NASS Journal of Agricultural Sciences
http://ojs.nassg.org/index.php/NJAS

Infestation Rate and Abundance of Fruit Fly Species (Diptera, Tephritidae) on *Solanum aethiopicum, Solanum lycopersicum,* and *Capsicum* spp in Eastern of the Democratic Republic of Congo

Jean Augustin Rubabura Kituta[1*] Jean Berkmans Muhigwa Bahananga[2]

1. Agricultural Entomology laboratory, Entomology Section, Research Centre in Natural Sciences (CRSN-Lwiro), Bukavu, Congo
2. Department of Biology, State University of Bukavu (UOB-Bukavu), Bukavu, Congo

ARTICLE INFO

Article history
Received: 20 November 2021
Accepted: 14 December 2021
Published Online: 24 December 2021

Keywords:
Infestation rate
Incubation
Abundance
Tephritidae
Pests

ABSTRACT

This study assessing the infestation rate of fruit fly species on *Solanum aethiopicum, Solanum lycopersicum,* and *Capsicum* spp, using incubation method, was conducted in Agricultural entomology laboratory of Research Centre in Natural Sciences (CRSN) Lwiro, at Kabare in The South Kivu Province in eastern part of the Democratic Republic of Congo. Five species of Tephritidae flies observed, i.e. *Bactrocera dorsalis, B. latifrons, Dacus bivitatus, Ceratitis capitata,* and *Zeugodacus Cucurbitae.* The highest infestation rate was observed on *B. dorsalis* and following *C. capitata* in those solanaceous chilli pepper (*C. frutescens*), eggplant (*S. aethiopicum*) and tomato (*S. lycopersicum*) than Z. *cucurbitae, B. latifrons and D. bivittatus*. However, the localities Kamakombe, Buhandahanda, Lwiro, Bishibiru have predominant in the majority of hosts in chilli pepper, eggplant and tomato.

1. Introduction

Fruit flies (Diptera,Tephritidae) are listed among the most important pests of many fruits in the world. Representatives of the tribe Dacini comprise several economic pests, especially in the genera *Ceratitis* MacLeay, *Dacus* Fabricicus and *Bactrocera* Macquart [1]. The latter is a large genus, including more than 500 species with main distribution in Asia and Oceania. However, in Africa only a few indigenous species are known, none of them of great economic importance, except for the olive fruit fly [*Bactrocera oleae* (Gmelin)], which is a notorious pest of cultivated olives in the Mediterranean region. However, several Asian *Bactrocera* species have been introduced to Africa [2]. In Virgilio *et al.* (2011) [3] study, the McPhail traps baited with four different attractants yielded 819 tephritid specimens of 29 species from seven genera (Bactrocera, Carpophthoromyia, Ceratitis, Dacus, Celidodacus, Perilampsis, Trirhithrum). The three most abundant species sampled (*Dacus bivittatus, D. punctatifrons, Bactrocera invadens*) showed significant variations in abundance across locations and sites and accounted for 98.29% of the overall dissimilarity between habitats. He reported the abundant presence of

**Corresponding Author:*
Jean Augustin Rubabura Kituta,
Agricultural Entomology laboratory, Entomology Section, Research Centre in Natural Sciences (CRSN-Lwiro), Bukavu, Congo;
Email: dodorubabura@gmail.com

 DOI: http://dx.doi.org/10.36956/njas.v4i1.457

Dacus bivittatus, *Bactrocera invadens* (currently referred to as *Bactrocera dorsalis*) and *Dacus punctatifrons* and to a lesser extent of *Carpophthoromyia tessmanni*, *Ceratitis cosyra*, *Ceratitis* (*Pardalaspis*) sp., *Ceratitis* (*Pterandrus*) sp., *Ceratitis serrata*, *Ceratitis striatella*, *Dacus ciliatus*, *Dacus gypsoides*, *Dacus radmirus*, *Dacus setilatens*, *Trirhithrum nigerrimum*, *Trirhithrum obscurum* and the presence of other fruit flies Tephritidae; *Dacus humeralis, Dacus fumosus, Dacus Langi*, on the tropical forest and the rural villages of the Congo River basin (Congo, Lomami, Aruwimi, Itimbiri) on Oriental province of the Democratic Republic of Congo. Rubabura *et al.* (2015) [4] captured in their study on Kabare territory of the South Kivu province in the DR Congo an abundant quantity of *Ceratitis fasciventris*, afterwards *C. cosyra, Ceratitis anonae* and the presence of *Ceratitis capitata, Ceratitis rosa* and *Ceratitis punctata*. Again Rubabura *et al*. (2019) [5] reported an important abundance of fruit flies *B. dorsalis* and *Ceratitis fasciventris* and also, the less abundance of *C. cosyra, C. anonae* and *D. bivittatus* as well as the presence of *Dacus punctatifrons, Dacus eminus, C. capitata, C. rosa, Perilampsis curta, C. punctata, Zeugodacus cucurbitae, Bactrocera mesomelas, Dacus hargreavesi, Dacus siliqualactis, Dacus hamatus* and *Carpophthoromyia vittata* in South Kivu, the Albertine Rift zone part of the Democratic Republic of Congo. Up till now most studies focusing on fruit flies in the region did not include solanaceous crops. The three solanaceous species eggplant (*Solanum aethiopicum*), tomato (*Solanum lycopersicum = Lycopersicon Lycopersicon = Lycopersicon esculentum*), pepper and capsicum (*Capsicum* spp) are the major commercial crops in South Kivu, at the eastern part of the Democratic Republic of Congo. Those solanaceous species are attacked by more insect pest fruit flies Tephritidae and of other families (Aleyrodidae, Aphididae, Gelechiidae, Zygaenidae, Thripidae, Tetranychidae, Coccidae, etc). According to Mziray et al. (2010) [6], despite having a narrow host range, *B. latifrons* is a pest of quarantine importance and has the potential to permanently establish itself and compete and/or coexist with other native and previously introduced tephritid species. Because of this, elements of its population biology and demography [7-10] and dispersal and host preference [11] have been studied extensively in Hawaii for more than two decades. Thirty years ago, control measures in this region through the use of parasitoids [12] and twenty eight years ago, fruit fly bait [13] were presented, and thirty and over years, a specific lure was developed for its detection [14,15]. Nevertheless, *B. latifrons* has much less reproductive potential than the other Dacinae pests and is considered less competitive than *B. dorsalis, Z. cucurbitae* and *C. capitata* [7,16]. By referring to the increase in the cultivation of Solanaceae and the importation of this agricultural production (fresh vegetables and fruits) from the various border countries (Rwanda, Burundi and Tanzania) to South Kivu. Also, due to the low capacity for phytosanitary surveillance at the borders, South Kivu has suffered from the various invasions of harmful species over the last decade. These solanaceous can constitute a vast reservoir of superfluous and increase the rate of introduction of fruit flies in the province of South Kivu in the east of the Democratic Republic of the Congo. Again, no detailed study on presence and abundance of fruit fly species on solanaceous species (*S. aethiopicum, S. lycopersicum, Capsicum* spp) was conducted in Kabare altitude zone on South Kivu. The aim of our study was to know the species of Tephritidae flies, their infestation rate and to determine the abundance, adults of emerged flies by locality and by Solanaceae (*S. aethiopicum, S. lycopersicum, Capsicum* spp) present in the Bugorhe area in Kabare altitude zone on South Kivu, Eastern of the Democratic Republic of Congo.

