) *B. dorsalis* females that have consumed protein prefer the aroma of fruits to the aroma of protein. Therefore, the addition of a fruit aroma to fruit fly traps has the potential to control female *B. dorsalis* fruit flies.

Fruit aromas are usually added to fruit fly traps in the form of juice[22-24]. However, the use of juice has a disadvantage in terms of its short-term durability[24,25]. Therefore, alternative ways of separating the fruit aromas that guarantee their durabilities, such as extraction and distillation processes, are needed[26]. The technique of extracting active compounds from the plants can be done through the immersion of the plant materials in organic solvents[27,28]. The distillation technique is also commonly used to isolate volatile active plant compounds[29,30].

There is very little information about the effect of fruit extracts on attracting female *B. dorsalis*. Siderhurst and Jang[31] reported that the ethanolic extract of the *Ketapang*, the tropical almond (*Terminalia catappa* L.), was attractive to mated *B. dorsalis* females. The results of another study showed that the extract of methylene chloride-water (1:1) from the leaves of *Geranium aralias* (*Polyscias guilfoylei* [W. Bull]) was also attractive to *B. dorsalis* females[32].

Previously, there had been no report on the effect of products following the distillation of host fruits in the form of either essential oil or distillate (aromatic water) on the attraction of female *B. dorsalis* and females of other fruit fly species. However, the attraction of male fruit flies to some essential oils has been studied. El-Gendy *et al.*[33] reported that the essential oil derived from cubeb fruit (Java pepper) (*Piper cubeba*) attracted male fruit flies of *Bactrocera zonata* (Saunders), with an attractiveness equivalent to methyl eugenol. Clove essential oil (*Eugenia caryophyllata*) is also known to attract male fruit flies of *B. zonata* and *Ceratitis capitata* (Wiedemann)[34]. Male fruit flies are attracted to essential oils derived from Java pepper and cloves because the essential oils contain several attractive compounds, one of which is methyl eugenol.

This study aimed to determine the attraction of female and male fruit flies of *B. dorsalis* to the aromas of some host plant fruits, namely apples, guava, oranges, star fruit, mangos, papaya, banana and chillies. In the first stage, the attraction of *B. dorsalis* fruit flies to the juice of the 8 host fruits was evaluated. It was then tested to determine the attraction of the fruit flies to the extract and distillate water of the host fruit with the strongest attractiveness.

MATERIALS AND METHODS

Study area: This study was conducted from August, 2019 to May, 2020 at the Laboratory of Pesticide and Environmental Toxicology, Faculty of Agriculture, Universitas Padjadjaran, Sumedang, Indonesia at an elevation of 752 m above the sea level.

Plant material: A total of 8 types of fruit were tested to determine the attractiveness of their aromas to the *B. dorsalis*. The fruits were the Malang apple (*Malus sylvestris* (L.) Mill., guava (*Psidium guajava* Linn), sweet orange (*Citrus sinensis* L.), star fruit (*Averrhoa carambola* Linn), *Arumanis* mango (*Mangifera indica* L.), California papaya (*Carica papaya* L.), *Ambon lumut* banana (*Musa acuminata* Colla [AAA Group] 'Dwarf Cavendish') and large red chillies (*Capsicum annum* L.) var. Pertiwi. All of the fruits were ripe (ready for consumption) except for the chillies whose skins were still green. The fruits were purchased from a local fresh fruit market/supermarket.

Fruit juice: Juice was obtained by adding water and blending the fruits and water for about 3 min. Each litre of juice contained 300 g of fruit. All of the juice was stored in the refrigerator at 4 ± 1°C before use. Each of the fruit juices was then removed and placed outside the refrigerator for 60 min before application.

Banana fruit extract: The banana fruit extract was made using the maceration technique and the organic solvents methanol and ethyl acetate. Bananas that had been peeled were cut into small pieces and dried in the oven (50°C) for several days until the weight was constant. Next, the banana pieces were soaked in methanol (99.85%) or ethyl acetate (99.8%) at a ratio of 1:10 (w/v). The maceration results were then filtered using filter paper so then the filtrate was obtained and evaporated using a rotary evaporator at a temperature of 50°C. This was to separate the fruit extract from the methanol or ethyl acetate solvent. The fruit extract obtained was then stored in a refrigerator at a temperature of 4±1°C until ready to use.

Banana distillate: Distillate water was made by putting banana fruit juice (300 g of fruit in 1 L of juice) in a distillation flask. The flask was then heated to boiling so then the water vapour flowed into the cooling channel. The water that dripped from the cooling line was collected in the bottle. The distillate was then stored in a refrigerator at a temperature of 4±1°C until ready for use.

Fruit fly traps: The fruit fly traps were made from 1 L clear plastic tubes (13 cm high and 9 cm diameter) with a lid. In the upper third of each trap (±8 cm from the bottom of the tube), a clear tube (1 cm diameter and 2.5 cm long) was installed on each of the four sides for the entry of the fruit flies into the trap tubes. At the bottom of each trap was placed dry tissue paper that had been cut into rounds to absorb the juice poured into it.

