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Identification and Abundance of Fruit Fly Species Responsible for Fruit Drop of Sweet Orange (*Citrus sinensis* L. Osbeck) in Benue State, Nigeria

S. O. Atanu[1*], B. C. Echezona[2] and K. I. Ugwuoke[2]

[1]Department of Crop Production, University of Agriculture, Makurdi, Benue State, Nigeria.
[2]Department of Crop Science, University of Nigeria, Nsukka, Enugu State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author SOA designed the study, wrote the protocol, performed the statistical analysis, managed the literature searches, analyses of the study and the first draft of the manuscript. Authors BCE and KIU supervised and co–supervised the work respectively. All authors read and approved the final manuscript.

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ABSTRACT

Background and Objective: Citrus is one of the most important and among the top ten widely cultivated fruits in Nigeria. It is produced more in the Guinea and Sudan Savanna zones of the country with Benue State having the highest annual production. In the South of Savanna region of Africa, particularly in Nigeria; despite the economic, nutritional and health benefits of citrus, limited research work has been carried out on the identification and control of fruit flies of economic importance to the crop. The objectives of this study are to identify and determine the abundance of the fruit fly species responsible for fruit drop of citrus in Benue State, Nigeria.
Materials and Methods: Fruit fly identification was done through fruit culture experiment carried out in the College of Agronomy Teaching and Research Farm, Federal University of Agriculture, Makurdi in October 2014 and October 2015.The experiment was a 2 x 3 factorial in a completely randomized design with four replications. The two factors were Zones (Zone A and B) and Varieties (Ibadan Sweet, Valencia and Washington Navel). Ten naturally infested orange fruits from four

**Corresponding author: E-mail: samonaanu@gmail.com;*

randomly selected citrus trees of each variety in each zone were weighed and placed in each plastic rearing box with dimension 39 x 27 x 26 cm containing sterilized moist soil securely covered with 1 mm mesh net for pupation and adult insect emergence. Emerged adults were killed using Mobil insecticide (Cyphenothrin), counted, sexed and stored in specimen bottles with 70% alcohol for preservation and later identification.

Results: Fruit fly species identified from citrus fruit culture were: *Bactrocera invadens* (Drew), *Ceratitis capitata* (Weid) and *Dacus bivittata* (Biggot). *Bactrocera invadens* were the most abundant species and accounted for 63.70% in Washington navel and 63.10% in Valencia in 2014 and 2015 respectively. The varieties showed no significant differences ($p>0.05$) on the abundance of *Ceratitis capitata* and *Dacus bivittata* in 2014. In 2015 however, Ibadan Sweet variety showed significant difference ($p < 0.05$) on the abundance of *Ceratitis capitata* (28.30%) when compared with other varieties (15.8%) each.

Conclusion: Fruit fly species responsible for citrus fruit drop in Benue State were *Bactrocera invadens* (Drew), *Ceratitis capitata* (Weid) and *Dacus bivittata* (Biggot) with *Bactrocera invadens* (Drew) recorded as the most abundant species.

Keywords: Citrus; fruit fly; abundance; Benue State.

1. INTRODUCTION

Sweet orange (*Citrus sinensis* L. Osbeck) is a tropical to semi-tropical evergreen, small flowering tree, growing to about five to eight meters (5 m-8 m) tall [1]. It is widely cultivated in tropical as well as sub-tropical African countries. Oranges are classified into two: sweet and sour orange. Sweet orange is among the important fruits of the world, occupying the third position among the sub-tropical fruits [2] and the second - largest in terms of production volume next to banana [3,4]. Oranges probably originated from south-East Asia and were cultivated in China by 2500 B.C. [5]. It is now grown almost all over the world as food for humans because of its high nutritional values, source of vitamins and other uses [6]. The policy of government on the promotion of citrus production in Africa as reported by Mohammed [4] is quite encouraging as the sector has attractive and multiple social and economic advantages. According to Adewale et al. [7], citrus is one of the most important and among the top ten widely cultivated fruit crop in Nigeria. It is produced more in the Guinea and Sudan Savanna zones of the country [8] with Benue State having the highest annual production of the crop [9]. Also, the relatively higher mean number of fruit flies per trap recorded in Kaduna and Benue states in the Guinea savanna ecological zone as reported by Umeh et al. [10] could be due to the presence of large orchards of sweet oranges and mangoes in these states.