2. Materials and Methods

2.1 Site and Location of Experiment

The particular study was conducted in Agricultural Entomology laboratory of the Research Centre in Natural Sciences (CRSN/Lwiro) during 2020 to 2021. It was carried out in Bugorhe area, which is located at the Kabare territory (Latitude: 2° 30′ and 2° 50′ S, Longitude: 28° 45′ and 28° 55′ E, South-Western of the Kivu Lake,Altitude: 1737 m) at the South Kivu province, eastern part of DR Congo. Simultaneously incubation of solanaceous carried out.

2.2 Data Collection

A pre-survey was carried out during the period from June, July until August 2020 in different localities of the Bugorhe area to inquire about information on the species of fruit and vegetables of cultivated Solanaceae market gardeners. Once the latter are known, 12 ripe fruits of these species *S. aethiopicum*, *S. lycopersicum*, *Capsicum* spp damaged or infested are picked 4 times in each of the localities during the study period in 2020 and 2021 and then the samples of these fruits are sent to the Agricultural Entomology laboratory of the Research Centre in Natural Sciences, CRSN-Lwiro for incubation. Collection depended on the availability of these Solanaceous fruits.

2.3 Incubation of Solanaceous Fruits

The frequency of sampling is invariable, but depends

DOI: http://dx.doi.org/10.36956/njas.v4i1.457

on the time of year. An incubation study was carried out over a two-months period from 10 February to 10 March 2020 and 2021 on *S. aethiopicum, Capsicum* spp collected in the field at Lwiro, Ciranga, Kamakombe, Kashenyi, Bishibiru, Kamakombe, Cegera and Buhandahanda localities, Kabare territory. For each fruit species, 12 fruits were sampled and incubated at periods of up to 4 or 5 weeks, depending on the stage of infestation of the fruits. Convenience sampling was used to select the fruits collected. It is a non-probability sampling plan where the sampling units are selected on purpose. The basis of selection was the presence of visual fruit fly puncture marks on the surface of the fruit. The infested fruits collected are placed in incubation units and provided with labels, following the method described by Ekesi and Billah (2007) [17]. The incubation units consist of two plastic tubs of different diameters, depending on the size of the fruits. All fruits collected were washed, weighed, placed and incubated (4 fruits per box individually). The bins are respectively 30 cm and 20 cm in diameter. The trays are superimposed, a layer of fine sand 2 to 3 cm thick at the bottom of the large tray, on which is placed the second small tray containing the infested fruit (s) to be incubated. The trays are then covered with a fine cloth or muslin cloth, to ensure good ventilation of the medium and prevent secondary infestations during incubation. Then, the boxes with the fruits are placed in the laboratory to allow the flies to form pupae. The pupae are removed from the sand by sieving from the first 10 days of incubation. The sand is sieved at intervals of 3 to 4 days. The pupae are counted and placed in Petri dishes and / or in a transparent box with a perforated lid, lined with toilet paper and kept in cages until adults emerge. The sieving is continued until the fruit has completely rotten. They are then dissected to collect any residual pupae or larvae. The methods of breeding fruit flies are described by Ekesi *et al.* (2007) [18] were used. The pupae are separated and then counted. After emergence of adult flies, Tephritidae are placed in tubes filled with ≥ 90% ethanol for storage. Before, the fruit flies emerging in each species of fruit collected are separated by sex, counted according to the 4 lots and the locality of origin and then, determine. The total number of different species of flies also emerging in each species of fruit collected is separated by sex, counted according to the 4 lots and the locality of origin.

2.4 Identification of Tephritidae

Several types of determination keys are used: the recent systematic review of tephritids including that of White and Elson-Harris (1994) [1], CABI (2005) [19], White (2006) [20], De Meyer *et al.* (2008) [21].

2.5 Statistical Analysis

The fruit collection followed the procedures used by Copeland *et al*. (2002) [22]. Next, the fruit fly infestation rate (expressed as the number of emerging adults per unit fruit weight) was calculated:

• The infestation rate (IR) measures the extent of Tephritidae host species emerged in fruits and is expressed as the number of pupae per unit of weight [23]. This parameter was determined by site according to the solanaceous, host species but also for the entire study area, considering these different levels of observation. The formula below was used for the calculation of infestation rate of host species:

$$IR = \frac{Number\ of\ host\ species\ emerged\ from\ the\ infested\ fruits\ of\ the\ sample}{Average\ weight\ of\ infested\ fruits\ in\ the\ sample\ in\ Kg.}$$

• The relative abundance (RA) and frequency (F) of fruit fly species incubated were calculated by the following formulae:

$$RA = \frac{Total\ number\ of\ fruit\ flies\ emerged\ of\ one\ species}{Total\ number\ of\ species\ emerged}$$

$$F = \frac{Total\ number\ of\ fruit\ flies\ emerged\ of\ one\ specie}{Total\ number\ of\ all\ species\ emerged} x\ 100$$

Principal coordinate's analysis of host fruit flies Infestation Rate was done by using the software PAleontological Statistics (PAST) Version 4.07. The rarefaction is a technique to assess species richness from the results of sampling. In fact, the Principal coordinate's analysis, also known as classical scaling, is a metric multidimensional scaling method based on projection, which uses spectral decomposition to approximate a matrix of distances/dissimilarities by the distances between a set of points in few dimensions. The points may be used in visualizations.

The temporal abundance of tephritidae flies is determined from samples of fruits *S. aethiopicum, S. lycopersicum, Capsicum* spp from the geographical position (longitude and latitude) of these 8 localities of the Bugorhe area by using Data Location and Inverse Distance to a Power. The methods mentioned above explains the statistics for Data Locations are concerned with the location of the data points: The location of data points is often useful when determining the density or the distance from each other and the values calculated in the statistics are in the same units as the original data set. So, the data metrics are calculated based on the XY data points. The DTMs are derived by using different interpolation methods. Indeed, the applied interpolation methods can be changed depending on the structure of the surface and the number of control points [24]. In this study, a different interpolation method is interpreted to define a surface. Measured points are transferred to Surfer 17.1 software and the volume of the object is calculated by using the previously mentioned interpolation methods. So, the better the surface is described, the closer the amount of volume is to the real value. According the results closest to the real value of the volume is obtained from the following methods: inverse distance to a power (95.00%). The most suitable contour map of the object is obtained from the triangulation with linear interpolation and inverse distance to a power method. The most suitable 3D model of the object is obtained from triangulation with inverse distance to a power method.

Software R [25] was used to analyze Linear Model Regression of flies and making histogram and boxplot of fruit flies observed during incubation of Solanaceous. Mean and standard deviation were calculated too.