Fruit fly rearing: The rearing of *B. dorsalis* fruit flies was carried out in a room at a temperature of 25±2°C, a humidity of 60-75% and a photoperiod of 12:12 hrs. The *B. dorsalis* fruit flies were kept in an iron-framed gauze cage (50×50×50 cm) and fed with white sugar and protein hydrolysate (3:1) and water. The food and water were changed every week. The fruit fly eggs were harvested using a 300 mL plastic cup filled with mango-scented water (nutrisari®). The larval rearing was carried out using an artificial diet as described by Hidayat *et al.*[35]. The female and male adults (mated) used in this study were between 14-21 days old.

Test of fruit juice attractiveness to *B. dorsalis*: The test of fruit juice attractiveness was carried out using the choice test method in a test cage made of a PVC pipe frame measuring 200×200×200 cm covered with white gauze. One day before the treatments, the fruit flies (100 males and 100 females mated, both of which were 14-21 days old) were separated from their colonies by being trapped one by one and placed in a cage measuring 50×50×50 cm. They were fed sugar, protein hydrolysate (yeast hydrolysate) and water. On the day of the experiment, the fruit flies were released into the cage at±60 min before trapping to provide an opportunity for them to adapt to the experimental cage. Next, the juice of mango, apple, papaya, guava, orange, star fruit, chilli and banana, each of which totalled 50 mL, was poured into their respective trap which was hung in the experimental cage (±50 cm from the cage floor) with a distance between the traps of 30 cm. For the chillies, apart from being in the form of a juice, 3 chillies (±45 g) were also put into the trap. For the control, 50 mL of mineral water was used. The experiment was repeated 5 times using a randomized block design. Observations were made on the number of fruit flies (male and female) entering each trap over 6 hrs with an observation interval every 15 min. The last observation was made 24 hrs after the treatments.

Test of the attractiveness of the extract and distillate water of banana fruit to *B. dorsalis*: The test of the attractiveness of methanol extract, ethyl acetate extract and the distillate of banana fruit to male and female *B. dorsalis* fruit flies was carried out using the choice test method in a test cage made of a PVC pipe frame measuring 200×200×200 cm covered with white gauze. One day before the treatments, the fruit flies (100 males, 100 females, both of which were 14-21 days old) were separated from their colonies by being trapped one by one and placed in a cage measuring 50×50×50 cm. They were fed sugar, protein hydrolysate (yeast hydrolysate) and water. On the day of the experiment, 5 mL banana fruit extract at a concentration of 5% (5 g extract/100 mL distillate) was put into a fruit fly trap. For the distillate, the volume added was 5 mL (without dilution). The fruit extract and the distillate water of the banana were poured into tissue paper (unscented) and then each tissue paper was put into a tea filter bag. For comparison, a tea filter bag with 5 mL banana juice was also put into the trap. Meanwhile, mineral water was used as the control. The 5 traps above were hung using a thread at a position of±50 cm from the bottom surface of the test cage and the distance between the treatments was 75 cm.

Analysis of the volatile compounds of the juice, extract and distillate water of banana fruit: The qualitative and quantitative analysis of the volatile compounds was measured using a Gas Chromatography-Mass Spectrometry (GCMS) Pyrolysis Shimadzu GCMS-QP 2010 brand with a column length of (rt×5 ms) 60 m, a diameter of 0.25 mm and a thickness of 0.25 m. The initial column oven temperature was maintained at 50°C for 5 min and then increased by 2.5°C min^{-1} to 150°C and finally set at 90°C min^{-1} to 280°C. In the pyrolysis stage, it was set to 300 for the liquid sample (400°C for the solid sample). Gas chromatography was set at a pressure of 101.0 kPa, with a total flow of 46.5 mL min^{-1}, a column flow of 0.85 mL min^{-1} and a linear velocity of 23.7 cm sec^{-1}. The ion source and the interface temperatures were maintained at 200 and 280°C with a split ratio of 1:50 with a 1 µL of sample injected. From the results of the GCMS-Pyrolysis test in the form of chromatograms, the contents of the chemical compounds have been analyzed and tabulated using the Wiley 7 program.

Data analysis: The data were first checked for normality and homogeneity. Furthermore, the data were analyzed using the ANOVA (analysis of variance) test to determine whether or not there were differences between the treatments. When there was a difference found, the data was further tested using Tukey's test at a 95% confidence level. The statistical program used was Minitab v.18.

RESULTS

Effect of the eight juice aromas on the total of trapped *B. dorsalis*: The results show the number of females in Fig. 1a and males in Fig. 1b fruit flies that entered the traps containing the fruit juices increased with the increase in exposure time. Meanwhile, in the traps containing chillies and mineral water (the control), the number of fruit flies trapped only increased at the beginning of the observation, then there was no increase in catches. Among all of the fruit juices tested, the highest cumulative catch at 360 min after exposure was found on the juice of the papaya (4.6 flies) for females and banana (4.6 flies) for males.

The results show that of all of the fruit juice aromas tested, the aromas that significantly affected the number of female *B. dorsalis* fruit flies trapped after 24 hrs, compared to control (0.6 flies), were those of chilli juice (4.8 flies), papaya juice (5.8 flies) and banana juice (5.6 flies) ($F_{9,36} = 4.17$, p = 0.001). However, there was no significant difference in the number of female fruit flies trapped among the three treatments. The results also showed that among all of the fruit juices tested, only the aromas of banana juice (5.6 flies), papaya juice (4.8 flies), orange juice (4.8 flies) and chilli juice (4.2 flies) were able to significantly attract male *B. dorsalis* compared to control (0.4 flies) ($F_{9,36} = 6.03$, p = 0.000) in Table 1.

