MORPHOMETRIC DETECTION OF DIFFERENT FRUIT FLY COLLECTED FROM DIFFERENT MANGO GROWING REGIONS OF BANGLADESH

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BY

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CERTIFICATE

*This is to certify that thesis entitled, "**MORPHOMETRIC DETECTION OF DIFFERENT FRUIT FLY COLLECTED FROM DIFFERENT MANGO GROWING REGIONS OF BANGLADESH**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in ENTOMOLOGY**, embodies the result of a piece of bona-fide research work carried out by **JUGOL KISHOR ROY**, Registration no. **14-06150** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2021
Place: Dhaka, Bangladesh

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The Author
June, 2021

Dedicated

To

My beloved

Parents

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ABSTRACT

The experiment was conducted at the farmer's orchard of Dinajpur and Thakurgaon districts during the period from April to June 2020 for morphometric detection of mango fruit fly collected from different mango growing regions of Bangladesh. Five locations of Dinajpur and Thakurgaon districts was selected and surveyed for collection of Mango fruit fly. The samples were used in detecting the morphometric similarities/dissimilarities at the Entomology Laboratory of Sher-e-Bangla Agricultural University for further testing. The location for collection of the samples in Dinajpur were Biral, Bochagonj, Kaharole, Fulbari and Khanshama and in Thakurgaon were Sadar, Pirganj, Ranisankail, Baliadangi and Haripur. Data were collected on wing, head, thorax and abdomen of fruit flies and further study was ensured. The fruit fly samples were collected at different location of Dinajpur and Thakurgaon districts of Bangladesh using pheromone trap (methyl-eugenol) at mango field. Four different species were identified using stereomicroscope. The name of the fruit flies were Oriental fruit fly (*Bactrocera dorsalis*), melon fruit fly (*Zeugodacus cucurbitae*), pumpkin fruit fly (*Zeugodacus tau*) and peach fruit fly (*Bactrocera zonata*). 85.41% of oriental fruit flies were found in pheromone trap which was the highest number of fruit fly in mango field. However, 2.44 % of peach fruit fly were identified which was the lowest number. Moreover, 8.81% and 3.34% percent of melon fruit fly and pumpkin fruit fly were collected from pheromone trap respectively. Therefore, numbers of oriental fruit fly were highest compare to other fruit fly. The highest infestations were observed at Dinajpur district compared to Thakurgaon district in mango orchard. Dinajpur district Oriental fruit fly was larger compare to Thakurgaon district Oriental fruit flies were smaller. Therefore, Dinajpur district Melon fruit fly was prominent compare to other district and melon fruit fly were larger compare to Oriental fruit fly.

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LIST OF ABBREVIATIONS

Abbreviated form	Full form
%	Percentage
@	At the rate of
AEZ	Agro-Ecological Zone
Agril.	Agricultural
Agric.	Agriculture
Agron.	Agronomy
Annu.	Annual
Appl.	Applied
BBS	Bangladesh Bureau of Statistics
Biol.	Biology
Chem.	Chemistry
cm	Centi-meter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAP	Days After Planting
DAS	Days After Sowing
Dev.	Development
Ecol.	Ecology
eds.	Editors
Environ.	Environmental
et al.	et alia (and others)
etc.	et cetera (and other similar things)
Exptl.	Experimental
FAO	Food and Agricultural Organization
g	Gram (s)
Hortc.	Horticulture
i.e.	id est (that is)
J.	Journal
kg	Kilogram (s)
L.	Linnaeus
LSD	Least Significant Difference
M.S.	Master of Science
m2	Meter squares
mg	Milligram
MoP	Muriate of Potash
Nutr.	Nutrition
Physiol.	Physiological
Progress.	Progressive
Res.	Research
SAU	Sher-e-Bangla Agricultural University

LIST OF ABBREVIATIONS

Abbreviated form	Full form
Sci.	Science
Soc.	Society
SRDI	Soil Resources and Development Institute
t ha^{-1}	Ton per hectare
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	Variety
viz.	videlicet (L.), Namely
Vm	Vermicompost
μMol	Micromole