3. Results

3.1. Tephritidae Fruit Fly Species Observed

The Figure 1 presented the relative abundance of the host fruit flies between the localities. In fact, the fruit flies *B. dorsalis* was more abundant in Bishibiru locality (0.074) and Nyamakana locality (0.078) than in Buhandahanda locality (0.124), Ciranga-Kankule locality (0.265) and Kashenyi locality (0.399) in the green histogram. Also, *Z. cucurbitae* was more abundant in abundant in Buhandahanda locality (0.001) and Bishibiru, Kamakombe and Lwiro localities (0.002) than in Cegera and Kashenyi localities (0.004), and Ciranga-Kankule locality (0.005) in the red histogram behind. However, the fruit flies *D. bivittatus* was more abundant in Cegera, Bishibiru, Kashenyi and Lwiro localities (0.001) than in Ciranga-Kankule locality (0.004) in the yellow histogram. So, the fruit flies *B. latifrons* was more abundant in Bishibiru, Cegera, Kamakombe, Kashenyi and Nyamakana localities (0.001) than in Ciranga-Kankule and Buhandahanda localities (0.004) and Lwiro locality (0.007) in the blue histogram. Then, the fruit flies *C. capitata* was more abundant in Bishibiru locality (0.001) than in Lwiro locality (0.004) and Nyamakana locality (0.005) in the red histogram below.

3.2 Infestation Rate of Fruit Flies' Species

In view of principal coordinates (PCoA) in the Figure 2 and 3, the highest infestation rate was observed on *B. dorsalis* and following *C. capitata* in those solanaceous fruits chosen in the study compare to host *Z. cucurbitae*, *B. latifrons* and *D. bivittatus* (Figure 2). The solanaceous fruits have more infestation rate of host in Kamakombe, Buhandahanda, Lwiro, Bishibiru localities than in Kashenyi, Ciranga-Kankule and Nyamakana localities (Figure 3).

3.3 Temporal Abundance

The Figure 4 is a use of the count data metrics can be represented in the map below. The grid represents the number of fruit flies observed during the incubation in study area. Then, this map can then be used to represent a link between the number of fruit flies (*B. dorsalis, B. latifrons, D. bivittatus, C. capitata, Z. cucurbitae*) and the location. In those maps, temporal abundance is in accordance with zoning of the color *i.e.* the red color shows the huge temporal abundance of species in those maps following with the yellow color which has a great temporal abundance of species compare to the green and blue colors. After yellow color is coming the green color and, the later blue color.

Additionally, the Figure 5 of the inverse distances to a power shows the visually maps of irregularly spaced *B. dorslis*, *B. latifrons, C. capitata, D. bivittatus* and *Z. cucurbitae* in surface of this area. Additionally, *B. dorslis*, *B. latifrons, C. capitata, D. bivittatus* and *Z. cucurbitae* set has a stationary variance but also a non-stationary mean value within the search radius. According below map, the fruit flies are present in the area study. The top shows the great temporal abundance and the emptiness explains the minor temporal abundance in those inverse distances to power of species.

3.4 Fruit Fly Species Recorded on Solanaceous

Several fruit flies were observed such as *B. dorsalis, B. latifron, Z. cucurbitae, D. bivittatus* and *C. capitata.* The average at eggplant was of 69 larvae per kg of fruit ± 41.78 for *B. dorsalis,* of *2* larvae per kg of fruit ± 0.97 for *Z. cucurbitae*, of 2 larvae per kg of fruit ± 0.89 for *D. bivittatus* and of 1 larva per kg of fruit ± 1.13 for *B. latifrons.* According chili pepper, the average was of 44 larvae per Kg of fruit ± 33.70 for *B. dorsalis* and of 1 larva per kg of fruit ± 0.58 for *B. latifrons*. Additionally, the average of *B. dorsalis* on tomato was of 57 larvae per kg of fruit ± 39.59 and of 3 larvae per kg of fruit ± 1.53 *C. capitata* on pepper. The boxplot and the linear model regression show tendency of fruit flies observed during incubation of Solanaceous fruits (Figures 6 and 7).

DOI: http://dx.doi.org/10.36956/njas.v4i1.457

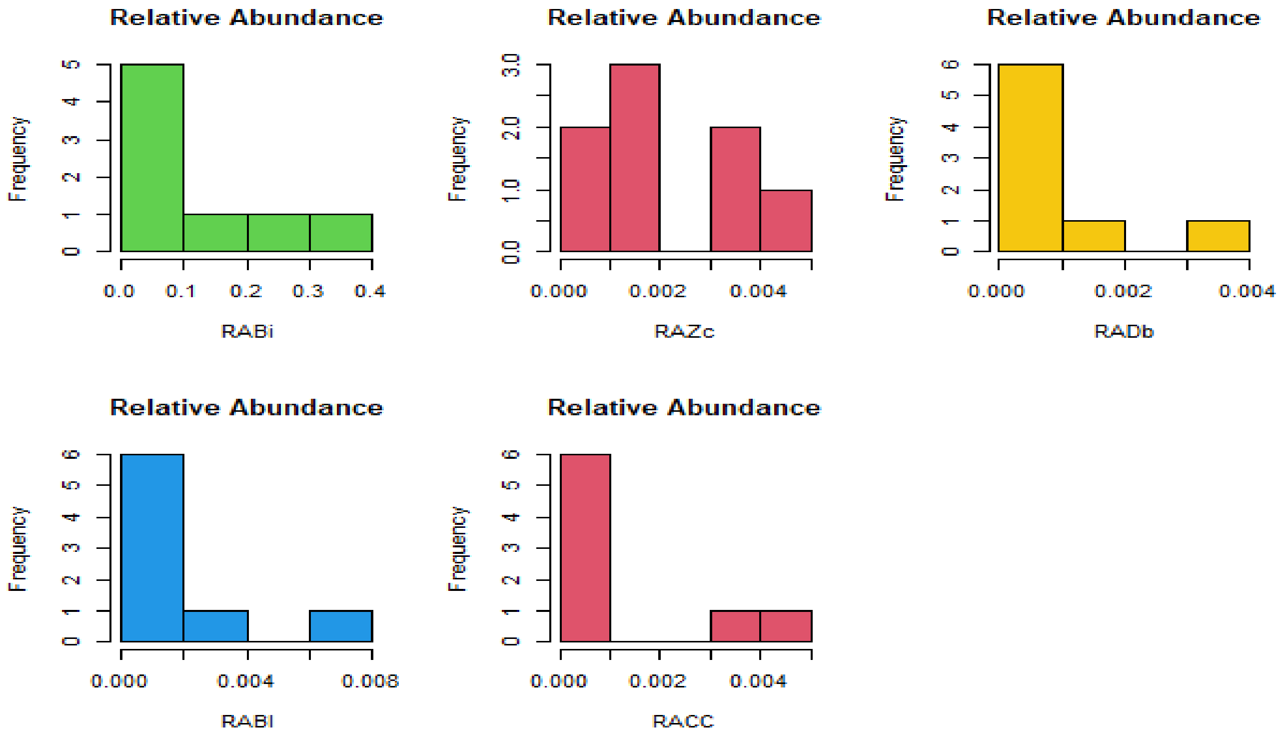


Figure 1. Relative abundance of host between the localities
RA: Relative abundance, Bi: *Bactrocera dorsalis* Hendel; Bl: *Bactrocera latifrons* (Hendel); Zc: *Zeugodacus cucurbitae* (Coquillett); Cc: *Ceratitis capitata* (Wiedemann); Db: *Dacus bivittatus* (Bigot).