Effect of the four best fruit aromas on the total trapped female *B. dorsalis*: The four best fruit aromas from the previous test (the juice aromas of banana, papaya, mango and chilli) were further tested for their attractiveness to *B. dorsalis*. The results show that banana fruit juice was able to attract female fruit flies with a consistently higher catch than the other fruit juice aromas in Fig. 2a. The aroma of banana juice was also more attractive than the juice aromas of the other fruits to male fruit flies, especially after 4 hrs of observation in Fig. 2b. Among all of the fruit juices tested, the highest cumulative catch at 360 min after exposure was found on the juice of the banana (17.33 flies for females and 5 flies for males).

The results show that out of all the fruit juice aromas tested, only the aroma of banana juice (22.6 flies) had a significant effect on the number of trapped female *B. dorsalis* at 24 hrs compared to control (1.6 flies) ($F_{4.18} = 15.22$, p = 0.000). Meanwhile, the number of female fruit flies trapped in the chilli, mango and papaya juice treatments was not significantly different from the control. The results also showed that among the 4 fruit juice aromas tested, only banana juice (9.2 flies) had a significant effect on the number of trapped male *B. dorsal* compared to control (0.4 flies) ($F_{4.18} = 2.66$, p = 0.071) in Table 2.

Table 1: Number of female and male *B. dorsalis* trapped in the plastic traps containing fruit juice 24 hrs after treatment

	Number of trapped *B. dorsalis*	
Treatments	Female	Male
Apple juice	3.0 ± 0.63^{abc}	2.0 ± 0.45^{bcd}
Star fruit juice	3.6 ± 0.93^{abc}	2.2 ± 0.58^{abcd}
Chili fruit	1.4 ± 0.40^{bc}	1.0 ± 0.55^{cd}
Chili juice	4.8 ± 1.46^{ab}	4.2 ± 0.73^{abc}
Guava juice	2.0 ± 0.32^{abc}	2.2 ± 0.37^{abcd}
Orange juice	2.8 ± 0.73^{abc}	4.8 ± 1.66^{ab}
Mango juice	4.2 ± 0.73^{abc}	3.4 ± 0.87^{abcd}
Papaya juice	5.8 ± 1.32^{a}	4.8 ± 0.37^{ab}
Banana juice	5.6 ± 1.54^{a}	5.6 ± 1.47^{a}
Aquadest (control)	0.6 ± 0.40^{c}	0.4 ± 0.24^{d}

Means in the same columns followed by different letters show a significant difference at the 95% confidence level (Tukey test: p<0.05)

Table 2: Number of female and male *B. dorsalis* trapped in the plastic traps containing fruit juice 24 hrs after exposure

	Number of trapped *B. dorsalis*	
Treatments	Female	Male
Chili juice	6.60 ± 1.91^{b}	5.2 ± 1.98^{ab}
Mango juice	8.20 ± 2.91^{b}	4.6 ± 1.21^{ab}
Papaya juice	7.0 ± 1.38^{b}	5.6 ± 2.06^{ab}
Banana juice	22.6 ± 2.11^{a}	9.2 ± 2.76^{a}
Aquadest (control)	1.6 ± 0.68^{b}	0.4 ± 0.24^{b}

Average value in the same column followed by different letters shows a significant difference at the 95% confidence level (Tukey test: p<0.05)

