Assessing the Impact of Tephritid Fruit Flies on Diverse Fruit and Vegetable Crops in West Bengal's Terai Agro-Ecological Region

ABSTRACT

The flies belong to the family Tephritidae of the Insect order Diptera and are referred to as Fruit flies because they infest a wide variety of fruits and vegetables. Globally, Dacinae fruit flies of the genus *Bactrocera* Macquart are one of the most important pests of fruits and vegetables. A study was conducted during 2021, to assess the association of tephritids with different fruits and vegetables like Ber, Citrus, Guava, Mango, Bottle gourd, Cucumber and Pumpkin.A total of nine species were collected by installing traps comprising of sex attractants such as Cue-lure, Methyl Eugenol and by rearing from Infested fruits. Among nine, six species were collected through cue-lure traps namely *Zeugodacus tau* (Walker), *Zeugodacus cucurbitae* (Coq.), *Bactrocera rubigina* (Wang and Zhao), *Zeugodacus caudatus*(Fabricus), *Bactrocera divenderi* (Maneesh, Hancock and Prabhakar) and *Dacus longicornis* (Wiedemann). Two species were collected through methyl eugenol trapsnamely *Bactroceradorsalis* (Hendel) and*Bactrocera zonata* (Saunders). Four species namely *Zeugodacustau* (Walker), *Zeugodacuscucurbitae* (Coq.), *Bactrocera dorsalis* (Hendel) and *Bactrocera minax* (Enderlein) were recovered from infested fruits of ber, citrus,bottle gourd, cucumber and pumpkin. Species richness in different fields wasmaximum in citrus and from the recovery of infested fruits maximum in ber. Species composition of *Z.tau*wasmaximum in pumpkin, and bottle gourd and *B.dorsalis* were maximum in mango, guava, ber and citrus. Species composition of *Z.tau* were recovered maximum from infested pumpkin and cucumber, *Z.cucurbitae* were recovered maximum from infested bottle gourd and *B.dorsalis* were recovered maximum from infested ber and citrus fruits.Relative abundance of *Z.tau* were recorded maximum in pumpkin and bottle gourd and *B.dorsalis*was recorded maximum in mango, guava, ber and citrus. A relative abundance of *Z.tau*was recovered maximum in pumpkin and cucumber-infested fruits, *Z.cucurbitae* were recovered maximum from bottle gourd-infested fruits and *B.dorsalis* were recovered maximum from ber and citrus-infested fruits. In different fields, species evenness was observed maximum in citrus and from recovery of infested fruits maximum in ber.

Keywords:Fruit flies, Tephritid, Bactrocera, Species Richness, Composition, Relative abundance, Eveness

1. INTRODUCTION

Fruits and vegetables are grown all over the country along with other agricultural crops. In the world, India ranks 2nd position for the production of fruits and vegetables. It provides additional income to the country. India is a wide country with diverse climatic conditions where all varieties of fruits and vegetables are grown. Vegetables like cucurbits (pumpkin, Bottle gourd, Ridge gourd, cucumber), onion, Ginger, Solanaceous (tomato, okra, chilli, brinjal), crucifers (cabbage, cauliflower, broccoli) are grown. Fruits like apple, pear, plum, mango, guava, ber, papaya, citrus, banana, pomegranate and many more are cultivated. One of the most important challenges in the production of fruits and vegetables is ideal yield and quality. It is reduced by the infestation of Insect pests and diseases. Many insect pests like lepidopteran, coleopteran, dipteran and many more attack fruits and vegetables. Among them, the most destructive insect pest of fruits and vegetables in the world isfruit flies (Vayssieres *et al*., 2008; Ekesi *et al*., 2009). The Fruit flies belong to the family Tephritidae of the Insect order Diptera.The fruit flies cause major losses in horticultural crops in tropical and sub-tropical regions (Meghana and Laskar, 2024; Rubabura et al., 2019). Due to its cosmopolitan distribution, polyphagous nature, the nature of the damage, losses and quarantine status have economic importance (Drew *et al*., 2007; Kapoor 2006; Ukey *et al*.,

2013). The genera *Anastrepha*, *Bactrocera*, *Ceratitis*, *Dacus*, *Rhagolatis* contain the most important species of economic importance on horticultural crops worldwide (Raga et al., 2020; White and Elson-Harris 1992). They attack wide varieties of wild and commercial vegetables and fruits causing considerable damage to the crops (Meghana and Laskar, 2024; De Meyer *et al*., 2012).Tephritids cause fruit dropping making them inedible and associated with quarantine restrictions that are imposed by importing countries to prevent the entry and establishment of exotic fruit fly species (Ekesi, 2012). Fruit flies "(Diptera: Tephritidae) cause significant losses during the production and marketing of horticultural products" (Raga et al., 2021).

In India, 200 species of tephritids (Fruit flies) are recorded which is about 5% of world's tephritid fauna (Verghese *et al*., 2002).Fruit flyspecies attack many families belonging to fruits and vegetables. About 36% of the tephritid species infest soft fruits, which consist of various commercially cultivated vegetables and fruits (White and Elson-Harris 1992). *Z. cucurbitae*, *B. dorsalis*, *Z. tau* are serious pests of fruits and vegetables which destroy the growth and development.

Bactrocera dorsalis infests more than 46 hosts including many fruit crops grown commercially like cucurbits, guava, mango, papaya, avocado, papaya (De Meyer 2010; Cugala *et al*., 2014; Mwatawala *et al*., 2006; Jose and Santos, 2013). *Bactrocera dorsalis* complex has various host range belongs to 38 families, 75 genera, 118 species (Allwood *et al*., 1999).It attacks many families of vegetables and fruits like Cucurbitaceae, Caricaceae, Rutaceae, Fabaceae, Malvaceae, Myrtaceae, Sapotaceae, Rhamnaceae, Solanaceae, Moraceae, Vitaceae (Tsuruta *et al*., 1997).*Bactrocera* tau infested fruit species belong to families Leguminoseae, Rutaceae, Sapotaceae, Myrtaceae, Solanaceae, Moraceae (Allwood *et al*., 1999; Boopathi *et al*., 2013a). *B. tau* infests tomato fruits causing quality reduction and fruit abortion (Gupta et al., 1990; Boopathi et al., 2013a). *B.cucurbitae*, *Dacus punctatifrons* are also attack tomato fruits. *Bactrocera tau*, *Bactrocera latifrons* infests solanaceous fruits like brinjal, chilli, tomato and *Bactrocera diversa* attacks cucurbits.

Due to wide host range, high dispersal capacity, wide tolerance to climate, polyphagous nature and quick proliferation of fruit flies was difficult to control by using insecticides which cause huge yield losses in vegetables and fruit crops (Baral *et al*., 2006; Muhammad *et al*., 2004; Ndiaya *et al*., 2008).Tephritids attack a various variety of fleshy, soft vegetable and fruit crops and lead to 35 – 81% direct loss all over the season depending on variety and locality (Lux *et al*., 2003a; Lux *et* al., 2003b; Ekesi *et al*., 2009; Otieno, 2009). Infestation caused by tephritid fruit flies outcomes in severe losses in trade value and export opportunity because of strict quarantine regulations enforced by many importing countries (Adhikari *et al*., 2016; Poudel and Regmi 2008). Crop loss occurs in vegetable crops in India was reported as 30 – 40% (Rai *et al*., 2014).

Forty three species are known in genera, *Bactrocera* and *Dacus*. Out of thirty six species in 11 sub genera, 17 species of *Bactrocera* are economically significant causing heavy losses to wide varieties of vegetables and fruits in India (Kapoor, 2002).Tephritids cause 100% yield loss in cucurbits as they are quarantine pests (Dhillon *et al*., 2005).In India, melon fruit fly (*Bactrocera cucurbitae*) is a major threat to cucurbits (Shah *et al*., 1948; Senior – white 1924).Tephritid fruit flies also infest many fruit crops like Mango, Guava, Ber, Papaya, Citrus and many more.About 15-85% loss in mango production by fruit flies has been noted (Anonymous 2013).Loss in guava yield is about 3-40% as reported by Haseeb and Sharma (2007).

More than 75% of losses are recorded in ber field due to fruit fly infestation (Nizamani *et al*., 2015; Saxena and Rawat, 1968) and fruit damage about 55-65% (Sharma *et al*., 1998) and 90-100% (Vadivlu, 2014; Singh and Vashista, 1985).More than 35% post-harvest losses are caused by fruit flies (Musasa *et al*., 2015).In Northern India, *Bactrocera minax* causes significant damage in tangerine (Nath, 1973).