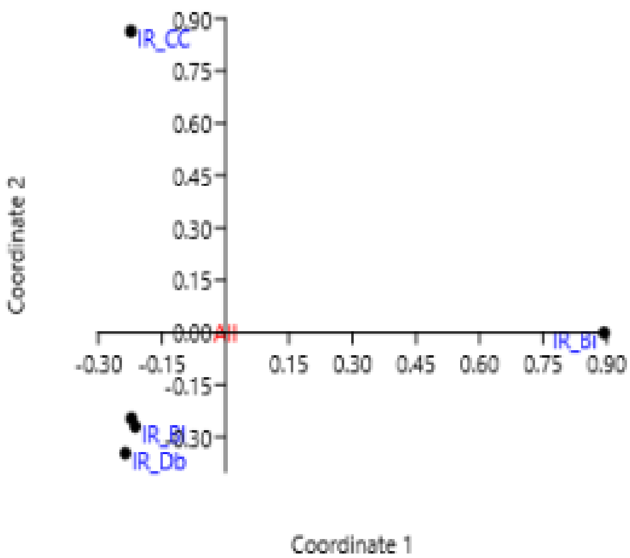


Figure 2. Host Infestation rate per species

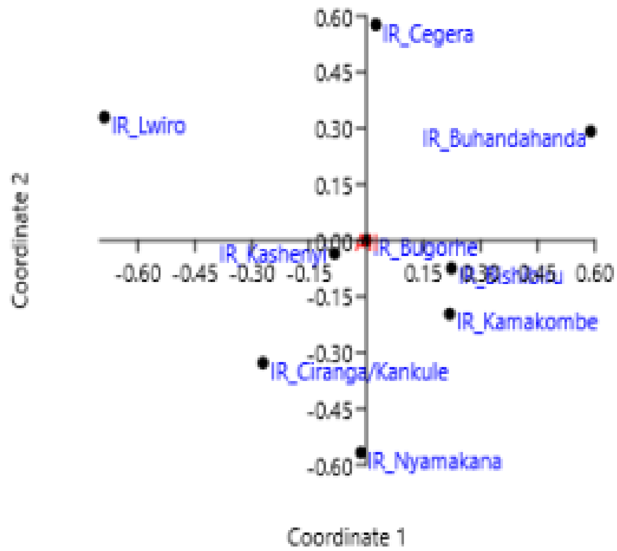
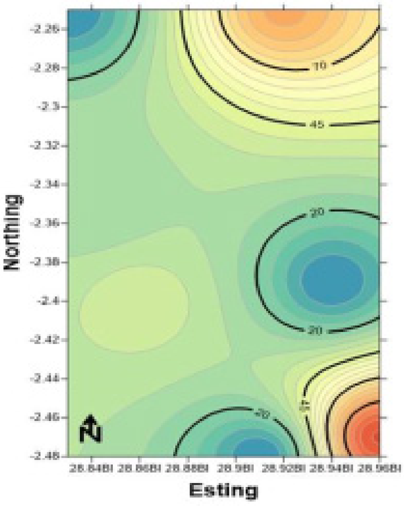
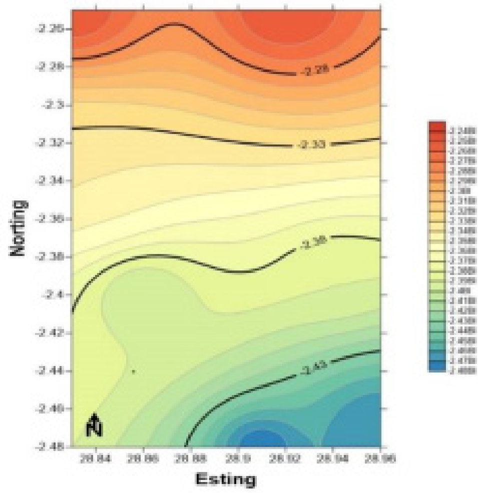


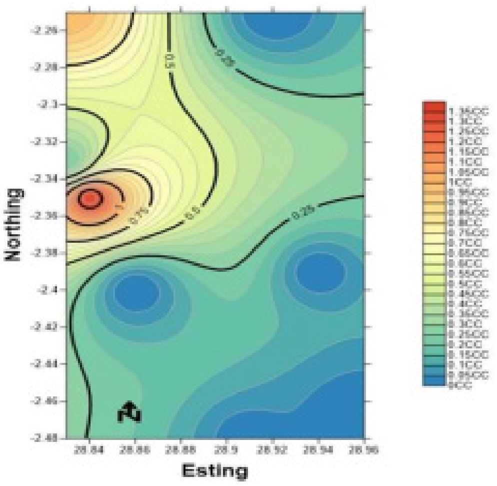
Figure 3. Host Infestation rate per localities