CHAPTER I

INTRODUCTION

Mango (*Mangifera indica* L.), a tropical and sub-tropical fruit, belongs to the family *Anacardiaceae*, which was originated in South Asia and has been in cultivation for more than 4000 years (Bose, 1985; Candole, 1984 and Mukherjee, 1949). It is originated in Asia particularly southern Asia and eastern India, then it spread to Africa and United State of America (Popenoe, 1920; Mukherjee, 1972 and Verheij, 1991). Mango is an important major fruit crop in the tropical s subtropical region of Asia (De Candolle, 1904; Purseglove, 1972 and Sial *et al.*, 2015). 38.67 million tons of mangoes were produced worldwide in 2010 (FAO, 2010). 76.49 % of the world's mango production came from Asia with India being the largest producer of 42.25 % of the world's mango production (FAO, 2012). Bangladesh is the 3rd highest country in mango production of Asia accounting as 19.80 % of global production in 2000 (Soe, 2008). At present, Bangladesh produces 242,000 tons of mango annually from 65 thousand hectares of land at the rate of 4.72 tons per hectare (BBS, 2015). In Bangladesh, mango ranks 1st in terms of area and 3rd in terms of production (BBS, 2018). This yield is much lower compared to that of our neighboring countries like India (8.95 t ha^{-1}) (Ghosh, 1998) and the Philippines (9.41 t ha^{-1}) (Espino and Javier, 1989). The production of mangoes has now been spread worldwide although the species and quality are quite different.

Mango is one of the favorite fruits in Bangladesh and has been repeatedly acclaimed as the 'King of Fruits' (Ahmed, 1994). Its plays a major role in local, national, regional and international markets (De Meyer, 1996). It has a unique position in respect of nutritional quality, taste, consumer's preference etc. among the fruits grown in Bangladesh (Ahmad, 1985). Mango is rich in several vitamins. Besides, mango contains appreciable quantity of iron, vit-C, carotene and soluble sugar. Moreover, it provides a lot of energy (as much as 74 kcal/100g edible portion) which is nearly equals the energy values of boiled rice of similar quantity by weight (Hossain, 1989). Although it grows well in all parts of Bangladesh, the grafted mango trees are concentrated in a few places in the north western region and seedling mangoes are grown in the southern and other parts of Bangladesh (Bhuyan, 1995). Bangladesh

Agricultural Research Institute (BARI) has already released 10 (ten) mango varieties with variable quality. In general, the cultivars are location specific and the commercial varieties of one region may not do so well when grown in other areas (Majumder *et al.*, 2001).

These crops represent an important part of the gastronomic culture for Bangladeshi people. A constantly growing population, rising of incomes and urbanization levels increase the demand of fruit and vegetables. To fill up the gap of this demand, better farming strategies are necessary. The presences of pests such as fruit flies constitute an obstacle in their production. Fruit flies belonging to the family Tephritidae (Order: Diptera) are considered as a very destructive group of insects that cause enormous economic losses in agriculture, especially in a wide variety of fruits, vegetables and flowers (Diamantidis *et al*., 2008). The total number of species within this family exceeds 4,000. Approximately 10% of them are serious pests distributed around the world in temperate, subtropical and tropical areas (Christenson and Foote, 1960 and Singh, 2003). In particular, two species belonging to this family are of great importance in Bangladesh, namely the Melon fly (*Bactrocera cucurbitae* (Coquillet)) and the Oriental fruit fly (*Bactrocera dorsalis*). In cucumber (*Cucumis sativus L*) and bitter gourd (*Momordica charantia*) field infestation problems caused by *B. cucurbitae* are very common in Bangladesh (Ramadan and Messing, 2003). Over 175 species of insects have been reported damaging mango trees (Nayar *et al.*, 1976 and Fletcher, 1970). The cost of losses due to infestation of fruit flies can be surprisingly high, there are examples where losses have been up to 100% in cucurbit species, caused by Melon fly (*Bactrocera cucurbitae*) (Dhillon *et al.*, 2005). Crop losses in mango (12-60%), guava (40-90%) and papaya (12-60%) have also been recorded by Allwood and Leblanc (1997).