2. MATERIALS AND METHODS

2.1 Experimental Site

During 2020 and 2021 the field studies were conducted at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India. During respective years of study,the laboratory investigations were carried out in the Department of Entomology, UBKV, Pundibari, Cooch Behar.The Instructional Farmis located at 26º 19´ N latitude and 89º 23´ E longitude at an altitude of 43 meter above the Mean Sea Level (MSL). Top soils are dark brown in colour, about 1-3 feet deep, sandy loam in texture, high in raw humus content, porous, low water retention capacity, medium to high nitrogen content, low to medium potassium content but poor in secondary micronutrients.Soil of the region is acidic in reaction and pH of soil ranged from 4.2 to 6.8.About 80 per cent of total rainfall received from the South-West monsoon during the rainy months from June to September. Average maximum and minimum temperatures varied from 24˚C to 33.2˚C.The whole area is humid and warm except having a short spell of winter during the months of December-February. However, the pattern of rainfall is erratic and not uniformly distributed round the year.

2.2 Collection and Rearing of fruit flies

From different fields tephritid fruit flies are collected by installing traps comprising of sex attractants such as Cue-lure and Methyl Eugenol. Cue-lure and Methyl eugenol lure are prepared in laboratory by soaking cotton wick in a solution containing either cue-lure or methyl eugenol chemical, Cypermethrin and water. Then cotton wick is wrapped by using aluminium foil and fixed in traps. The traps containing para-pheromone about four per each field at a height of 1.5 – 2m with a distance of 20m were placed. From each trap, every day fruit flies were recorded.Tephritids infested fruits were collected from Instructional farm of Uttar Banga Krishi Vishwavidyalaya, Pundibari. Damaged fruits collected from Bottle gourd, Cucumber, Pumpkin, Ber, Citrus field were placed in a plastic or glass tray (42×35×7 cm)containing a dry medium such as loose soil and covered with muslin cloth on top to prevent infestation of another flies which cause secondary infection and trays were kept for rearing in an insect rearing cage.Every two days samples were checked for puparia and fruits from which larva emerged was discarded. After pupation,soil was sieved for collecting pupae. Again pupae were placed in a tray containing soil for adult emergence at least 3 – 4 weeks. Sugar solution as a food was placed in a tray which was used by adult fruit flies for development of full body and coloration which was helpful for identification (Meghana and Laskar, 2024).

2.3 To assess the association of tephritids with different fruits and vegetables

Fruit fly species collected from traps installed in field and rearing of infested fruits in different crops such as bottle gourd, cucumber, pumpkin,ber, citrus, mango and guava used to analyse the tephritids associated with different vegetables and fruits.

2.3.1 Species richness in different fruits and vegetables

Measure of number of species in a sample (Kishore *et al*.,2018). More species were found when the sample size is large. Species richness was determined by using Menhinick Index.

$$\text{Species richness} = \frac{S}{\sqrt{n}}$$

Where S = Number of species in a sample
n = Total number of individuals in a sample

2.3.2 Species composition in different fruits and vegetables:

Species composition was calculated to recognize the similar species present in a locality. It is expressed as percent and all species were added up to 100% (Ndah *et al*.,2013). It was determined by using density of the species in a locality.

$$\text{Species composition} = \frac{\text{Number of individuals of one species}}{\text{Total number individuals of all species}} \times 100$$

2.3.3 Relative abundance of species in different cucurbits and fruits:

After collection of tephritid fruit flies from para pheromone traps and rearing of infested fruits, 100 fruit flies were collected randomly from each crop. Insects were separated based on species and their relative abundance was calculated based on the formula (Kishore *et al*.,2018).

$$\text{Relative abundance} = \frac{\text{Number of individuals of one species}}{\text{Total number of individuals of all species}} \times 100$$

2.3.4 Species evenness of tephritids determined in different fruits and vegetables:

Species evenness was calculated to know the equitabilty of species in a community. It was estimated by using Pielou's Evenness Index (J) (Pielou 1966).

$$\text{Species evenness (J)} = \frac{H'}{\ln (S)}$$

where H' = Shannor – Weiner Index
S = Number of species in a sample
ln = Natural logaritham of a number.

The findings of the study have been presented in tabular as well as graphical form as applicable in appropriate manner.

3. RESULTS& DISCUSSION

3.1 To assess the association of tephritids with different fruits and vegetables:

3.1.1 Species richness of fruit flies collected from traps:

The number of species in Bottle gourd, Pumpkin, Ber, Mango, Guavaand Citrus were documented (Kishore *et al*.,2018). If the value is higher, then the species richness is higher. Observationsare presented in Table 1 and Fig.1.

Table 1: Determination of species richness in different fields.

Fields Taken Into Consideration	Species Richness (R)
Citrus	0.54
Guava	0.35
Pumpkin	0.29
Bottle gourd	0.29
Mango	0.26
Ber	0.26

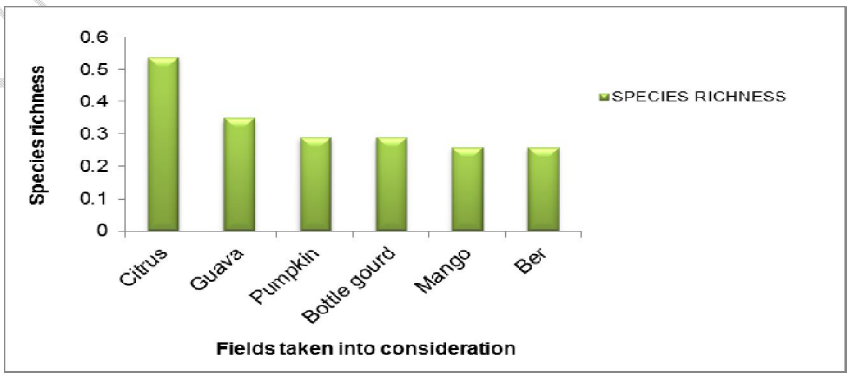

Fig. 1. Species Richness in Different Fields

From the undergone research work, data represented in Table 1 and Fig.1.Proves that in different fields such as bottle gourd, pumpkin, ber, mango, guava and citrus, species richness is determined. In citrus, species richness value is 0.54 followed by in guava 'R' is 0.35, in pumpkin and bottle gourd 'R' is 0.29, in mango and ber 'R' is 0.26. As the value is more, then species richness is maximum. Species richness is greater in citrus and least in mango and ber.

3.1.1.1 Species richness of fruit flies recovered from infested fruits:

Number of species in Bottle gourd, Cucumber, Pumpkin, Ber and Citrus were documented (Kishore *et al*.,2018). If the obtained value is more, then the species richness is more. Observations were presented in the Table 2 and Fig.2.

Table 2: Determination of species richness from recovery of infested fruits.

Fruit Flies Infested Fruits	Species Richness (R)
Ber	0.38
Cucumber	0.30
Citrus	0.27
Bottle gourd	0.18
Pumpkin	0.14

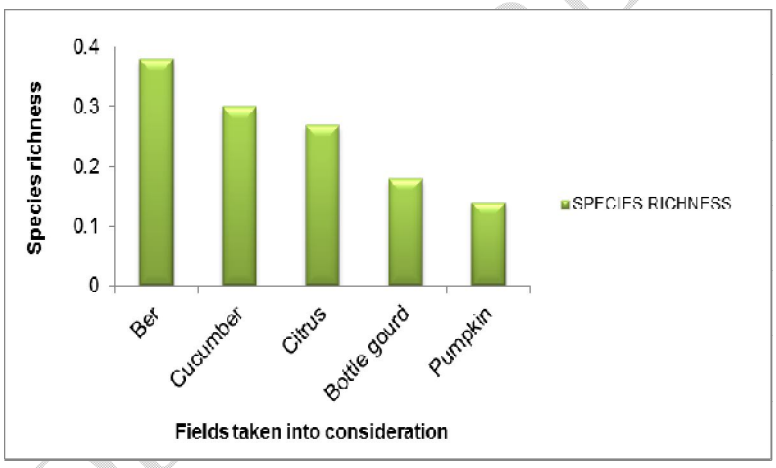

Fig. 2. Species Richness in Infested Fruits

From the undergone research work, data represented in Table 2 and Fig.2.Proves that from recovery of infested fruits such as bottle gourd, cucumber, pumpkin, ber, and citrus, species richness is determined. In ber, species richness value is 0.38 followed by in cucumber 'R' is 0.30, in citrus 'R' is 0.27, in bottle gourd 'R' is 0.18 and in pumpkin 'R' is 0.14. As the value is more, then species richness is maximum. Species richness is greater in ber and least in pumpkin.

3.1.2Species composition of fruit flies collected from traps:

Number of similar individuals recorded in different fields were documented. It was expressed in percentage (Ndah *et al*.,2013). If the obtained value is more, then the composition of that species is more. Observations were presented for different fields in the tables and figures.

3.1.2.1 Species composition of fruit flies in pumpkin:

Table 3: Determination of species composition of tephritids in pumpkin collected by traps.