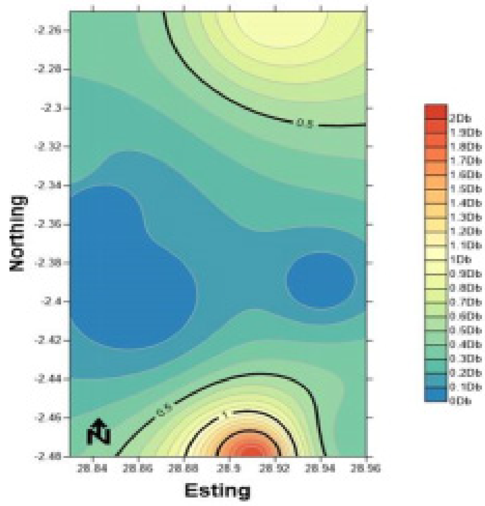
***B. dorasalis* map**



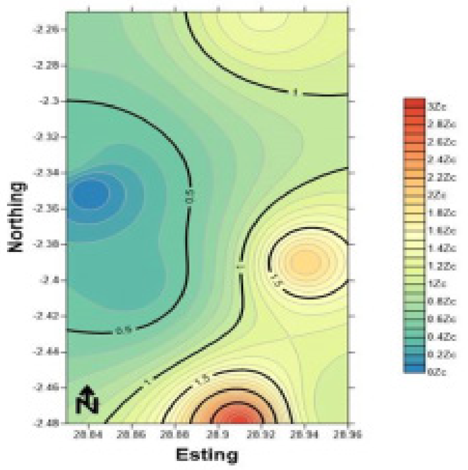
***B. latifrons* map**



***C. capitata* map**



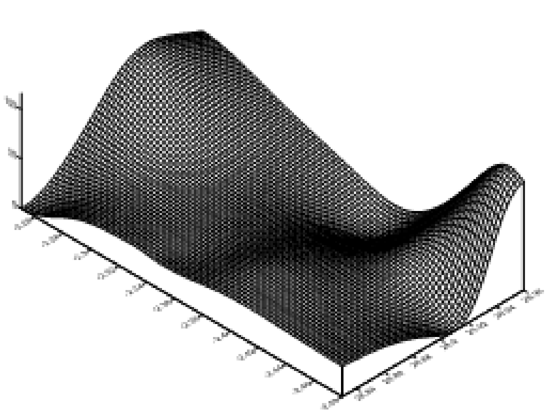
***D. bivittatus* map**



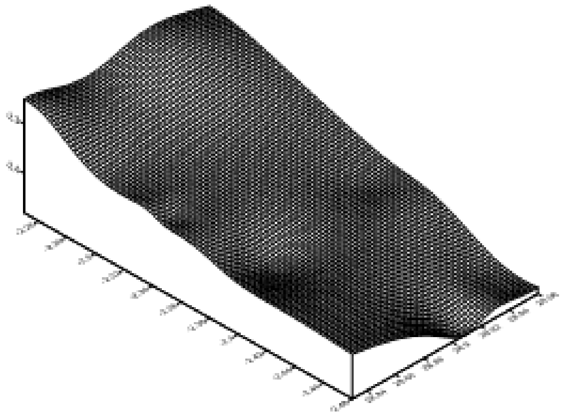
***Z. cucurbitae* map**

Figure 4. Data Locations of different fruit flies in area of study

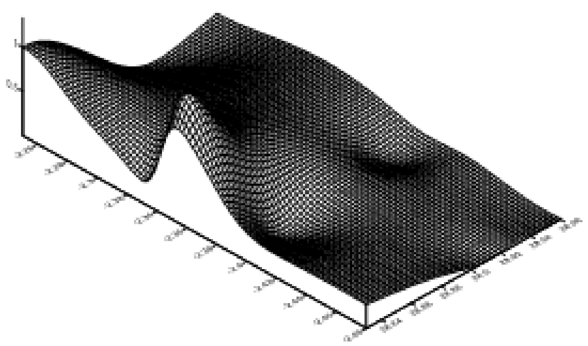
DOI: http://dx.doi.org/10.36956/njas.v4i1.457



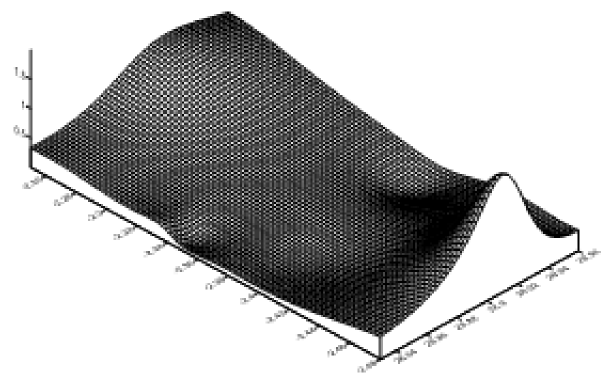
Inverse distance to a power of *B. dorsalis*



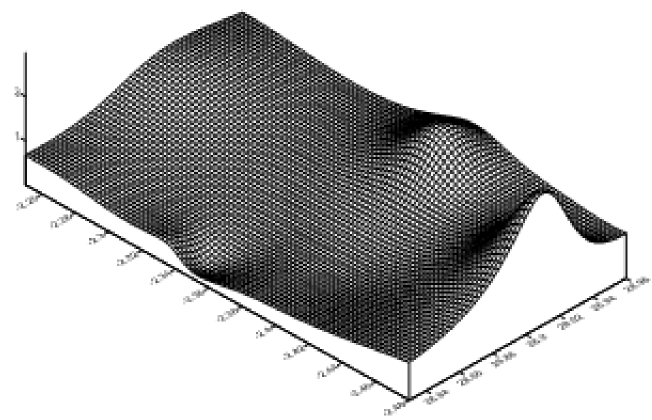
Inverse distance to a power of *B. latifrons*