Fruit fly is one of the most serious pests of mango fruit production in Bangladesh (Alam, 1969; Akhtaruzzaman *et al.*, 1999; Akhtaruzzaman *et al.*, 2000; Drew *et al.*, 2005; Vayssieres *et al.*, 2008 and Ekesi *et al.*, 2009).

In recent years, some taxonomists have reported on the Dacinae fruit fly fauna of countries such as India, Bangladesh and China around Myanmar (Kapoor, 1993; Leblanc *et al*., 2013, 2014; Fericia Kueh Tai Hui *et al*., 2013; Drew *et al*., 2007; Hardy, 1973; Liang *et al*., 1993; Tsuruta and White; 2001, Tsuruta, 1998). The major pests which affect the marketable fruit yields in mango in India are Tephritid fruit flies, which include *Bactrocera dorsalis* (Hendel) and *Bactrocera correcta* Bezzi, which are common in mango ecosystem (Nath and Bhushan, 2006).

There are four major genera of fruit fly Tephritidae such as *Bactrocera*, *Anastrepha*, *Ceratitis* and *Rhagoletis* (White and Elsonharris, 1992; Malacrida *et al.,* 2007). Over 75 species of the genus Bactrocera fruit flies were updated and *B. dorsalis* is serious destructive pest around the worldwide (Clarke *et al.,* 2005; Ekesi *et al.,* 2016; Wei *et al.,* 2017). *B. dorsalis* was a destructive polyphagous pest that has damaged more than 250 species of fruits and vegetables over the last decade (Lin *et al.,* 2004; Xie and Zhang, 2005; Li *et al.,* 2012; Chen *et al.,* 2015 Liu *et al.,* 2017). The guava fruit fly, *B. correcta* is also a destructive pest in Asia (Jaleel *et al.,* 2018; Zhang *et al.,* 2019). Thus, *Bactrocera* fruit flies are major key pests in tropical region of Asia. Nakahara *et al.* (2018) previously reported the seasonal occurrence information of serious plant quarantine pest species such as *B. correcta*, *B. dorsalis* and *B. cucurbiae*, this study summarizes all the species collected in the survey under the view of a fauna of the fruit flies, which is the first comprehensive report of fruit fly species occurring in mango orchards in West Bengal, India.

Female fruit flies lay eggs under the skin of the fruit, which hatch into larvae that feed in the decaying flesh of the crop. Infested fruits quickly rot and become inedible or drop off from the tree causing direct loss to the farmer. Besides the direct damage to the fruit, presence of fruit fly is associated with quarantine restrictions that are imposed by fruits and vegetable importing countries. Without control, direct damage has been reported from 30 to 100% depending on the fruit maturity stage, variety, location and season (Vayssieres *et al.*, 2009; Vayssieres *et al.,* 2008; De Meyer *et al.,* 2007 and Mwatawala *et al.*, 2006). Rahman (2005) reported 37.50 % infestation in mango due to fruit fly. The major portion of mango is damaged by these pests every year which reduce total production as well as market price of mango. The *Bactrocera dorsalis* complex of tropical fruit flies is one of the most important pest species complexes in world agriculture (Clarke *et al.*, 2005). Due to attack of mango fruit fly, a large amount of loss occurs through the country. So, if we can identify the variation of mango fruit fly occurs due to different reasons like mutation, resistance and adaptation in definite region, then effective management can be taken.

OBJECTIVES:

- To detect the number of fruit fly species infesting mango fruit and
- To identify the variation of mango fruit fly through morphometric method.