Name of the Species	Species Composition (%)
Zeugodacus tau (Walker)	48.1
Bactrocera dorsalis (Hendel)	19.6
Zeugodacus cucurbitae (Coq.)	17.7
Bactrocera rubigina (Wang and Zhao)	6.3
Zeugodacus caudatus (Fabricus)	3.1
Bactrocera zonata (Saunders)	2.2
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	1.3
Dacus longicornis (Weidemann)	1.2

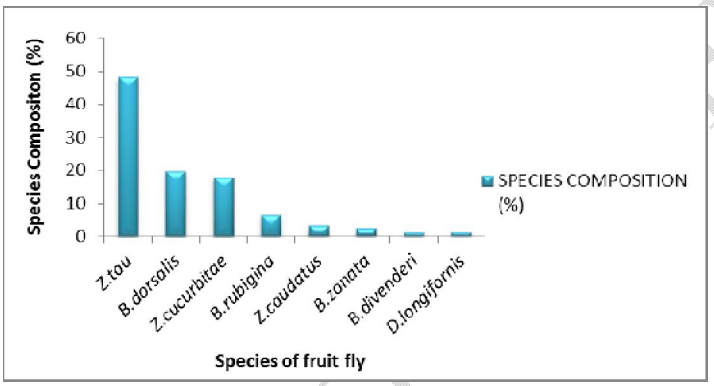

Fig. 3. Species Composition (%) in Pumpkin

Overall information from an experiment Table 3 and Fig.3. reveals as species composition in pumpkin is determined in percent. In pumpkin, *Zeugodacus tau* recorded about 48.1% followed by *Bactrocera dorsalis* (19.6%), *Zeugodacus cucurbitae* (17.7%), *Bactrocerarubigina* (6.3%), *Zeugodacus caudatus* (3.1%), *Bactrocera zonata* (2.2%), *Bactrocera divenderi*(1.3%) and *Dacus longicornis* (1.2%). As the percentage is more, then the species composition of that particular species is more. So, Species composition of *Zeugodacustau* in pumpkin is more and minimum is *Dacus longicornis*.

3.1.2.2 Species composition of fruit flies in Bottle gourd:

Table 4: Determination of species composition of tephritids in Bottle gourd collected by traps.

Name of the Species	Species Composition (%)
Zeugodcus tau (Walker)	36.6
Zeugodacus cucurbitae (Coq.)	26.9
Bactrocera dorsalis (Hendel)	25.7
Bactrocera rubigina (Wang and Zhao)	4.5
Bactrocera zonata (Saunders)	2.4
Zeugodacus caudatus(Fabricus)	1.6
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	1.2
Dacus longicornis (Weidemann)	0.9

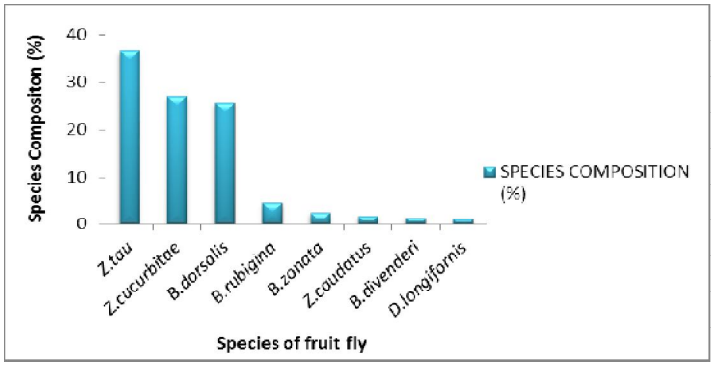

Fig 4: Species Composition (%) in Bottle gourd

Inclusive information from anresearch is represented in Table 4 and Fig.4. shown as species composition in bottle gourd is determined in percent. In bottle gourd, *Zeugodacus tau* recorded about 36.6% followed by *Zeugodacus cucurbitae* (26.9%), *Bactrocera dorsalis* (25.7%), *Bactrocerarubigina* (4.5%), *Bactrocera zonata* (2.4%), *Zeugodacus caudatus*(1.6%), *Bactrocera divenderi*(1.2%) and *Dacus longicornis* (0.9%). As the percentage is more, then the species composition of that particular species is more. So, Species composition of *Zeugodacustau* in bottle gourd is more and minimum is *Dacus longicornis*.

3.1.2.3 Species composition of fruit flies in Mango:

Table 5:Determination of species composition of tephritids in Mango collected by traps.

Name of the Species	Species Composition (%)
Bactrocera dorsalis (Hendel)	34.8
Zeugodacustau(Walker)	33.3
Zeugodacus cucurbitae (Coq.)	16.3
Zeugodacus caudatus(Fabricus)	5.7
Bactrocera rubigina (Wang and Zhao)	4.7
Bactrocera zonata (Saunders)	3.2
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	1.6

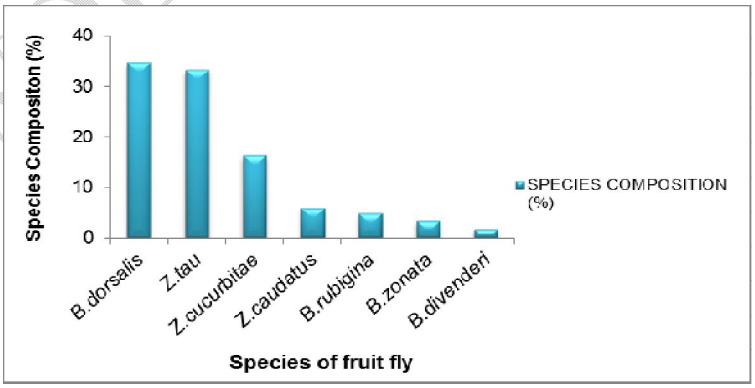

Fig. 5. Species Composition (%) inMango

Inclusive information from a research is represented in Table 5 and Fig.5. shown as species composition in mango is determined in percent. In mango, *Bactrocera dorsalis* recorded about 34.8% followed by *Zeugodacus tau* (33.3%), *Zeugodacus cucurbitae* (16.3%), *Zeugodacuscaudatus*(5.7%), *Bactrocera rubigina* (4.7%), *Bactrocera zonata* (3.2%), *Bactrocera divenderi*(1.6%). As the percentage is more, then the species composition of that

particular species is greater. So, Species composition of *Bactroceradorsalis* in mango is maximum and minimum is *Bactrocera divenderi*.

3.1.2.4 Species composition of fruit flies in Guava:

Table 6:Determination of species composition of tephritids in Guava collected by traps.

Name of the Species	Species Composition (%)
Bactrocera dorsalis (Hendel)	50.3
Zeugodacus tau(Walker)	18.9
Bactrocera rubigina (Wang and Zhao)	7.9
Bactrocera zonata (Saunders)	7.3
Zeugodacus caudatus(Fabricus)	6.8
Zeugodacus cucurbitae (Coq.)	6.5
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	1.8

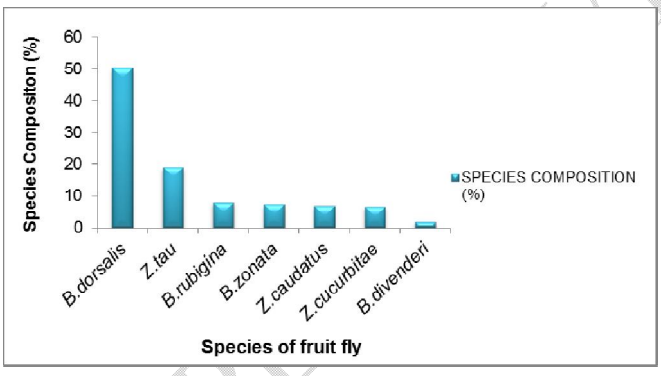

Fig. 6. Species Composition (%) inGuava

After an experiment, data is represented in Table 6 and Fig.6. shown as species composition in guava is determined in percent. In guava, *Bactrocera dorsalis* recorded about 50.3% followed by *Zeugodacus tau* (18.9%), *Bactrocera rubigina* (7.9%), *Bactrocerazonata* (7.3%), *Zeugodacus caudatus*(6.8%), *Zeugodacus cucurbitae* (6.5%), *Bactrocera divenderi*(1.8%). As the percentage is more, then the species composition of that particular species is greater. So, Species composition of *Bactroceradorsalis* in guava is maximum and minimum is *Bactrocera divenderi.*

3.1.2.5 Species composition of fruit flies in Ber:

Table 7:Determination of species composition of tephritids in Ber collected by traps.