Citrus species are attacked by many pests and diseases requiring up to one hundred and sixty million dollars to control them, to avoid what can develop into total loss [11]. Some of the arthropods that are harmful to this crop include mite species, fruit flies, scale insects, aphids, etc. [11]. Fruit flies (*Diptera: Tephritidae)* are the worst pest of fruits all over the world [12]. They are present in most countries and attack many types of fruits as well as fruiting vegetables, ornamentals and nuts.

Feeding by fruit fly larvae (maggots) damage the fruits internally causing premature ripening, drop and rot of the fruits. Fruit flies apart from causing losses in horticultural produce across the world are a major quarantine concern for most countries [13]. With the increasing globalization of trade [14] and with the export promotion drive initiated by the government of the federal republic of Nigeria [14] there is serious need for production of fruits of good quality that meet the standard of export market and quarantine regulations. There are many species of fruit flies that can attack fruits and vegetables. The loses from fruit flies infestations can be caused by a single species of fruit fly or as a result of several species that attack the same plant at the same time.

Understanding how to identify the species of fruit flies is an important issue for fruit fly management [15]. Wrong identification may lead to mismanagement. Simple identification methods can be applied under loupe or binocular microscope [16]. The identification can be made by examining the face mark, thorax, abdominal band and marks on the wing [16]. The male can be differentiated from the female through the presence or absence of ovipositor [17]. According to Uchoa-Fernandes et al. [17], only adult female can attack crop. Male fruit flies are

not harmful. The diversity of frugivorous tephritidae has been evaluated in several regions of the world by using two sampling methods: The capture of adults in traps with food baits and rearing of adults from larvae found infesting fruits [17].

In the south of the Sahara region of Africa particularly in Nigeria, limited research work has been carried out on identifying and controlling fruit flies of economic importance to the crop [10]. Despite the economic, nutritional and health benefits of citrus, there have been limited studies involving crucial aspects of citrus production in Benue state [18]. The aim of this study is to identify and study the abundance of fruit fly species responsible for fruit drop of citrus in the state.

2. MATERIALS AND METHODS

The experiment was conducted in the College of Agronomy Teaching and Research Farm, Federal University of Agriculture, Makurdi (7°41' N, 8°28' E) and at an altitude of 228 m above sea level, in the Southern Guinea Savanna agro-ecological zone of Nigeria in October, 2014 and 2015 respectively. The experiment was a 2 x 3 factorial in a completely randomized design with four replications. The two factors were Zones (Zone A and B) and Varieties (Ibadan Sweet, Valencia and Washington Navel). Ten naturally infested orange fruits, each set collected from under four randomly selected citrus trees from each variety in each zone were weighed and placed in each plastic rearing box with dimension 39 x 27 x 26 cm containing sterilized moist soil securely covered with 1 mm mesh net for pupation and adult fruit fly emergence. Emerged adults were killed using domestic insecticide (Mobil insecticide – Neo-pynamin, Prallethrin and Cyphenothrin), counted, sexed and stored in specimen bottles with 70% alcohol for preservation and later identification. Data recorded were analyzed using GenStat Discovery Edition 4 software and significant treatment means were separated using Fisher's Least Significant Difference (F-LSD) at 5% level of probability.

3. RESULTS

Effect of varieties on mean number of adult fruit flies that emerged per fruit (NAPF) number of adult fruit flies that emerged per kilogram (NAPKG) showed significant difference ($p<0.05$) in 2014 and 2015 (Table 1). Valencia variety was observed to have significantly ($p<0.05$) higher NAPF (0.86), NAPKG (3.14) in 2014 and higher NAPF (0.92) in 2015 when compared with Ibadan sweet variety (0.40) in both years. There was however no significant difference ($p > 0.05$) among the varieties on the number of days to first adult emergence in both years and NAPKG in 2015.There was also no interaction between the varieties and zones in both years.

The effect of varieties zones and their interaction on the number of adults that emerged (NATE), number of female adults that emerged (NFATE) and number of male adults that emerged (NMATE) in 2014 and 2015 showed significant difference ($p < 0.05$) among the varieties in both years (Table 2). Significantly higher NATE, NFATE and NMATE (8.62, 4.00 and 4.25) which was statistically similar to Washington variety (7.62, 4.00 and 3.62) respectively were recorded in Valencia variety when compared with Ibadan Sweet (4.00, 2.12 and 1.88).