Inverse distance to a power of *C. capitata*



Inverse distance to a power of *D. bivittatus*



Inverse distance to a power of *Z. cucurbitae*

Figure 5. Inverse distance to a power of different fruit flies in area of study

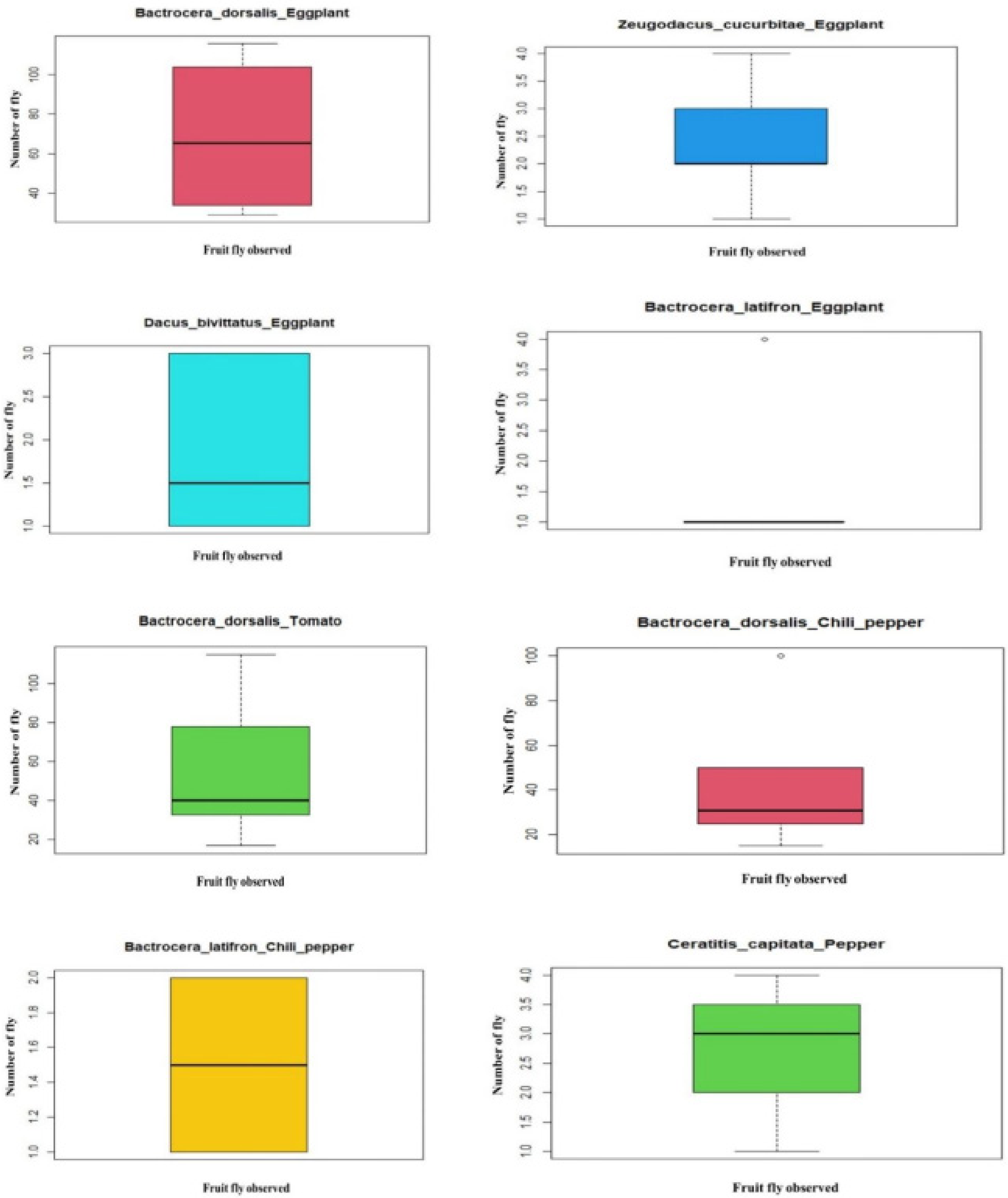


Figure 6. Boxplot of fruit flies observed during incubation of Solanaceous

DOI: http://dx.doi.org/10.36956/njas.v4i1.457

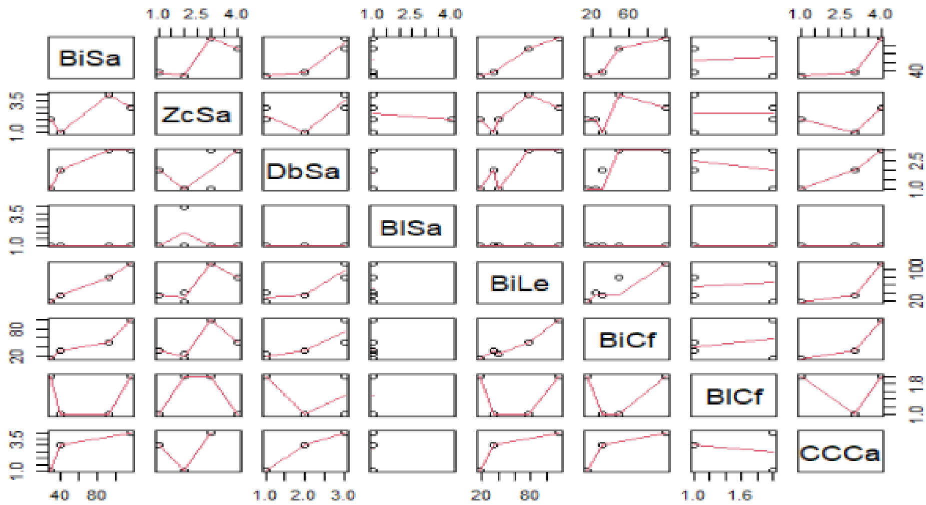


Figure 7. Linear model regression of flies observed

Bi: Bactrocera dorsalis, Bl: Bactrocera latifrons, Db: Dacus bivittatus, CC: Ceratitis capitata, Zc: Zeugodacus cucurbitae, Sa: Solanum aethiopicum, Le: L. esculentum, Cf: Capsicum frutescens, Ca: Capsicum annuum

4. Discussion

The highest relative abundance of *B. dorsalis* was in Bishibiru locality (0.074) than in Nyamakana locality (0.078), Buhandahanda locality (0.124), Ciranga-Kankule locality (0.265) and Kashenyi locality (0.399), Kamakombe and Lwiro localities (0.002) than in Cegera and Kashenyi localities (0.004), and Ciranga-Kankule locality (0.005). However, the predominant of *D. bivittatus* was more in Cegera, Bishibiru, Kashenyi and Lwiro localities (0.001) than in Ciranga-Kankule locality (0.004). So, the majority of hosts' *B. latifrons* was in Bishibiru, Cegera, Kamakombe, Kashenyi and Nyamakana localities (0.001) than in Ciranga-Kankule and Buhandahanda localities (0.004) and Lwiro locality (0.007). Then, the fruit flies *C. capitata* was more abundant in Bishibiru locality (0.001) than in Lwiro locality (0.004) and Nyamakana locality (0.005). Most fruit species can be grown on the highland due to the subtropical climate [26]. Altitude by itself does not determine fruit fly distribution but associated with other factors such as weather and host plants availability play an important role (Mwatawala et al., 2006; Geurts et al., 2012) [27,28].

The highest infestation rate was observed on *B. dorsalis* and following *C. capitata* in those solanaceous. This result goes in the same way of Mwatawala et al. [29], *B. dorsalis* was the dominant species in incidence expressed as the ratio of infested to total number samples collected, as well as infestation rate, expressed as number of flies emerging per unit weight. Infestation by native pests, such as *C. capitata* and *C. cosyra*, was minor compared to *B. invadens*. Indeed, several authors Vargas and Nishida (1985b) [30], White and Elson-Harris (1994) [1] and Mziray et al. (2010) [6] shows that *B. dorsalis* and *Z. cucurbitae* are the highly aggressive invasive species and also, *C. capitata, D. ciliatus, D. punctatifrons* and *D. bivittatus* are the major native pest pests on the areas of ecological interest. So, the invasive oriental fruit fly, *B. dorsalis* was recorded in Africa mainland since 2003 [31]. However, soon after its discovery in Kenya*, B. dorsalis* spread throughout Africa [32,33]. So, in many countries *C. capitata* species is often considered as highly polyphagous with almost 400 host plants known worldwide [34-37]. It is an other exotic polyphagous Tephritidae of major economic impacts are, most of the records date back from the 1950s such as the mango fruit fly the Mediterranean fruit fly *Ceratitis capitata* Wiedemann [38,39].

The localities Kamakombe, Buhandahanda, Lwiro, Bishibiru have predominant in the majority of hosts in solanaceous fruits than Kashenyi, Ciranga-Kankule and Nyamakana localities this may be explained by the use of more vegetable activities in those areas [40] and the high dependence on pesticides by vegetable farmers is an indication that they are not aware of other pest management strategies that are effective, inexpensive and yet friendly to the environment. This improper use of pesticides by market gardeners may induce resistance of pest to pesticides in those areas [41].

Furthermore, a few adults of *B. dorsalis* emerged from *Capsicum annuum* specie in this study in east of DRC, where Chili pepper (*C. frutescens*), eggplant (*S. aethiopicum*) and tomato (*S. lycopersicum*) were highly preferred by *B. dorsalis*. This result goes in the same way with the result of Badii *et al.* (2015) [42]. According to White and Elson-Harris (1992) [1], Sub-Saharan Africa is a reservoir of 915 fruit fly species from 148 genera, nearly, 299 of these species are considered as pests by feeding on fruits of economic importance. Three fruit fly species: *C. capitata*, *C. cosyra* and *C. rosa* Karsch are reported to attack *L. chinensis* in South Africa [43] and in La Réunion, *B. dorsalis* and *C. quilicii* De Meyer, Mwatawala & Virgilio were also recorded as a pest on this plant [44]. Commercial species of pepper and chilies are known to host *C. cosyra* and *B. dorsalis* in west and central African countries [42, 44]; *C. capitata*, *N. cyanescens* and *B. dorsalis* in some of the islands of the Indian Ocean [45].