Name of the Species	Species Composition (%)
Bactrocera dorsalis (Hendel)	39.0
Zeugodacus tau(Walker)	23.9
Zeugodacus cucurbitae (Coq.)	20.4
Zeugodacus caudatus(Fabricus)	5.2
Bactrocera zonata (Saunders)	4.7
Bactrocera rubigina (Wang and Zhao)	4.6
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	1.9

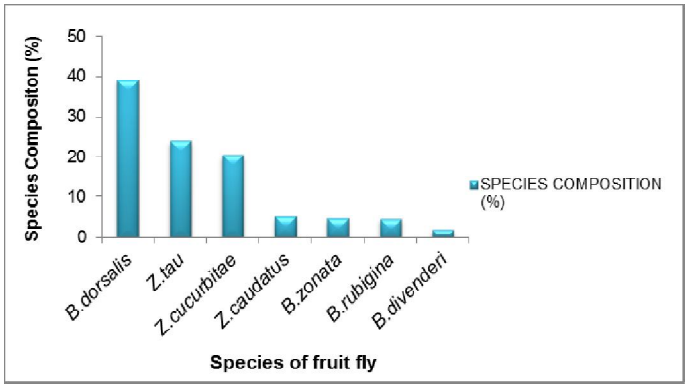

Fig. 7. Species Composition (%) inBer

Overall information from an experiment Table 7 and Fig.7. reveals as species composition in ber is determined in percent. In ber, *Bactrocera dorsalis* recorded about 39.0% followed by *Zeugodacus tau* (23.9%), *Zeugodacus cucurbitae* (20.4%), *Zeugodacus caudatus* (5.2%), *Bactrocera zonata* (4.7%), *Bactrocera rubigina* (4.6%) *Bactrocera divenderi*(1.3%) As the percentage is more, then the species composition of that particular species is more. So, Species composition of *Bactroceradorsalis* in ber is more and minimum is *Bactrocera divenderi*.

3.1.2.6 Species composition of fruit flies in Citrus

Table 8:Determination of species composition of tephritids in Citrus collected by traps.

Name of the Species	Species Composition (%)
Bactrocera dorsalis (Hendel)	45.7
Zeugodacus tau(Walker)	22.2
Zeugodacus cucurbitae (Coq.)	19.1
Zeugodacus caudatus(Fabricus)	7.3
Bactrocera zonata (Saunders)	5.7

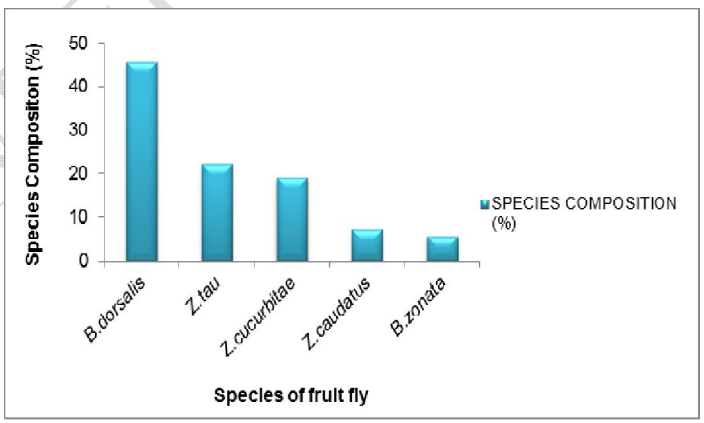

Fig. 8. Species Composition (%) inCitrus

Inclusive information from an research is represented in Table 8 and Fig.8. shown as species composition in citrus is determined in percent. In citrus, *Bactrocera dorsalis* recorded about 45.7% followed by *Zeugodacus tau* (22.2%), *Bactroceracucurbitae* (19.1%), *Zeugodacuscaudatus*(7.3%), *Bactrocera zonata* (5.7%). As the percentage is more, then the species composition of that particular species is greater. So, Species composition of *Bactroceradorsalis* in citrus is maximum and least recorded is *Bactrocera zonata*.

3.1.3Species composition of fruit flies recovered from infested fruits:

Number of similar individuals recorded from recovery of infested fruits were documented. It was expressed in percentage (Ndah *et al*.,2013). If the obtained value is more, then the composition of that species is more. Observations were presented in the tables and figures.

3.1.3.1 Species composition of fruit flies in Pumpkin:

Table 9:Determination of species composition of tephritids recovered from pumpkin.

Name of the Species	Species Composition (%)
Zeugodacus tau(Walker)	49.8
Zeugodacus cucurbitae (Coq.)	46.5
Bactrocera dorsalis (Hendel)	3.5

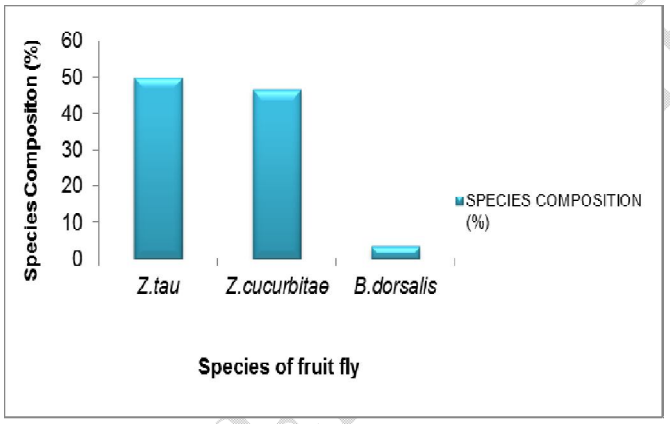

Fig. 9. Species Composition (%) inPumpkin

Through the experiment done and result represented in Table 9 and Fig.9. concludes as species composition of tephritids recovered from pumpkin infested fruit is determined in percent. From infested fruits of pumpkin, *Zeugodacus tau* about 49.8% is recorded followed by *Zeugodacus cucurbitae* (46.5%) and *Bactrocera dorsalis* (3.5%). As the value is more, then the species composition in a particular infested fruit is maximum. Here, species composition is greater in *Zeugodacus tau* and least in *Bactrocera dorsalis*.

3.1.3.2 Species composition of fruit flies in Bottle gourd:

Table 10:Determination of species composition of tephritids recovered from bottle gourd.

Name of the Species	Species Composition (%)
Zeugodacus cucurbitae (Coq.)	48.2
Zeugodacus tau(Walker)	47.4
Bactrocera dorsalis (Hendel)	4.3

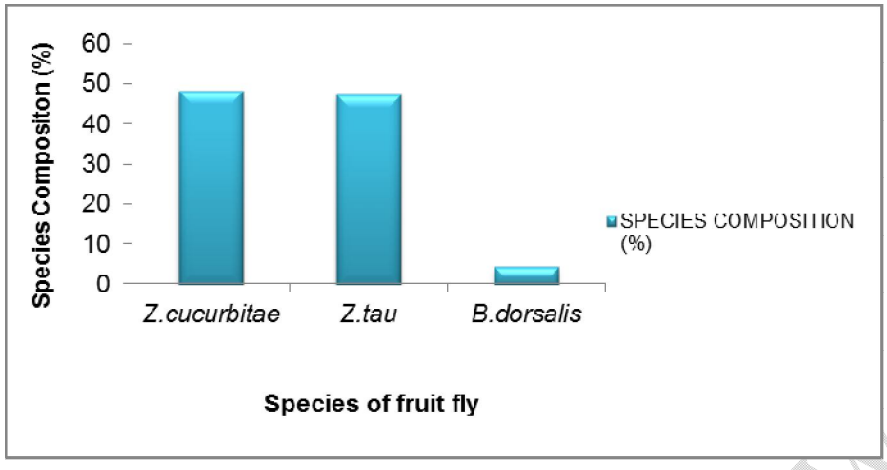

Fig. 10. Species Composition (%) inBottle Gourd

Through the research work and data presented in Table 10 and Fig.10. explains as species composition of tephritids recovered from bottle gourd infested fruit is determined in percent. From infested fruits of bottle gourd, *Zeugodacus cucurbitae* about 48.2% is recorded followed by *Zeugodacus tau* (47.4%) and *Bactrocera dorsalis* (4.3%). As the value is more, then the species composition in a particular infested fruit is maximum. Here, species composition is greater in *Zeugodacus cucurbitae* and least in *Bactrocera dorsalis*.

3.1.3.3 Species composition of fruit flies in Cucumber:

Table 11:Determination of species composition of tephritids recovered from cucumber.