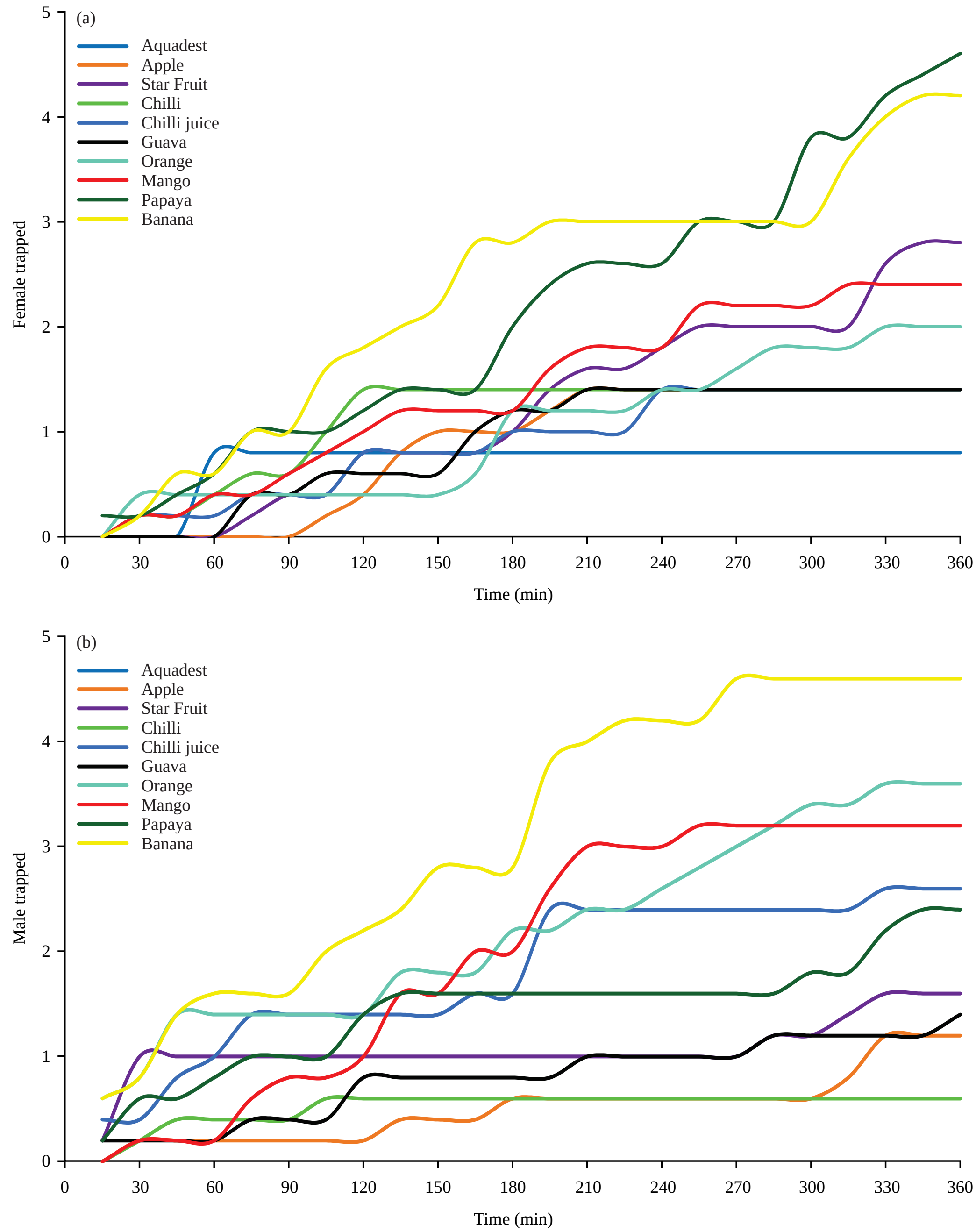


Fig. 1(a-b): Number of (a) Female *B. dorsalis* and (b) Male *B. dorsalis* entering the plastic traps each of which contained a fruit juice during 360 min with an observation interval of every 15 min

Effect of banana extract and distillate water on the total trapped female *B. dorsalis*: From the results of the previous experiments in this study, it was known that the aroma of banana fruit was the most attractive to females *B. dorsalis*, the main pest in chili cultivation. In this experiment, during the first 6 hours of the observation, the number of female fruit flies trapped tended to increase with increasing observation time in Fig. 3a. However, the attractiveness of the methanol extract of banana began to increase sharply to the female fruit flies 4 hrs after the observation. Banana extract and distillate water were also able to attract male fruit flies in Fig. 3b. A sharp increase in the number of male fruit fly catches occurred during the 4-6 hrs of observation. For the treatments of methanol and ethyl acetate extracts, the number of trapped