Those fruit flies *B. dorsalis, B. latifrons, D. bivitatus, C. capitata, Z. cucurbitae* were located in study area. This result rejoined the result of Rubabura *et al*. (2019; 2021) [5,46], Ndayizeye et al. (2019) [47] and Ndayizeye and Kataraka (2021) [48]. Several fruit flies were observed such as *B. dorsalis, B. latifrons, Z. cucurbitae, D. bivittatus* and *C. capitata*. The average at eggplant was of 69 ± 41.78 for *B. dorsalis*, of 2 ± 0.97 for *Z. cucurbitae*, of 2 ± 0.89 for *D. bivittatus* and of 1 ± 1.13 for *B. latifrons*. According chili pepper, the average was of 44 ± 33.70 for *B. dorsalis* and of 1 ± 0.58 for *B. latifrons*. Additionally, the average of *B. dorsalis* on tomato was of 57 ± 39.59 and of 3 ± 1.53 *C. capitata* on pepper. The result goes in the same way of the result of Rubabura *et al.* (2021) [46].

5. Conclusions

It was concluded the five species of Tephritidae flies observed such as *B. dorsalis, B. latifrons, D. bivitatus, C. capitata, Z. cucurbitae* and the highest infestation rate was observed on *B. dorsalis* and following *C. capitata* in those solanaceous chilli pepper (*C. frutescens*), eggplant (*S. aethiopicum*) and tomato (*S. lycopersicum*) than *Z. cucurbitae, B. latifrons* and *D. bivittatus*. However, the localities Kamakombe, Buhandahanda, Lwiro, Bishibiru have predominant in the majority of hosts in chilli pepper, eggplant and tomato.

Acknowledgement

The authors are thank-full to Marc De Meyer of Invertebrates Section at the Royal Museum for Central Africa for the many tips, for the ideas, proofreading and correction of this article as well as for the unfailing emotional support and the Bugorhe Agriculture Farm and agents of agricultural entomology laboratory of the Research Centre in Natural Sciences (CRSN) Lwiro, for providing facilities and cooperation for the conduction of this experiment.

References

[1] White, I.M. and Elson-Harris, M.M., 1994. Fruit flies of economic significance: their identification and bionomics [reprint with addendum]. *CAB International*, Wallingford.

[2] White, IM., 2006. Taxonomy of the Dacina (Diptera: Tephritidae) of Africa and the Middle East. *Afr. Entomol.Mem.* 2, 1-156.

[3] Rubabura, K.JA., Munyuli, B.M.T., Bisimwa, B.E. and Kazi, K.S., 2015. Invasive fruit fly, Ceratitis species (Diptera: Tephritidae), pests in South Kivu region, eastern of Democratic Republic of Congo. International *Journal of Innovation and Scientific Research*. 16(2):403-408.

[4] Virgilio, M., Backeljau, T., Emeleme, R., Juakali, J.L. and De Meyer, M., 2011. A quantitative comparison of frugivorous tephritids (Diptera: Tephritidae) in tropical forests and rural areas of the Democratic Republic of Congo. *Bull Entomol Res*. 101(5):591-597.

[5] Rubabura, K.JA., Chihire, B.P., Bisimwa, B.E., 2019. Diversity and abundance of fruit flies (family: Tephritidae) in the Albertine rift zone, Democratic Republic of the Congo, and preliminary prospects for biological control. *Adv Plants Agric Res.* 9(1):41-48. DOI: https://doi.org/10.15406/apar.2019.09.00408.

[6] Mziray, H.A., Makundi, R.H., Mwatawala, M., Maerere, A.A and De Meyer, M., 2010. Host Use of *Bactrocera latifrons,* a New Invasive Tephritid Species in Tanzania, Ecology and behavior. *J. Econ. Entomol*. 103(1): 70-76.
DOI: https://doi.org/10.1603/EC09212.

[7] Vargas, R.I. and Nishida, T., 1985a. Life history and demographic parameters of *Dacus latifrons* (Diptera: Tephritidae). *J. Econ. Entomol.* 78: 1242 1244.

[8] Vargas, R.I., Walsh, W.A., Armstrong, J.W., Jang, E.B. and Kanehisa, D., 1996. Survival and development of immature stages of four Hawaiian fruit flies (Diptera: Tephritidae) reared at five different temperatures. *Ann. Entomol. Soc. Am.* 89: 64 -69.

[9] Vargas, R.I., Walsh, W.A., Kanehisa, D., Jang, E.B. and Armstrong, J.W., 1997. Demography of four Hawaiian fruit flies (Diptera: Tephritidae) reared at five constant temperatures. *Ann. Entomol. Soc. Am.* 90: 162-168.

[10] McQuate, G.T., Bokonon-Ganta, A.H. and Peck, S.L., 2007. Population biology and prospects for suppression of the solanaceous fruit fly, *Bactrocera latifrons* (Diptera: Tephritidae). *Proc. Hawaiian Entomol. Soc.* 39: 111-115.

[11] Peck, S.L. and McQuate, G.T., 2004. Ecological as-

DOI: http://dx.doi.org/10.36956/njas.v4i1.457

pects of *Bactrocera latifrons* (Diptera: Tephritidae) on Maui, Hawaii: movement and host preference. *Environ. Entomol.* 33: 1722-1731.

[12] Bokonon-Ganta, A.H., McQuate, G.T. and Messing, R.H., 2007. Natural establishment of a parasitoid complex on *Bactrocera latifrons* (Diptera: Tephritidae) in Hawaii. *Biol. Control* 42: 365-373.

[13] McQuate, G.T., 2009. Effectiveness of GF-120 fruit fly bait as a suppression tool for *Bactrocera latifrons* (Diptera: Tephritidae). *J. Appl. Entomol.* 133: 444-448.

[14] McQuate,G.T. and Peck, S.L., 2001. Enhancement of attraction of alpha-ionol to male *Bactrocera latifrons* (Diptera: Tephritidae) by addition of a synergist, cade oil. *J. Econ. Entomol.* 94: 39-46.

[15] McQuate, G. T., Keum, Y.-S., Sylva, C. D., Li, Q. X. and Jang, E. B., 2004. Active ingredients in cade oil which synergize the attractiveness of α-ionol to male *Bactrocera latifrons* (Diptera: Tephritidae). *J. Econ. Entomol.* 97: 862-870.

[16] Yang P., 1992. Demographic investigations on selected dacine fruit flies in southern China and Hawaii. Ph. D. dissertation, University of California, Davis.

[17] Ekesi, S., De Meyer, M., Mohamed, S. A., Virgilio, M. and Borgemeister, C., 2016. Taxonomy, ecology and management of native and exotic fruit fly species in Africa. *Annual Review of Entomology*, Vol 61, 61, 219-238.

[18] Ekesi, S. and Billah, M.K., 2007. A field guide to the management of economically important tephritid fruit flies in Africa.*ICIPE Science Press*, Nairobi, Kenya.

[19] CABI., 2005. Crop Protection Compendium, Edition. Commonwealth Bureau of Agriculture International, Wallingford, UK.

[20] White, I.M., 2006. Taxonomy of the Dacina (Diptera: Tephritidae) of Africa and the Middle East. *Afr. Entomol. Mem.* 2, 1-156.

[21] De Meyer, M., Mohamed, S., White, I.M., 2014. Invasive Fruit Fly Pests in Africa. A diagnostic tool and information reference for the four Asian species of fruit fly (Diptera, Tephritidae) that have become accidentally established as pests in Africa. Http://www.africamuseum.be/fruitfly/AfroAsia.htm (website accessed on 1/12/2008).