In 2015, Valencia variety had the highest NATE, NFATE and NMATE which were significantly different ($p < 0.05$) from Ibadan Sweet (4.12, 2.12 and2.00 respectively) but statistically similar to Washington Variety except in NATE (7.25) and NFATE (3.00). There was no significant difference among the zones and the interaction between zones and varieties in both years.

The following fruit flies species were identified from the citrus fruit culture: *Bactrocera invadens* (Drew), *Ceratitis capitata* (Weid) and *Dacus bivittata* (Biggot). Out of these species, *Bactrocera invedens* was the most abundant (63.70% and 63.10% in 2014 and 2015 respectively). The effect of varieties showed significant difference ($p < 0.05$) among the identified fruit fly species in both years (Table 3). The abundance (63.70%) of *Bacteocera invadens* was highest in Washington navel variety which was significantly different ($p<0.05$) from its abundance (42.70%) in Ibadan sweet but statistically similar to its abundance (61.66%) in Valencia variety in 2014. The varieties showed no significant differences in the abundance of *Ceratitis capitata* and *Dacus bivittata* in 2014. However, in 2015, Ibadan sweet variety showed significant difference ($p < 0.05$) on the abundance of *Ceratitis capitata* (28.30%) when compared with the abundance (15.00%) each in Valencia and Washington navel varieties respectively. The effect of the zones and their interactions showed no significant difference ($p>0.05$) on the abundance of the identified fruit flies in both years.

Table 1. Effect of varieties and zones and their interactions on days to first adult fruit fly emergence, number of adults per fruit and number of adults per KG in 2014 and 2015

Treatments	2014			2015		
	DTFAE	NAPF	NAPKG	DTFAE	NAPF	NAPKG
Varieties						
IBS	9.00	0.40	2.12	9.12	0.40	2.34
VAL	9.38	0.86	3.14	9.12	0.92	3.43
WN	9.00	0.76	2.34	9.25	0.72	2.27
Mean	9.12	0.67	2.54	9.17	0.68	2.68
LSD(0.05)	NS	0.15	0.18	NS	0.15	NS
Zones						
A	8.83	0.69	2.43	9.25	0.69	2.54
B	9.42	0.65	2.65	9.08	0.67	2.82
Mean	9.12	0.67	2.54	9.17	0.68	2.68
LSD(0.05)	NS	NS	NS	NS	NS	NS
Var. x Zones	NS	NS	NS	NS	NS	NS

DTFAE : Days to first adult fruit fly emergence, NAPF : Number of adults per fruit. NAPKG: Number of adults per kilogram. IBS: Ibadan Sweet, VAL; Valencia WN: Washington Navel. NS: Non-significant

Table 2. Effect of varieties, zones and their interactions on number of adults that emerged, number of female adults that emerged and number of male adults that emerged in 2014 and 2015

Treatments	2014			2015		
	NATE	NFATE	NMATE	NATE	NFATE	NMATE
Varieties						
IBS	4.00	2.12	1.88	4.12	2.12	2.00
VAL	8.62	4.00	4.25	9.25	4.38	4.88
WN	7.62	4.00	3.62	7.25	3.00	4.25
Mean	6.75	3.38	3.25	6.88	3.17	3.71
LSD(0.05)	1.55	1.64	1.17	1.49	1.21	1.24
Zones						
A	6.92	3.25	3.42	6.92	2.75	3.5
B	6.58	3.50	3.08	6.83	3.25	3.92
Mean	6.75	3.38	3.25	6.88	3.00	3.71
LSD(0.05)	NS	NS	NS	NS	NS	NS
Var. x Zones	NS	NS	NS	NS	NS	NS

NATE: Number of adults that emerged. NFATE: Number of female adults that emerged. NMATE: Number of male adults that emerged. IBS: Ibadan Sweet. VAL: Valencia WN: Washington Navel. NS: Non-significant

4. DISCUSSION

Although in earlier field trial carried out by Umeh and Garacia [19], *Dacus* and *Bactrocera* species were not included in the result because low number of the flies were observed in the experiment, the result of this study however showed that *Bactrocera invadens* (Drew) was the most abundant (63.70% and 63.10%) fruit fly species in 2014 and 2015 respectively in Benue State. This result however agreed with the result of Umeh and Onukwu [20] which revealed that the most abundant fruit fly species associated with sweet orange in a similar experiment carried out in Ibadan was *Bactrocera invadens* (Drew). This was probably due to the fly's development of tolerance to the essential oil in the rind of citrus fruit [21]. *Ceratitis capitata* (wied) species abundance was low. The result therefore confirmed other works that indicated a displacement of *Ceratitis capitata* by *Bactrocera invadens* [22,23]. This could be as a result of lapses in quarantine regulations that could encourage accidental importation of *Bactrocera invadens* infested fruits. The spread of this invasive fruit fly was further confirmed by the report of Umeh et al. [10] which revealed that although *Bactrocera invadens* was not captured in Anambra, Benue, Nasarawa and Plateau States in 2003, it was captured in all the states in 2006 trial. This situation calls for an urgent national attention to check its spread and destruction on fruits of economic importance.