Name of the Species	Species Composition (%)
Zeugodacus tau(Walker)	40.4
Zeugodacus cucurbitae (Coq.)	39.3
Bactrocera dorsalis (Hendel)	20.2

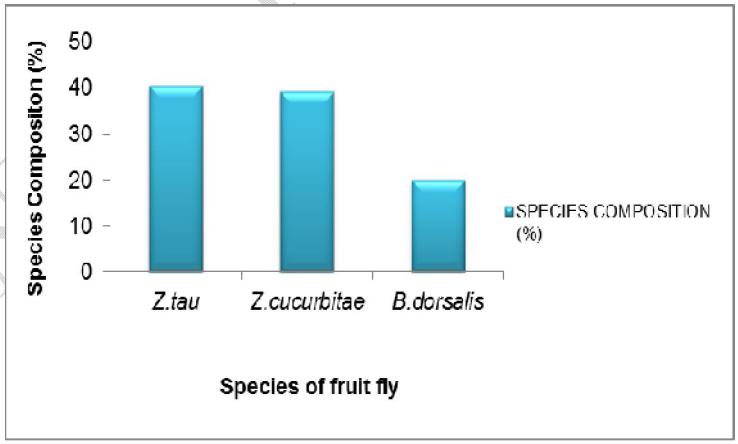

Fig. 11. Species Composition (%) inCucumber

Data recorded from experiment is represented in Table 11 and Fig.11 concludes as species composition of tephritids recovered from cucumber infested fruit is determined in percent. From infested fruits of cucumber, *Zeugodacus tau* about 40.4% is recorded followed by *Zeugodacus cucurbitae* (39.3%) and *Bactrocera dorsalis* (20.2%). As the value is more, then the species composition in a particular infested fruit is maximum. Here, species composition is greater in *Zeugodacus tau* and minimum in *Bactrocera dorsalis*.

3.1.3.4 Species composition of fruit flies in Ber:

Table 12:Determination of species composition of tephritids recovered from Ber.

Name of the Species	Species Composition (%)
Bactrocera dorsalis (Hendel)	35.4
Zeugodacus tau(Walker)	33.8
Zeugodacus cucurbitae (Coq.)	30.6

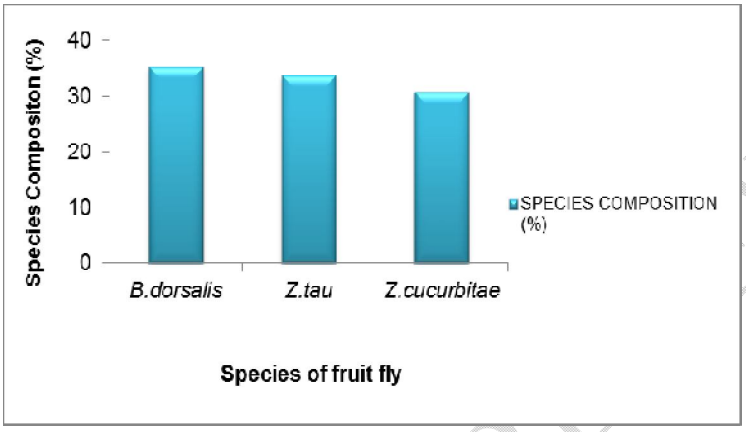

Fig. 12. Species Composition (%) inBer

Through the research work and data presented in Table 12 and Fig.12. explains as species composition of tephritids recovered from ber infested fruit is determined in percent. From infested fruits of ber, *Bactrocera dorsalis* about 35.4% is recorded followed by *Zeugodacus tau* (33.8%) and *Zeugodacus cucurbitae* (30.6%). As the value is more, then the species composition in a particular infested fruit is extreme. Here, species composition is greater in *Bactrocera dorsalis* and least in *Zeugodacus cucurbitae*.

3.1.3.5 Species composition of fruit flies in Citrus:

Table 13:Determination of species composition of tephritids recovered from Citrus.

Name of the Species	Species Composition (%)
Bactrocera dorsalis (Hendel)	55.7
Bactrocera minax (Enderlein)	44.2

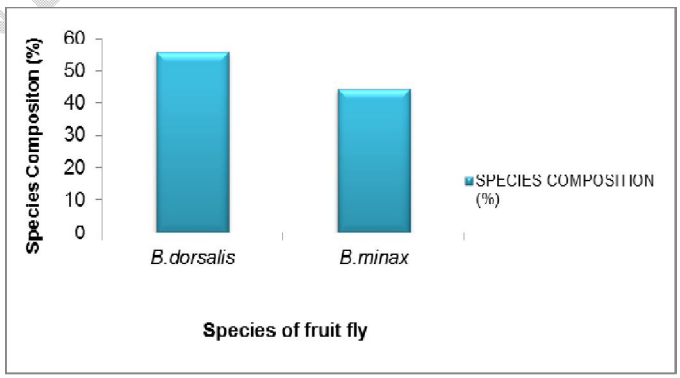

Fig. 13. Species Composition (%) inCitrus

Data recorded from research work and is represented in Table 13 and Fig.13. describes as species composition of tephritids recovered from citrus infested fruit is determined in percent. From infested fruits of citrus, *Bactrocera dorsalis* about 55.7% is recorded followed by

Bactrocera minax (44.2%) As the value is more, then the species composition in a particular infested fruit is greater. Here, species composition is greater in *Bactrocera dorsalis* and minimum recorded in *Bactrocera minax*.

3.1.4.Relative abundance of fruit flies collected from traps:

Abundance of individuals in a species in different fruits and vegetables were documented (Kishore *et al*.,2018). 100 individuals were selected randomly from each crop and recorded the abundance. It is expressed in percent and if the value is more, then the abundance of that species is more.Observations were presented in the Tables and Figures.

3.1.4.1Relative abundance of fruit flies in Pumpkin:

Table 14: Determination of relative abundance of tephritids in Pumpkin collected by traps.

Name of the Species	Relative Abundance (%)
Zeugodacus tau (Walker)	33
Bactrocera dorsalis (Hendel)	23
Zeugodacus cucurbitae (Coq.)	15
Bactrocera rubigina (Wang and Zhao)	9
Zeugodacus caudatus (Fabricus)	7
Bactrocera zonata (Saunders)	6
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	5
Dacus longicornis (Weidemann)	2

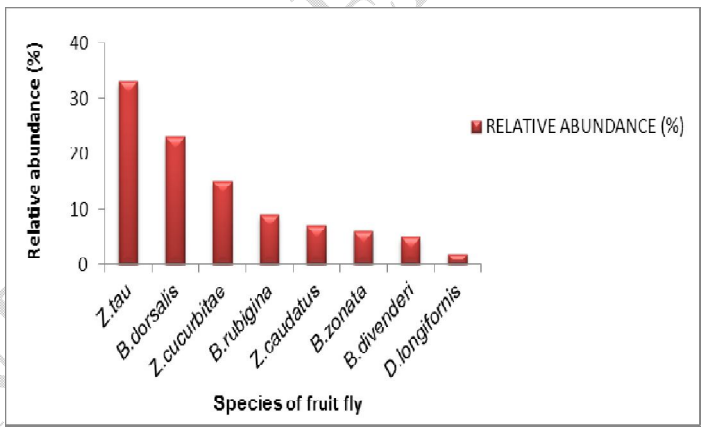

Fig. 14. Relative Abundance (%) in Pumpkin

Overall information from an experiment Table 14 and Fig.14. declared as relative abundance in pumpkin is determined in percent. About 100 fruit flies randomly taken and separated the species by this relative abundance is estimated. In pumpkin, *Zeugodacus tau* documented about 33% followed by *Bactrocera dorsalis* (23%), *Zeugodacus cucurbitae* (15%), *Bactrocera rubigina* (9%), *Zeugodacus caudatus* (7%), *Bactrocera zonata* (6%), *Bactrocera divenderi*(5%) and *Dacus longicornis* (2%) As the percentage is maximum then the relative abundance of that particular species is more. So, relative abundance of *Zeugodacustau* in pumpkin is more and least documented is *Dacus longicornis*.

3.1.4.2 Relative abundance of fruit flies in Bottle gourd

Table 15:Determination of relative abundance of tephritids in Bottle gourd collected by traps.

Name of the Species	Relative Abundance (%)
Zeugodacus tau (Walker)	29
Zeugodacus cucurbitae (Coq.)	23
Bactrocera dorsalis (Hendel)	15
Bactrocera rubigina (Wang and Zhao)	11
Bactrocera zonata (Saunders)	9
Zeugodacus caudatus(Fabricus)	6
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	4
Dacus longicornis (Weidemann)	3

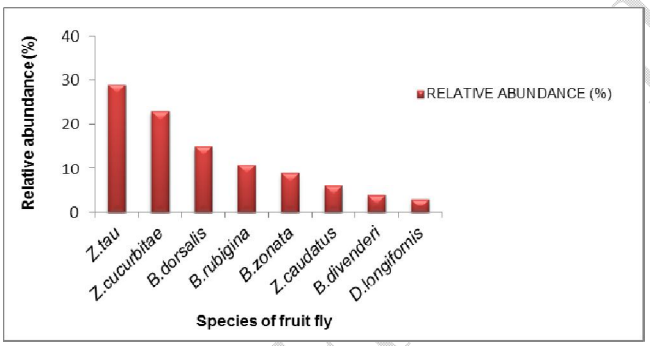

Fig. 15. Relative Abundance (%) in Bottle Gourd

From the Table 15 and Fig.15. based on data of an experiment performed concluded as relative abundance in bottle gourd is determined in percent. About 100 fruit flies randomly taken and separated the species by this relative abundance is estimated. In bottle gourd, *Zeugodacus tau* documented about 29% followed by *Zeugodacus cucurbitae* (23%), *Bactrocera dorsalis* (15%), *Bactrocera rubigina* (11%), *Bactrocera zonata* (9%), *Zeugodacus caudatus*(6%), *Bactrocera divenderi*(4%) and *Dacus longicornis* (3%) As the percentage is maximum then the relative abundance of that particular species is more. So, relative abundance of *Zeugodacus tau* in bottle gourd is more and least documented is *Dacus longicornis*.