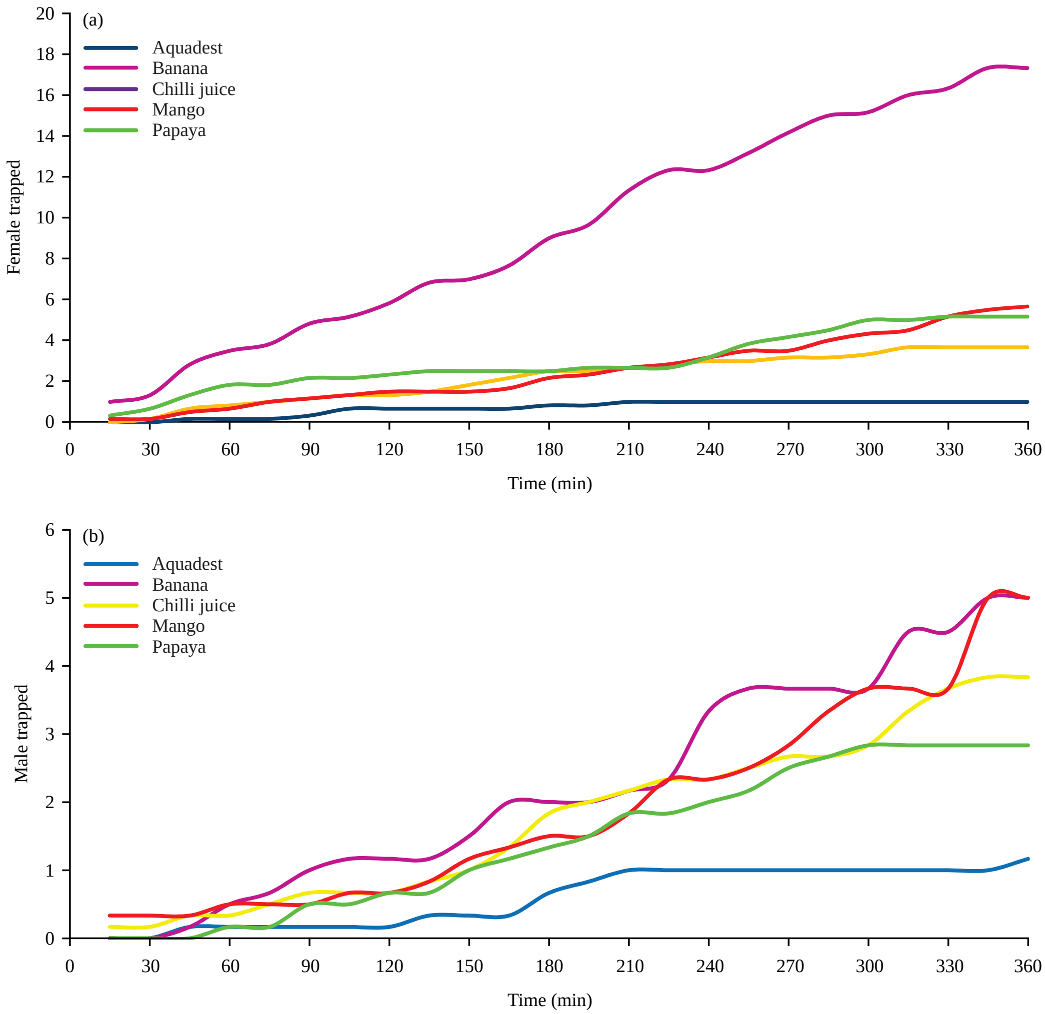
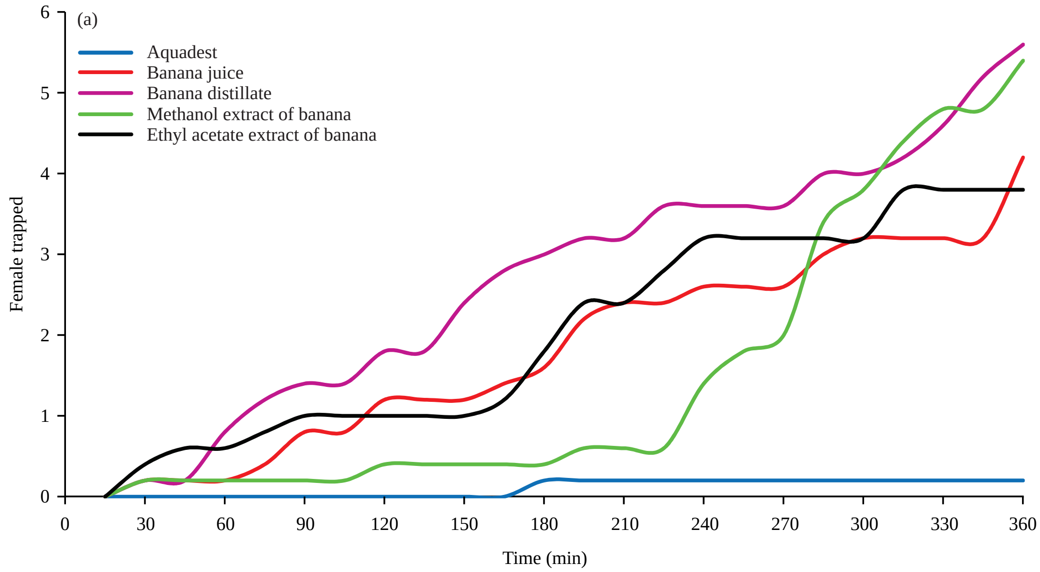


Fig. 2(a-b): Number of (a) Female *B. dorsalis* and (b) Male *B. dorsalis* fruit flies that entered the plastic traps, each of which contained the juice of one of 4 fruits during 360 min with an observation interval every 15 min

male fruit flies was relatively low during the 6 hrs of observation. Among all of the extracts of banana tested, the highest cumulative catch at 360 min after exposure was found on the banana distillate for females (5.6 flies) and banana juice for males (4.2 flies).

In the observation 24 hrs after exposure, it was found that banana distillate and the methanol extract of banana were able to significantly attract female *B. dorsalis* fruit flies compared to the control ($F_{4,4}$ = 4.60, p = 0.012). In the two extract treatments, the numbers of female fruit flies trapped were 11.0 and 12.0 per trap while in the control, there were only 0.8 per trap. Meanwhile, out of all of the treatments tested, only the fruit juice was able to significantly trap male *B. dorsalis* (8.2 flies/trap) compared to the control (1 fly/trap) in Table 3.

Analysis of the volatile compounds in the juice extract and distillate water of banana fruit using GCMS pyrolysis: Chemical analysis using GCMS Pyrolysis of the juice of the green *Ambon lumut* banana fruit (*Musa acuminata* Colla) found 29 volatile compounds, the most common of which were 3,7-dimethyl-2,4,6,8-tetraoxabicyclo (3.3.0) octane (21.61%), 2-furancarboxaldehyde, 5-(hydroxymethyl)-(CAS) HMF (15.15%), 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one (10.85%), acetic acid (CAS) ethylic acid (7.5%), hexadecanoic acid (CAS) palmitic acid (7.1%), 2-furancarboxaldehyde (CAS) furfural (7.06%) and 2,5-dimethyl -4-hydroxy-3(2H)-furanone (5.58%) in Table 4. Eleven volatile compounds were found in the ethyl acetate extract, the most common of which were 1,1-dimethylhydrazine (31.29%), 5-acetoxymethyl-2-furaldehyde (19.59%), tributyl acetyl