[22] Copeland, R.S., Wharton, R.A., Luke, Q. and De Meyer, M., 2002. Indigenous hosts of Ceratitis capitata (Diptera: Tephritidae) in Kenya. *Ann. Entomol. Soc. Am*. 95, 672-694.

[23] Vayssières, JF, Sinzogan, A, Adandonon, A., 2009. Principales méthodes de lutte intégrée contre les mouches des fruits en Afrique de l'Ouest. Fiche Nº6. Projet Régional de Lutte Contre les Mouches des Fruits en Afrique de l'Ouest. UPR Production Fruitière, Montpellier, France; IITACIRAD. Cotonou - Bénin. p.4.

[24] Yilmaz, M.H., 2007. The effect of interpolation methods in surface definition: an experimental study. *Earth Surf. Process. Landforms*, 32, 1346-1361. DOI: https://doi.org/10.1002/esp.1473

[25] R Core Team, 2018. R: A Language and Environment for Statistical Computing.Vienna: R Foundation for Statistical Computing. https://www.R-project.org.

[26] Rasolofoarivao, H., Raveloson Ravaomanarivo, L.H., Delatte, H., 2021. Host plant ranges of fruit flies (Diptera: Tephritidae) in Madagascar. *Bulletin of Entomological Research* 1-12. DOI: https://doi.org/10.1017/S000748532100051.

[27] Mwatawala, M.W., De Meyer, M., Makundi RH and Maerere, A.P., 2006. Biodiversity of fruit flies (Diptera, Tephritidae) in orchards in different agro-ecological zones of the Morogoro region, Tanzania. *Fruits* 61, 321-332.

[28] Geurts, K., Mwatawala ,M., De Meyer, M. and Heckel, D., 2012. Indigenous and invasive fruit fly diversity along an altitudinal transect in Eastern Central Tanzania. *Journal of Insect Science* 12, 1536-2442.

[29] Mwatawala, M., De Meyer, M., Makundi R. and Maerere, A., 2009. Host range and distribution of fruit-infesting pestiferous fruit flies (Diptera, Tephritidae) in selected areas of Central Tanzania. *Bulletin of Entomological Research* , 99, 629-641.

[30] Vargas R. I., Nishida T., 1985b. Survey of *Dacus latifrons* (Diptera: Tephritidae). *J. Econ. Entomol*. 78: 1311-1314.

[31] Lux, S.A., Copeland, R.S., White, I.M., Manrakhan, A. and Billah, M.K., 2003. A new invasive fruit fly species from the *Bactrocera dorsalis* (Hendel) group detected in East Africa. International *Journal of Tropical Insect Science* 23, 355-361.

[32] De Meyer, M., 2000. Systematic revision of the subgenus Ceratitis MacLeay s.s.(Diptera, Tephritidae). *Zoological Journal of the Linnean Society* 128,439-467.

[33] De Meyer, M., Robertson, M.P., Mansell ,M.W., Ekesi, S., Tsuruta, K., Mwaiko, W.,Vayssieres, J-F. and Peterson, A.T., 2009. Ecological niche and potential geographic distribution of the invasive fruit fly *Bactrocera invadens* (Diptera,Tephritidae). *Bulletin of Entomological Research* 100, 35 -48.

[34] Liquido, N.J., Barr, P.G. and Cunningham, R.T., 1998. Medhost: An Encyclopedic Bibliography of the

Host Plants of the Mediterranean Fruit Fly, *Ceratitis capitata* (Wiedemann). USDA ARS.

[35] Liquido, N., McQuate, G. and Suiter, K., 2015. Medhost: An encyclopedic bibliography of the host plants of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), version 3.0. USDA CPHST, Online Database.

[36] Copeland, R.S., Wharton, R.A., Luke, Q. and De Meyer, M., 2002. Indigenous hosts of *Ceratitis capitata* (Diptera: Tephritidae) in Kenya. Annals of the *Entomological Society of America* 95, 672-694.

[37] Moquet, L., Payet ,J., Glenac S and Delatte H, 2021. Niche shift of tephritid species after the Oriental fruit fly (*Bactrocera dorsalis*) invasion in La Réunion. Diversity and Distributions 27, 109-129.

[38] De Meyer, M., Quilici, S., Franck, A., Chadhouliati, A., Issimaila ,M., Youssoufa, M., Abdoul-Karime ,A-L., Barbet, A., Attié, M. and White, I., 2012. Records of frugivorous fruit flies (Diptera: Tephritidae: Dacini) from the Comoro archipelago. *African Invertebrates* 53, 69 -77.

[39] Dubois, J., 1965. La mouche des fruits malgache (*Ceratitis malgassa* Munro) et autres insectes des agrumes, pêchers et pruniers à Madagascar. *Fruits* 20,435-460.

[40] Report, 2021. Annually report of Agricultural Inspection of South Kivu, DRC.

[41] Van der Meijden, G., 1998. Pesticide application techniques in West-Africa. Food and Agriculture Organization of the United Nations FAO Regional Office for Africa Accra, Ghana and Agricultural Engineering Branch, Agricultural Support Systems Division, FAO, Rome, Italy.

[42] Badii, K., Billah, M., Afreh-Nuamah, K. and Obeng-Ofori, D., 2015. Species composition and host range of fruit-infesting flies (Diptera: Tephritidae) in northern Ghana. *International Journal of Tropical Insect Science,* 35, 137-151.

[43] Grové, T., Steyn, W.P. and De Beer, M.S., 2002. Fruit flies associated with litchi production in South Africa. Proceedings of 6th International Fruit Fly Symposium, Stellenbosch, South Africa, 313-316.

[44] Moquet, L., Payet, J., Glenac, S. and Delatte, H., 2021. Niche shift of tephritid species after the Oriental fruit fly (*Bactrocera dorsalis*) invasion in La Réunion. *Diversity and Distributions*, 27, 109-129.

[45] Franck, A. and Delatte, H., 2020. Plantes-hôtes des Mouches des fruits, Comores, Madagascar, Maurice, Mayotte, Réunion, Seychelles. *CIRAD* (Ed), pp. 160.

[46] Rubabura, K.JA. and Muhingwa, B.JB., 2021. Current status of the Solanum fruit fly *Bactrocera latifrons* (Hendel) in the eastern part of Democratic Republic of Congo.*Insect Environment*, Volume 24 (3)370-380.

[47] Ndayizeye, L., Nzigidahera ,B., Elamin Gesmallah, A., 2019. Detection of *Bactrocera latifrons* Hendel (Diptera: Tephritidae) on African eggplant in the different agro-ecological zones of Burundi. *International Journal of Tropical Insect Science*, 39(2): 1-6. DOI: https://doi.org/10.1007/s42690-019-00013.w.

[48] Ndayizeye, L., and Kataraka, C.B., 2021. First report of *Bactrocera latifrons* Hendel in the Democratic Republic of Congo. EPPO Bulletin. DOI: https://doi.org/10.1111/epp.12746.

  DOI: http://dx.doi.org/10.36956/njas.v4i1.457