3.1.4.3 Relative abundance of fruit flies in Mango:

Table 16:Determination of relative abundance of tephritids in Mango collected by traps.

Name of the Species	Relative Abundance (%)
Bactrocera dorsalis (Hendel)	39
Zeugodacus tau(Walker)	30
Zeugodacus cucurbitae (Coq.)	12
Zeugodacus caudatus(Fabricus)	9
Bactrocera rubigina (Wang and Zhao)	5
Bactrocera zonata (Saunders)	3
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	2

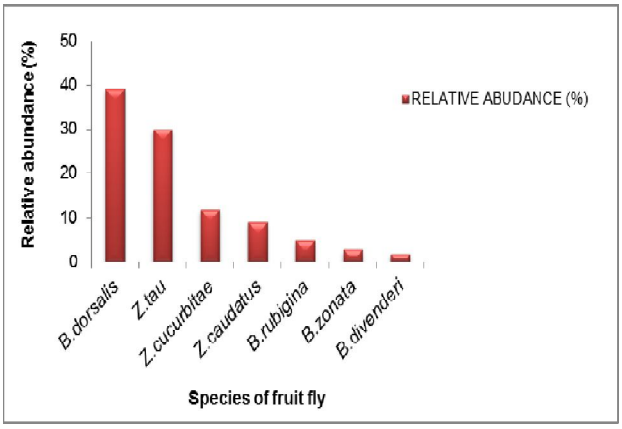

Fig. 16. Relative Abundance (%) in Mango

All-encompassing information from a research is represented in Table 16 and Fig.16. shown as relative abundance in mango is determined in percent. About 100 fruit flies randomly taken and separated the species by this relative abundance is estimated. In mango, *Bactrocera dorsalis* recorded about 39% followed by *Zeugodacus tau* (30%), *Zeugodacus cucurbitae* (12%), *Zeugodacuscaudatus*(9%), *Bactrocera rubigina* (5%), *Bactrocera zonata* (3%), *Bactrocera divenderi*(2%). As the percentage is more, then the relative abundance of that particular species is greater. So, relative abundance of *Bactroceradorsalis* in mango is extreme and least documented is *Bactrocera divenderi.*

3.1.4.4 Relative abundance of fruit flies in Guava:

Table 17:Determination of relative abundance of tephritids in Guava collected by traps.

Name of the Species	Relative Abundance (%)
Bactrocera dorsalis (Hendel)	32
Zeugodacus tau(Walker)	19
Bactrocera rubigina (Wang and Zhao)	13
Bactrocera zonata (Saunders)	12
Zeugodacus caudatus(Fabricus)	10
Zeugodacus cucurbitae (Coq.)	8
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	6

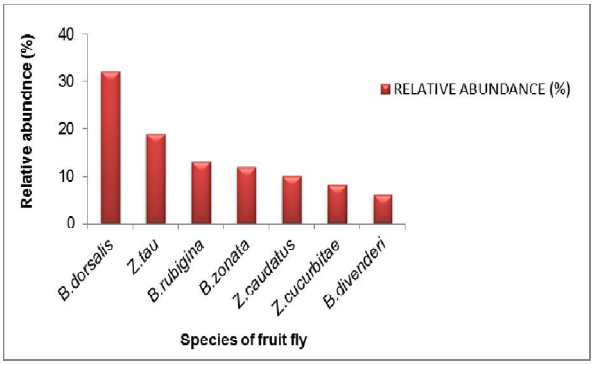

Fig. 17. Relative Abundance (%) in Guava

After an investigation, data is represented in Table 17 and Fig.17. shown as relative abundance in guava is determined in percent. About 100 fruit flies randomly taken and

separated the species by this relative abundance is estimated. In guava, *Bactrocera dorsalis* documented about 32% followed by *Zeugodacus tau* (19%), *Bactrocera rubigina* (13%), *Bactrocerazonata* (12%), *Zeugodacus caudatus*(10%), *Zeugodacus cucurbitae* (8%), *Bactrocera divenderi*(6%). As the percentage is maximum then the relative abundance of that particular species is greater. So, relative abundance of *Bactroceradorsalis* in guava is maximum and minimum is *Bactrocera divenderi*.

3.1.4.5 Relative abundance of fruit flies in Ber:

Table 18:Determination of relative abundance of tephritids in Ber collected by traps.

Name of the Species	Relative Abundance (%)
Bactrocera dorsalis (Hendel)	35
Zeugodacus tau(Walker)	22
Zeugodacus cucurbitae (Coq.)	18
Zeugodacus caudatus(Fabricus)	9
Bactrocera zonata (Saunders)	8
Bactrocera rubigina (Wang and Zhao)	5
Bactrocera divenderi (Maneesh, Hancock and Prabhakar)	3

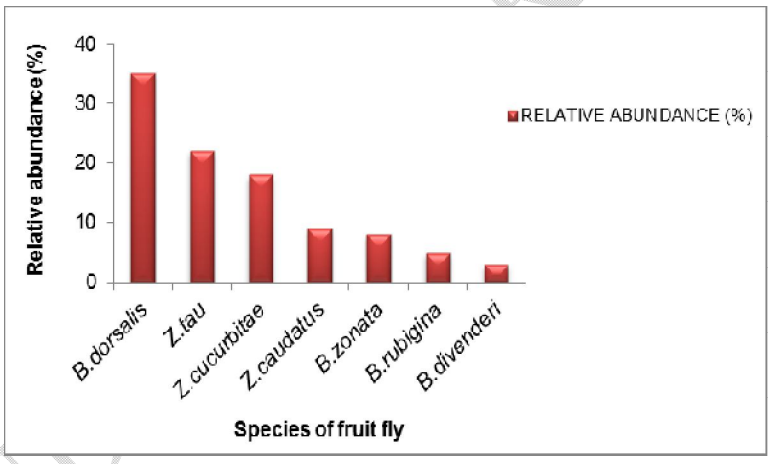

Fig. 18. Relative Abundance (%) in Ber

Data from an experiment Table 18 and Fig.18. reported as relative abundance in ber is determined in percent. About 100 fruit flies randomly taken and separated the species by this relative abundance is estimated. In ber, *Bactrocera dorsalis* recorded about 35% followed by *Zeugodacus tau* (22%), *Zeugodacus cucurbitae* (18%), *Zeugodacus caudatus* (9%), *Bactrocera zonata* (8%), *Bactrocera rubigina* (5%) *Bactrocera divenderi*(3%) As the percentage is greater, then the relative abundance of that particular species is more. So, relative abundance of *Bactroceradorsalis* in ber is more and least recorded is *Bactrocera divenderi.*

3.1.4.6 Relative abundance of fruit flies in Citrus:

Table 19:Determination of relative abundance of tephritids in Citrus collected by traps.

Name of the Species	Relative Abundance (%)

Bactrocera dorsalis (Hendel)	43
Zeugodacus tau(Walker)	24
Zeugodacus cucurbitae (Coq.)	20
Zeugodacus caudatus(Fabricus)	8
Bactrocera zonata (Saunders)	5

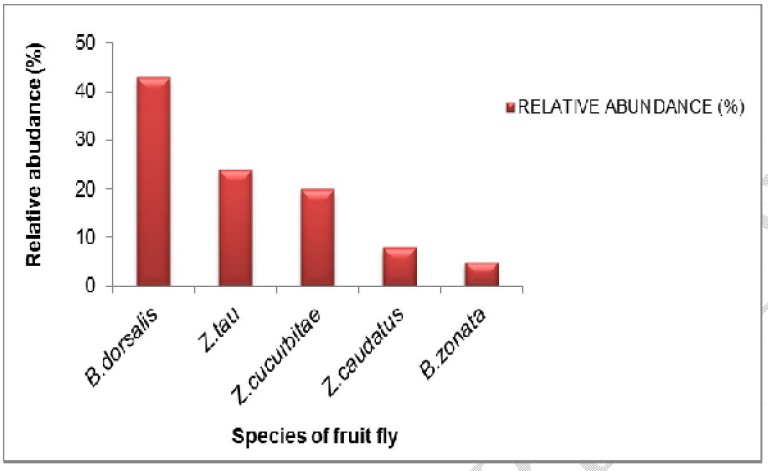

Fig. 19. Relative Abundance (%) in Citrus

Inclusive information from a research is represented in Table 19 and Fig.19. shown as relative abundance in citrus is determined in percent. About 100 fruit flies randomly taken and separated the species by this relative abundance is estimated. In citrus, *Bactrocera dorsalis* recorded about 43% followed by *Zeugodacus tau* (24%), *Zeugodacuscucurbitae* (20%), *Zeugodacus caudatus*(8%), *Bactrocera zonata* (5%). As the percentage is more, then the species composition of that particular species is greater. So, relative abundance of *Bactroceradorsalis* in citrus is maximum and least recorded is *Bactrocera zonata*.