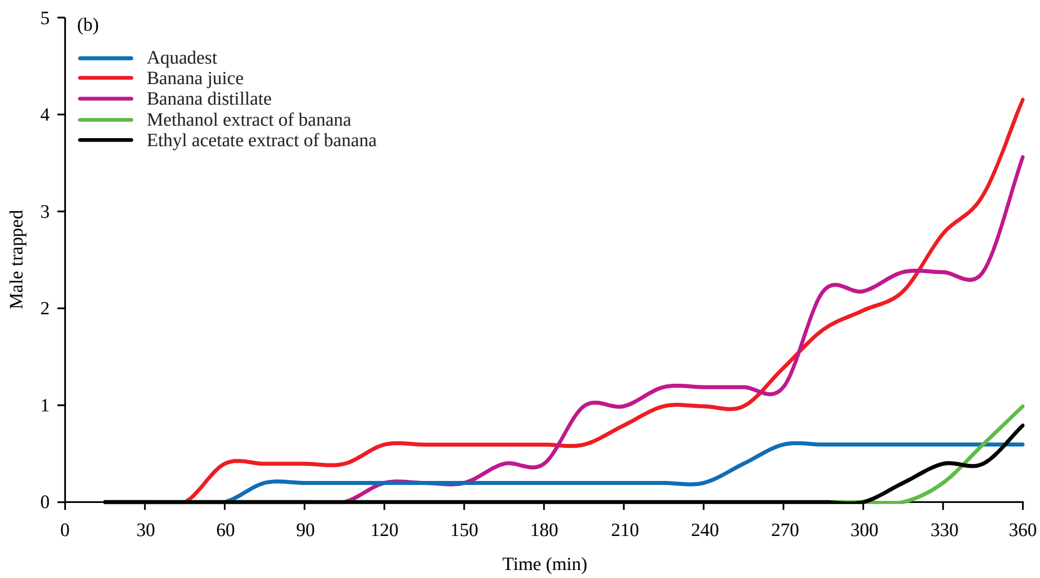


Fig. 3(a-b): Number of (a) Female *B. dorsalis* and (b) Male *B. dorsalis* trapped in the plastic traps containing the juice extract and distillate water of banana during the 6 hrs of observation

citrate (18.95%), d-glycero-1-gluco heptose (11.2%), 9,12-octadecatrienoic acid (5.02%) and n-aminopyridine (5%) in Table 5. Twenty volatile compounds were found in the distillate water of the green *Ambon lumut* banana, the most common of which were 2,2-dimethyl-1,3-dioxane-4,6-dione (37.39%), cyclopropane, 1,1-dibromo- 2-chloro-2-fluoro (31.13%) and 4H-pyran-4-one, 2,6-dimethyl-(CAS) 2,6-dimethyl-4-pyrone (7.88%) in Table 6. Twelve volatile compounds were found in the methanol extract of banana fruit, the most common of which were 5-hydroxymethylfurfural (59.77%), furfural (6.08%), n-hexadecanoic acid (4.87%) and 4h-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl (4.57%) in Table 7. Most of the volatile compounds found in the banana fruit were from the furan, aldehyde, alcohol, ester, acid, ketone, aliphatic hydrocarbon and flavonoid groups. The volatile compounds of the alcohol, aldehyde, ester, ketone and aliphatic hydrocarbon groups are supposedly able to attract *B. dorsalis*.

Table 3: Number of female and male *B. dorsalis* trapped in the plastic traps containing either juice, distillate water, or the extract of banana fruit during the observation 24 hrs after exposure

	Number of trapped *B. dorsalis*	
Treatments	Female	Male
Banana juice	8.0±3.42[ab]	8.2±3.37[a]
Banana distillate	11.0±2.37[a]	5.6±2.29[ab]
Methanol extract	12.0±2.53[a]	3.4±1.47[ab]
Ethyl acetate extract	5.2±1.32[ab]	2.0±0.63[ab]
Aquadest	0.8±0.80[b]	1.0±0.32[b]

Average values in the same columns followed by different letters show a significant difference at the 95% confidence level (Tukey test: $p<0.05$)