CHAPTER II

REVIEW OF LITERATURE

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae. Mango is indigenous to India. Cultivated in many tropical and subtropical regions and distributed widely in the world, mango is one of the most extensively exploited fruit for food, juice, flavor, fragrance and color. In several cultures, its fruit and leaves are ritually used as floral decorations at weddings, public celebrations and religious ceremonies (McGovern and LaWarre, 2001). Literatures cited below under the following headings and sub-headings reveal some information about the present study.

2.1 Origin and distribution of fruit fly

Fruit flies are distributed all over the world and infest a large number of host plants. It is considered to be the native of oriental, probably India and South East Asia and it was first discovered in the Yacyama Island of Japan in 1919 (Anon., 1987). However, the fruit fly is widely distributed in India, Bangladesh, Pakistan, Myanmar, Nepal, Malaysia, China, Philippines, Formosa (Taiwan), Japan, Indonesia, East Africa, Australia and Hawaiian Island (Atwal 1993 and Alam, 1966). It is also a serious pest in Mediterranean region (Andrewartha and Birch, 1960). Although, this pest is widely distributed but it does not occur in the UK, central Europe and continental USA (Mckinlay *et al*., 1992).

According to Kapoor (1993), the distribution of a particular species is limited perhaps due to physical, climatic and gross vegetational factors, but most likely due to host specificity. Such species may become widely distributed when their host plants are widespread, either naturally or cultivation by man. Two of the world’s most damaging Tephritids, *Bactrocera dorsalis* and *Bactrocera cucurbitae*, are widely distributed in Malaysia and other South East Asian countries (Vijaysegaran, 1987). Gapud (1993) has cited references of five species of fruit fly in Bangladesh e.g., *B. brevistylus* (melon fruit fly), *Bactrocera caudatus* (fruit fly) (strumeta), *B. cucurbitae* (melon fly), *B. dorsalis* Hendel (mango fruit fly) and *B. zonatus* (zonata fruit fly).

2.1.1 Nomenclature

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Diptera

Family: Tephritidae

Genus: *Bactrocera*

Species: *Bactrocera spp.*

2.2 Host range and economic importance of fruit fly

Many fruit fly species do serious damage to vegetables, oil-seeds, fruits and ornamental plants. In Bangladesh, Alam (1962) recorded ten cucurbit vegetables as the host of fruit fly. Tomato, green pepper, papaya, cauliflower, mango, guava, citrus, near. fig and peaches are also infested by fruit fly (Atwal, 1993 and Anon., 1987).

Kabir *et al*. (1991) reviewed that sixteen species of plants act as the host of fruit flies. Batra (1953) listed as many as 70 hosts of fruit fly species whereas Christenson and Foote (1960) reported more than 80 kinds of vegetables and fruits as the hosts.

According to Narayanan and Batra (1960), different species of fruit fly attack a wide variety of fruits and vegetables such as mango, guava, loquat, plum, peach, apple, quince, persimmon, banana, pomegranate, jujube, sweet lime, orange, chilies, jack fruit, carambola, papaya, avocado, bread fruit, coffees, berries, passion fruit, star apple, Spanish pepper, cucurbit fruit, cherries, black berry, grapes etc.

In West Africa and Côte d'Ivoire, in particular, mangoes are heavily attacked by an exotic, highly invasive species oriental fruit fly *Bactrocera dorsalis* (COLEACP, 2007; Duyck *et al*., 2007).