3.1.5Relative abundance of fruit flies recovered from infested fruits:

Abundance of individuals in a species recovered from infested fruits were documented (Kishore *et al*.,2018). It is expressed in percent and the abundance of species is more if the value is more. Observations were presented in the Tables and Figures.

3.1.5.1 Relative abundance of fruit flies in Pumpkin:

Table 20:Determination of relative abundance of tephritids recovered from pumpkin infested fruit

Name of the Species	Relative Abundance (%)
Zeugodacus tau(Walker)	21
Zeugodacus cucurbitae (Coq.)	18
Bactrocera dorsalis (Hendel)	11

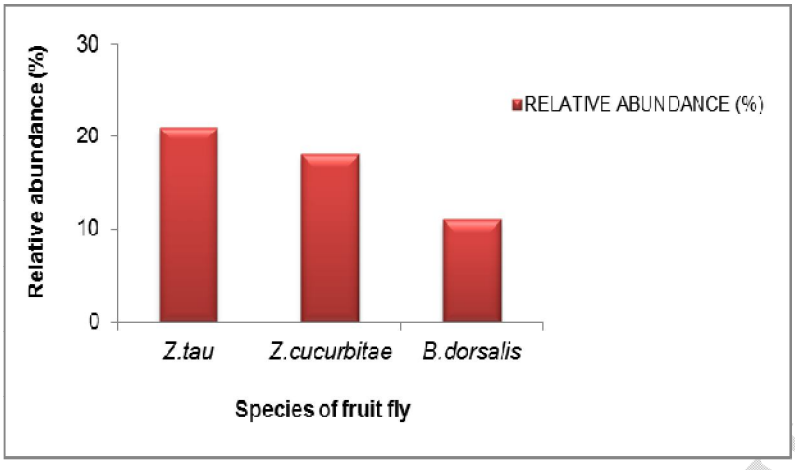

Fig. 20. Relative Abundance (%) in Pumpkin

Through the experiment done and result represented in Table 20 and Fig.20.concludes as relative abundance of tephritids recovered from pumpkin infested fruit is determined in percent. About 50 fruit flies are randomly collected and segregated different species by this relative abundance is estimated. From infested fruits of pumpkin, *Zeugodacus tau* about 21% is recorded followed by *Zeugodacus cucurbitae* (18%) and *Bactrocera dorsalis* (11%). As the value is more, then the relative abundance in a particular infested fruit is maximum. Here, relative abundance is greater in *Zeugodacus tau* and least in *Bactrocera dorsalis*.

3.1.5.2 Relative abundance of fruit flies in Bottle gourd:

Table 21:Determination of relative abundance of tephritids recovered from Bottle gourd infested fruit

Name of the Species	Relative Abundance (%)
Zeugodacus cucurbitae (Coq.)	24
Zeugodacus tau(Walker)	21
Bactrocera dorsalis (Hendel)	5

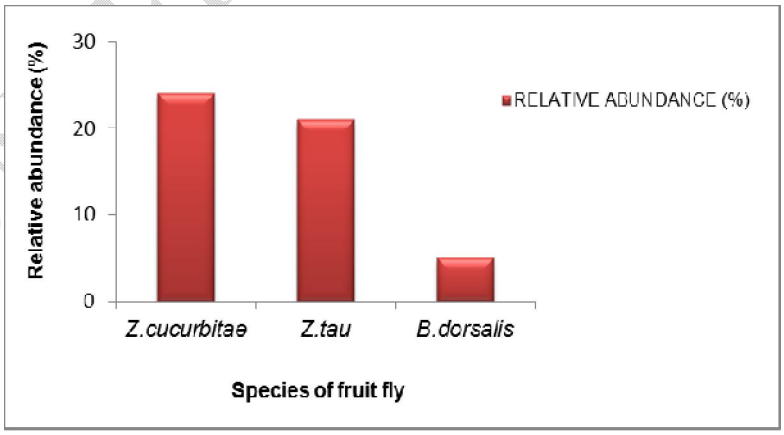

Fig. 21. Relative Abundance (%) in Bottle gourd

Through the research work and data presented in Table 21 and Fig.21. explains as relative abundance of tephritids recovered from bottle gourd infested fruit is determined in percent. About 50 fruit flies are randomly collected and segregated different species by this relative abundance is estimated. From infested fruits of bottle gourd, *Zeugodacus cucurbitae* about 24% is recorded followed by *Zeugodacus tau* (21%) and *Bactrocera dorsalis* (5%). As the

value is more, then the relative abundance in a particular infested fruit is maximum. Here, relative abundance is greater in *Zeugodacus cucurbitae* and least documentd in *Bactrocera dorsalis*.

3.1.5.3 Relative abundance of fruit flies in Cucumber:

Table 22:Determination of relative abundance of tephritids in recovered from Cucumber infested fruit

Name of the Species	Relative Abundance (%)
Zeugodacus tau(Walker)	22
Zeugodacus cucurbitae (Coq.)	18
Bactrocera dorsalis (Hendel)	10

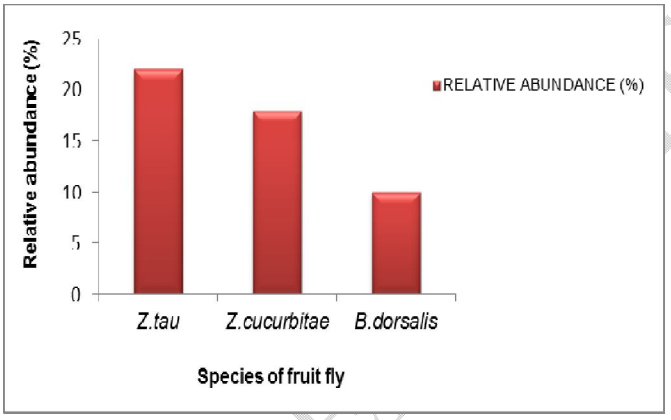

Fig. 22. Relative Abundance (%) in Cucumber

Data recorded from experiment is represented in Table 22 and Fig.22. concludes as relative abundance of tephritids recovered from cucumber infested fruit is determined in percent. About 50 fruit flies are randomly collected and segregated different species by this relative abundance is estimated.From infested fruits of cucumber, *Zeugodacus tau* about 22% is recorded followed by *Zeugodacus cucurbitae* (18%) and *Bactrocera dorsalis* (10%). As the value is more, then the relative abundance in a particular infested fruit is maximum. Here, relative abundance is greater in *Zeugodacus tau* and minimum in *Bactrocera dorsalis*.

3.1.5.4Relative abundance of fruit flies in Ber:

Table 23:Determination of relative abundance of tephritids recovered from Ber infested fruit.

Name of the Species	Relative Abundance (%)
Bactrocera dorsalis (Hendel)	20
Zeugodacus tau(Walker)	19
Zeugodacus cucurbitae (Coq.)	11

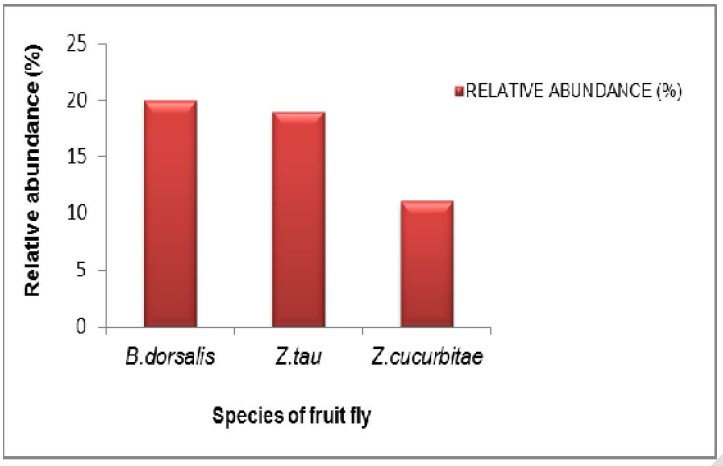

Fig. 23. Relative Abundance (%) in Ber

Through the research work and data presented in Table 23 and Fig.23. explains as relative abundance of tephritids recovered from ber infested fruit is determined in percent. About 50 fruit flies are randomly collected and segregated different species by this relative abundance is estimated.From infested fruits of ber, *Bactrocera dorsalis* about20% is recorded followed by *Zeugodacus tau* (19%) and *Zeugodacus cucurbitae* (11%). As the value is more, then the relative abundance in a particular infested fruit is extreme. Here, relative abundance is greater in *Bactrocera dorsalis* and least in *Zeugodacus cucurbitae*.