Table 4: Volatile components of juice banana fruits

Peak No.	RT	Components name	Relative (%)
1	4.108	Ammonium bicarbonate	0.20
2	4.512	Per acetic acid	0.89
3	6.126	Butanal, 3-methyl- (CAS) 3-Methylbutanal	1.39
4	7.047	Acetic acid, anhydride (CAS) Acetic oxide	0.97
5	7.613	Ammonium oxalate	1.97
6	7.955	Acetic acid (CAS) ethylic acid	7.50
7	8.308	2-Propanone, 1-hydroxy- (CAS) acetol	1.51
8	9.575	2,2-Bioxirane (CAS) butadiene dioxide	0.39
9	10.078	2-Furancarboxaldehyde (CAS) furfural	7.06
10	10.947	2-Furanmethanol (CAS) Furfuryl alcohol	1.83
11	11.208	cyclopent-2-EN-1,4-Dione	1.36
12	12.261	2-Furancarboxaldehyde, 5-methyl- (CAS) 5-Methyl-2-furfural	2.59
13	12.752	3,7-Dimethyl-2,4,6,8-tetraoxabicyclo[3.3.0]octane	21.61
14	13.311	2,3-Butanedione (CAS) diacetyl	2.04
15	13.812	2,3-Dihydro-5-hydroxy-6-methyl-4H-pyran-4-one	2.64
16	14.097	2,5-Dimethyl-4-hydroxy-3(2H)-furanone	5.58
17	14.475	Cyclopropyl carbinol	0.90
18	14.682	Ethanone, 1-(6-Methyl-7-Oxabicyclo[4.1.0] Hept-1-YL)	0.95
19	14.890	2,3-Dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one	10.85
20	15.475	4H-Pyran-4-one, 3,5-dihydroxy-2-methyl- (CAS) 3,5-Dihydroxy-2-methyl-4H-py	2.38
21	15.870	2-Furancarboxaldehyde, 5-(hydroxymethyl)- (CAS) HMF	15.15
22	16.954	Spiro[androst-5-ene-17,1'-cyclobutan]-2'-one, 3-hydroxy-, (3.beta.,17.beta.)	0.17
23	17.158	1,5-Pentadiol, diacetate	0.12
24	18.572	9,12,15-Octadecatrienoic acid, 2,3-dihydroxypropyl ester, (Z,Z,Z)- (CAS) 1-MO	0.60
25	19.875	Hydrazinecarboxamide, 2-(2-methylcyclohexylidene)- (CAS) cyclohexanone,	0.42
26	20.968	Hexadecanoic acid (CAS) palmitic acid	7.10
27	21.558	1-Octanol, 2-butyl- (CAS) 2-Butyl-1-octanol	0.15
28	22.183	9,12-Octadecadienoic acid (Z,Z)- (CAS) Linoleic acid	1.50
29	22.658	3-methylbutyl dodecanoate	0.17

Table 5: Volatile components of ethyl acetate extract of banana fruits

Peak No.	RT	Components name	Relative (%)
1	8.451	1,1-dimethyl hydrazine	31.29
2	10.202	Furfural	1.08
3	12.542	2,4-dihydroxy-2,5-dimethyl-3, (2H)-furan-3-one	1.93
4	39.876	4h-pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl	4.19
5	40.373	n-aminopyridine	5.00
6	40.645	2-propanamine, N-methyl-N-nitroso	1.23
7	42.004	5-acetoxymethyl-2-furaldehyde	19.59
8	42.250	2,6-dimethoxy, 2-propeno, Fenol	1.08
9	47.381	Tributyl acetylcitrate	18.95
10	55.971	d-Glycero-1-Gluco Heptose	11.2
11	57.488	9,12-octadecatrienoic acid	5.02

Table 6: Volatile components of distillate water of banana fruits

Peak No.	RT	Components name	Relative (%)
1	3.530	Cyclopropane, 1,1-dibromo-2-chloro-2-flouro	31.13
2	4.212	2,2-dimethyl-1,3-dioxane-4,6-dione	37.39
3	5.117	4H-Pyran-4-one, 2,6-dimethyl-(CAS) 2,6-dimethyl-4-pyrone	7.88
4	5.505	1,1-dibromo-2-chloro-2-flouro-Cycloprophane	15.92
5	14.205	beta-cyclocitral	0.45
6	16.419	2-butyl-1-octanol	0.30
7	16.617	3 alpha, 5 alpha- 3-thiocyanato Cholestan (thiocyanic acid)	0.12
8	16.851	beta-cedrene	0.22
9	17.267	4,4-dimethyl, oxime, 5 alpha, Cholestan-3-one	0.38
10	18.091	n-Hexadecane	0.33
11	18.847	n-Eicosane	0.37
12	19.217	1,6-dimethyl-4-(1-methylethyl), Naphthalene -(CAS) Cadalin	0.55
13	19.566	n-Octadecane	0.46
14	20.367	7-Oxoprostaglandin 1 Methyl Ester 15-tert-butyl dimethyl	1.84
15	20.917	Dodecanamide, N-dodecyl-N-(trifluoroacetyl)	1.35
16	21.572	4-(4-methylpiperazinyl)-N-(2,3-xylyl)-1,8-naphthalimide	0.47
17	22.260	3,7,11,15-tetramethylhexadecane-1-OL-trimethylsilyl ester trimethylsilyl ester	0.18
18	22.983	May myrsine	0.23
19	23.780	Octadecanoid acid, tetradecyl ester (CAS) Myristyl stearate	0.26
20	24.693	Pentatriacontane, 17-hydroxymethyl	0.16

Table 7: Volatile components of methanol extract of banana fruits

Peak No.	RT	Components name	Relative (%)
1	9.852	1,1-dimethyl hydrazine	1.17
2	10.236	Furfural	6.08
3	18.304	2-furanmethanol	2.81
4	35.836	Furaneol	1.04
5	37.432	2-Etyl Hexanal	1.05
6	38.823	2-Propen-1-ol	1.50
7	39.864	4h-pyran-4-one, 2,3-dihidro-3,5-dihydroxy-6-methyl	4.57
8	42.061	5-hydroxymethylfurfural	59.70
9	42.353	9,12,15-octadecatrienoic acid, methyl ester	1.64
10	47.806	n-Hexadecanoic acid	4.87
11	57.562	10 (E), 12 (Z)-conjugated linoleic acid	1.01
12	61.241	9,12,15-octadecatrienoic acid	2.15

DISCUSSION

Based on the results of this research using the laboratory scale, it was found that female *B. dorsalis* were more attracted to the juice aromas of banana, papaya and chilli than the juice aromas of the other fruits tested. Further laboratory testing showed that female *B. dorsalis* preferred the juice aroma of banana to that of papaya, mango and chilli. Different results were shown in the study of Jaleel *et al.*[36], who reported that the attractiveness of the aroma of banana to female *B. dorsalis* was not as strong as that of the aromas of guava and papaya. The differences in banana varieties supposedly affected the different attraction levels of the fruit flies.