Table 3. Effects of varieties zones and their interactions on the abundance (%) of identified fruit fly species in Benue State in 2014 and 2015

Treatments	2014			2015		
	Bactrocera invadens	***Ceratitis capitata***	***Dacus bivittata***	***Bactrocera invadens***	***Ceratitis Capitata***	***Dacus Bivittata***
Varieties						
IBS	42.70	24.00	33.30	43.70	28.30	27.90
VAL	61.60	17.20	22.30	63.10	15.80	21.90
WN	63.70	15.30	21.50	59.00	15.80	25.20
Mean	56.00	18.80	25.70	55.30	20.00	25.00
LSD(0.05)	18.01	NS	NS	12.41	7.250	NS
Zones						
A	58.50	18.80	23.80	54.70	20.50	25.30
B	53.50	18.90	27.60	55.90	19.40	24.70
Mean	56.00	18.80	25.70	55.30	20.00	25.00
LSD(0.05)	NS	NS	NS	NS	NS	NS
Var. x Zones	NS	NS	NS	NS	NS	NS

IBS: Ibadan Sweet; VAL: Valencia; WN: Washington Navel; NS: Non-significant

The influence of varieties on fruit flies emergence from citrus fruit culture showed significant difference ($p < 0.05$) among the identified fruit fly species in both years. While *Bactrocera invadens* (Drew) was more abundant in Washington Navel and Valencia Varieties in 2014 and 2015 respectively. *Ceratitis Capitata* (wied) although not significant ($p > 0.05$) in 2014, was signficiantly abundant (28.30%) in Ibadan Sweet in 2015. This was probably due to the quantity and quality of essential oil in the rind of Ibadan Sweet in 2015. *Dacus bivittata* (Biggot) was the least abundant of the identified fruit fly species and showed no significant difference ($p > 0.05$) among the varieties in both years. The result which indicated that *Bactrocera invadens* was more abundant in Valencia variety and showed significant difference in 2015 contradicted [10]'s report that revealed no significant difference in the fruit fly that emerged from Valencia variety. The contradiction could be due to the fly's tolerance to the level and quality of essential oil in the rind of the citrus fruits as reported by Nikos et al. [21]. *Ceratitis capitata* (Wied) was more abundant and significantly higher in Ibadan sweet variety when compare to Washington navel and Valencia varieties. The result could probably be due to the species preference of Ibadan sweet variety over Washington navel and Valencia varieties. Earlier studies by Umeh et al. [24,25] showed that some citrus varieties were less attacked by the indigenous *Ceratitis capitata*. Valencia and Washington navel varieties significantly ($p<0.05$) showed higher number of adults, female adults and male adults that emerged (8.62, 4.00 and 4.25; 7.62, 4.00 and 3.62 respectively) in 2014 and (9.25, 4.38 and 4.88; 7.25, 3.00 and 4.25 respectively) in 2015 when compared with Ibadan sweet variety where (4.00, 2.12 and 1.88) in 2014 and (4.12, 2.12 and 2.00) in 2015 emerged from fruit culture experiment. The result suggested that Valencia and Washington navel varieties were probably more attacked by fruit fly species than Ibadan sweet variety.

Zones did not have any significant influence on fruit fly species' emergence in 2014 and 2015 citrus fruit cultures, neither was there any interaction between the zones and the varieties on the emergence of fruit fly species in both years. The result suggested an even distribution of fruit flies in the zones.

5. CONCLUSION

Fruit fly species identified from citrus fruit culture were: *Bactrocera invadens*, *Ceratitis capitata* and *Dacus bivittata*. *B. invadens* was the most abundant species and recorded 63.70% in Washington navel and 63.10% in Valencia in 2014 and 2015 respectively in Benue State. Valencia and Washington navel varieties were more attacked by fruit flies species than Ibadan Sweet while the Zones neither had influence on the abundance of the fruit flies nor the Varieties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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