3.1.5.5 Relative abundance of fruit flies in Citrus:

Table 24:Determination of relative abundance of tephritids recovered from Citrus infested fruit

Name of the Species	Relative Abundance (%)
Bactrocera dorsalis (Hendel)	28
Bactrocera minax (Enderlein)	22

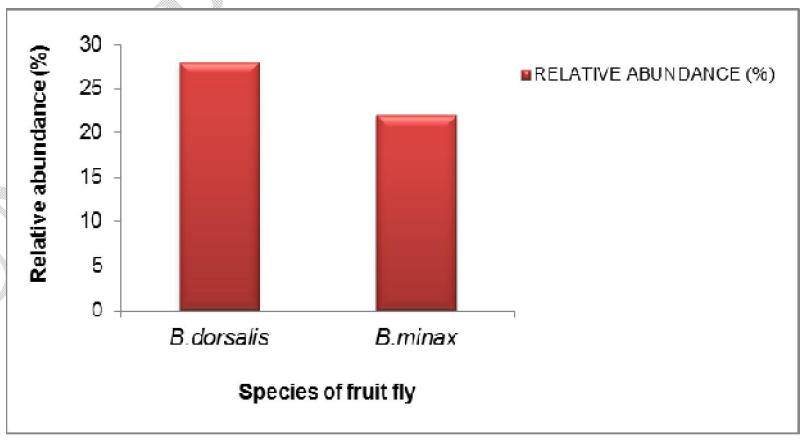

Fig. 24. Relative Abundance (%) in Citrus

Data recorded from research work and is represented in Table 24 and Fig.24. describes as relative abundance of tephritids recovered from citrus infested fruit is determined in percent. About 50 fruit flies are randomly collected and segregated different species by this relative abundance is estimated.From infested fruits of citrus, *Bactrocera dorsalis* about 28% is documented followed by *Bactrocera minax* (22%) As the value is maximum then the relative abundance in a particular infested fruit is greater. Here, relative abundance is greater in *Bactrocera dorsalis* and minimum recorded in *Bactrocera minax*.

3.1.6Species evenness of tephritids determined in different fruits and vegetables:

3.1.6.1Species evenness of fruit flies collected from traps:

Evenness of species in different fields were documented (Pielou 1966) and the species evenness is maximum when the value obtained is one and no species evenness observed when the value is zero. Observations were presented in the Table 25 and Fig.25.

Table 25: Estimation of Species evenness of tephritids collected by traps.

Field taken into consideration	Species Evenness (J)
Citrus	0.901
Ber	0.793
Pumpkin	0.792
Guava	0.761
Mango	0.726
Bottle gourd	0.701

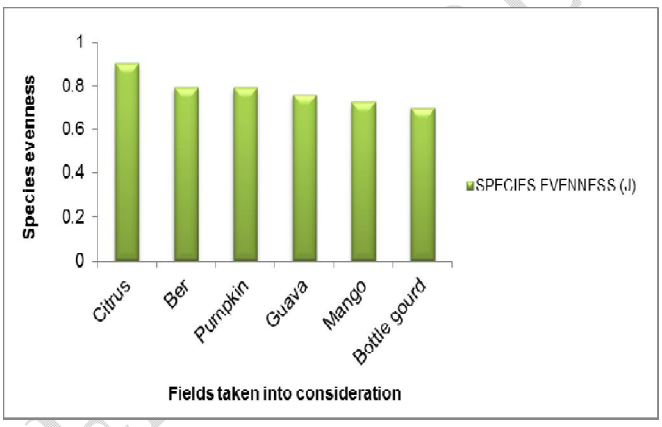

Fig. 25. Species Evenness (J) in different fields

After the experiment conducted, the data is recorded in Table 25 and Fig.25. concludes that species evenness in different fields such as pumpkin, bottle gourd, mango, ber, guava and citrus is determined. In citrus species evenness is 0.901 followed by in ber 'J' is 0.793, in pumpkin 'J' is 0.792, in guava 'J' is 0.761, in mango 'J' is 0.726 and in bottle gourd 'J' is 0.701. As the value obtained is 1 then there is species evenness in particular location. Here, Species evenness or equitability is seen in citrus as near to one and no evenness in ber, pumpkin, guava, mango and bottle gourd as the value is not equal to one.

3.1.6.2Species evenness of fruit flies recovered from infested fruits:

Evenness of species recovered from infested fruits were documented (Pielou 1966) and If the value obtained is one then there is species evenness and no species evenness observed when the value is zero. Observations were presented in the Table 26 and Fig.26.

Table 26:Estimation of Species evenness of tephritids recovered from infested fruits.

Field taken into consideration	Species Evenness (J)
Ber	1.004
Citrus	0.988
Cucumber	0.960
Bottle gourd	0.769
Pumpkin	0.751

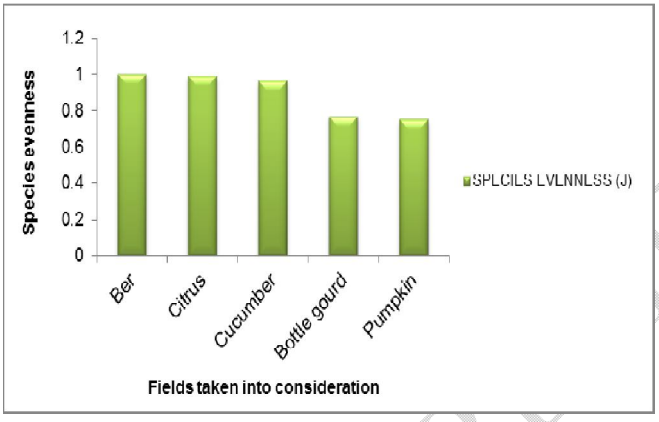

Fig. 26. Species Evenness (J) in Infested Fruits

After the experiment conducted, the data is recorded in Table 26 and Fig.26. concludes that species evenness from recovered infested fruits such as pumpkin, bottle gourd, cucumber, ber and citrus is determined. In ber species evenness is 1.004 followed by in citrus 'J' is 0.988, in cucumber 'J' is 0.960, in bottle gourd 'J' is 0.769 and in pumpkin 'J' is 0.751. As the value obtained is 1 then there is species evenness in particular location. Here, species evenness or equitability is seen in ber as it is equal to one and no species evenness or equitability in citrus, pumpkin, cucumber and bottle gourd.

4. CONCLUSION

Among selected fields, Species richness is maximum in citrus and minimum in mango and ber.From the recovery of fruits, Species richness is maximum in ber and least in pumpkin.Species composition of *Z. tau* is maximum and *D. longicornisis* minimum in pumpkin and bottle gourd and *B. dorsalis* is maximum and *B. divenderi* is minimum in mango, ber and guava. In citrus *B. dorsalis* is maximum and *B. zonata* is minimum. Species composition of Z. tau from recovery of pumpkin and cucumber, *Z. cucurbitae* from recovery of bottle gourd and *B. dorsalis* from recovery of ber and citrus are maximum. In pumpkin, cucumber and bottle gourd *B. dorsalis* is minimum and in ber *Z. cucurbitae* is minimum and in citrus *B. minax* is minimum.Relative abundance of *Z. tau* is greater and *D. longicornis* is least in pumpkin and bottle gourd, *B. dorsalis* is greater and *B. divenderi*is least in mango, guava and ber. In citrus *B. dorsalis* is maximum and *B. zonata* is minimum.From the recovery of fruits, relative abundance of *Z. tau* in pumpkin and cucumber, *Z. cucurbitae* in bottle gourd, *B. dorsalis* in ber and citrus is maximum. In pumpkin, cucumber, bottle gourd *B. dorsalis* is minimum and *Z. cucurbitae* and *B. minax* is minimum in ber and citrus respectively. Species evenness or equitability is observed in citrus and no evenness in pumpkin, bottle gourd, ber, mango and citrus.From the infested fruits, Species evenness or equitability is observed in ber and no evenness in citrus, bottle gourd, pumpkin and cucumber.Thus, from the aforementioned summarised findings of the present investigation it may be inferred that a good number of tephritid species are available in the agro-ecosystem of northern tract of West Bengal. In cucurbitaceous vegetables the predominant tephritid species found to infest is *Z.tau*. Relative abundance of a number of species differed from vegetation to vegetation and type of para-pheromone used for collection. Other population indices are also indicating

that trend. Hence, for efficient management of tephritid flies, use of pheromone traps may be accommodated depending on the crop on which the tephritid flies caused infestation on fruits.

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