Several studies have shown that banana fruits have the potential to attract and become the host of *B. dorsalis* and other species of fruit flies. Recently, Jaleel *et al.*[37] reported that banana fruit was able to attract male and female *B. dorsalis* and *Bactrocera correcta*, although the attractancy was lower than that of mango fruit, especially for the female flies. Banana is also known to attract male and female *Bactrocera invadens*[38]. Furthermore, banana fruit is infested by *B. dorsalis* in both a laboratory setting[39] and in the field study[40]. *B. dorsalis* and other Tephritidae fruit flies are generally not regarded as significant pests of economic importance for banana (Musa) because the banana and plantain fruits harvested on green stage one or earlier[41].

The aroma of green *Ambon lumut* banana (green *Ambon* variety) has the potential to be an attractant of female *B. dorsalis*. This study found that the methanol extract and distillate water of green *Ambon lumut* bananas are better than the banana juice and ethyl acetate extract at attracting female *B. dorsalis*. However, there was no difference found in the attractiveness of the three types of banana fruit extract to male *B. dorsalis*. To our knowledge, this is the first report on the attractiveness of distillate water and the methanol extract of banana fruit to female fruit flies. Nevertheless, there have been reports on the attractiveness of organic solvent extracts from other fruits to female *B. dorsalis* fruit flies.

Chung and Yawjen[42] showed that the ethyl ether extracts of soursop (*Annona montana* Macf.), climbing ylang-ylang (*Artabotrys uncinatus* Lam.), golden shower fruit (*Cassia fistula* Pers.), *mundu* (*Garcinia dulcis* Roxb.) and tropical almonds (*Terminalia catappa* L.) were able to attract female *B. dorsalis*. In addition, ethanol extract of *Terminalia catappa* was reported to attract the female of *B. dorsalis*[31].

The results also showed that of all the tested fruit juices, only banana juice was able to show its attractiveness to male *B. dorsalis*. The attractiveness of male fruit flies to banana juice is supposedly due to the sugar content. A previous study showed that banana juice contains about 20-27% sugar[43] including sucrose, fructose and glucose in a ratio of approximately 4:1:1[44]. Male *B. dorsalis* fruit flies require sugar as their energy source[45]. In addition to banana juice, orange juice and pineapple juice[46], as well as guava juice and star fruit juice[47], are known to attract male *B. dorsalis*.

The results of the chemical analysis using GCMS-Pyrolysis showed that there were 12 volatile compounds detected in the methanol extract of banana fruit. Of all the volatile compounds detected, there was 1 compound previously reported to have the ability to attract *B. dorsalis*, namely 2-furan methanol. This compound was reported to be one of the volatile compounds found in the protein hydrolysate[48]. Protein hydrolysate is an attractant (protein lure) of the female oriental fruit flies of *B. dorsalis* and the West Indian fruit flies of *Anastrepha obliqua* (Macquart)[18,48,49].

In addition to the banana methanol extract, the distillate water of the banana also has a good ability to attract female *B. dorsalis*. Of the twenty volatile compounds detected in the distillate water of bananas, at least 2 compounds have been previously reported to have the ability to attract fruit flies, namely beta-cyclocitral and beta-cedrene. Beta-cyclocitral is one of the aromatic compounds in banana distillate water that is known to attract the female flies of *Drosophila suzukii* (Matsumura)[50,51]. Beta-cedrene is known as an attractant of melon fruit flies, *Zeugodacus cucurbitae* (Coquillett)[52].

The results of this study indicate that the volatile compounds contained in the methanolic extract and distillate water of green *Ambon lumut* bananas have the potential to be developed as an attractant of female *B. dorsalis*. It is necessary to further evaluate the effectiveness of each volatile compound contained in bananas in terms of attracting female *B. dorsalis*. This finding is expected to provide an alternative for controlling female *B. dorsalis* that is more environmentally friendly. An attractant of female *B. dorsalis* is required for the monitoring and mass trapping of fruit flies. The female fruit fly attractant may also be used as the pull component in the push-pull control strategy of fruit flies.

CONCLUSION

From the results of this study, it can be concluded that the methanol extract and distillate water of the green *Ambon lumut* banana fruit has the potential to be developed as an attractant of female *B. dorsalis*. The effectiveness of the methanol extract of banana fruit is supposedly due to the volatile compounds that can attract female *B. dorsalis* fruit flies such as 2-furan methanol. Meanwhile, the attractiveness of the distillate water of banana to female *B. dorsalis* is supposedly due to the presence of volatile compounds such as beta-cyclocitral and beta-cedrene.

SIGNIFICANCE STATEMENT

This study discovered the potency of banana extracts that can be beneficial for attracting female *B. dorsalis* to reduce fruit damage. This study will help the researchers to uncover the critical areas of environmentally friendly fruit fly control that many researchers were not able to explore. Thus, a new theory on female fruit fly attractants may be arrived at.

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