Bactrocera invadens is an emerging polyphagous fruit fly pest and in Africa it has been reported to attack over 43 fruit species from 23 families with mango being one of the most preferred cultivated host (Ekesi and Billah 2007; Rwomushana *et al.* 2008; Mwatawala *et al.* 2009; Goergen *et al.* 2011). Direct damage to mango due to *B. invadens* has been reported to range from 30–80% depending on the cultivar, locality and season (Ekesi *et al.*, 2006; Rwomushana *et al.* 2008; Vayssie`res *et al.* 2009). *Bactrocera invadens* is believed to belong to the *B. dorsalis* (Hendel) complex of tropical fruit flies (Drew *et al.* 2005). This complex comprises of more than 75 species largely endemic to South-East Asia (Drew and Hancock, 1994) with undescribed species remaining in collections (Lawson *et al.* 2003). Indeed, the *B. dorsalis* complex of fruit fly species appear to be evolving rapidly demanding the need for closer assessment of their taxonomic identity through morphometric and genetic analysis. For example, Drew *et al.* (2005) depicted different thoracic colourations of *B. invadens* that are morphotypes of the same pest but that has complicated the taxonomic identity of this pest. Detail review of the *B. dorsalis* complex by Drew and Hancock (1994) has led to considerable debate over species, and a number of published works has aimed at defining the limits of some species populations [Armstrong and Cameron (2000); Muraji and Nakahara (2002); Nakahara *et al.*, 2001; Clarke *et al.*, 2005). A study by Tan *et al.* (2010) compared the profiles of phenylpropanoid metabolites of four Bactrocera species from the B. dorsalis complex, that includes *B. dorsalis s.s*., *B. invadens*, *B. correcta* and *B. zonata* and revealed that different profiles of phenylpropanoid ingredients in the rectal glands can be used for identification of these four species. Other studies on identification of the *B. dorsalis* complex by Schutze *et al.* (2011) used geometric morphometric analysis of wing size and shape to discriminate species within this complex. However, recent observations by Drew *et al.* (2008) emphasized the need to continue research on this complex to provide validity or otherwise, for all species in the complex, for both economic reasons and for refining the systematics of the Subfamily Dacinae.

Anastrepha obliqua (West Indian fruit fly) is one of the biggest limiting factors of mango production in Colombia; where mango is the second most important fruit product based on its planting area and it is cultured at low altitudes throughout the country (MADR, 2006; Sosa *et al.*, 2011); and therefore, the development of sustainable management systems has become a priority. This species of fruit fly is widely distributed at altitudes less than 1500 m, following the distribution of mango and the species of *Spondias*, which are its main hosts (Castañeda *et al.* 2010). Norrbom (2004) listed 104 species within 27 host plant families for *A. obliqua* (West Indian fruit fly); however, the plant species most affected by this pest are mango (*Mangifera indica*) and *Spondias* in Mexico (Orozco-Dávila *et al.* 2014), Colombia (Nuñez, 1981; Mangan *et al.* 2011), the southern Caribbean (Mangan *et al.* 2011) and Brazil (Zucchi 2000).

2.3 Biology of mango fruit fly

2.3.1 Eggs

Mango fruit fly eggs average about 1.17 mm long and 0.21 mm wide, which is slightly smaller than melon fly. The female may puncture fruit and deposit her eggs, or she may take advantage of cracks or other wounds, including the ovipositor punctures of other flies. Eggs may be deposited at a depth of 5-6 mm in soft fruit, whereas they may be very near the surface in hard fruit. The upper and lower-developmental thresholds for eggs are estimated at 38°C and 12°C, respectively. The average time for egg hatching is 1.6 days (Vargas *et al*. 1984) but hatching may be extended up to 20 days in cold weather.

2.3.2 Larvae

Fruit fly larvae are typical in form of tephritid fruit flies, cylindrical and broad posteriorly and tapering to point at the anterior end. There are three instars; all are whitish in color. The first instar ranges in size from about 1.20–2.30 mm, whereas the second ranges from 2.50–5.70 mm and third instar ranges from 7.0–11.0 mm. The upper and lower-developmental thresholds for larvae are estimated at 34°C and 11°C, respectively. Larval development generally requires about 7.8 days, though its development time can range from 6 to 35 days.

According to Renjhan (1949); Hollingsworth *et al*. (1997) from their separate research works, the larval period lasts from 6 to 11 days, with each stage lasting 2 or more days. Duration of larval development is strongly affected by host. The larval period lasts for 3 to 21 days, depending on temperature and the host.

Mature attacked fruits develop a water-soaked appearance (Calcagno *et al*., 2002). Young fruits become distorted and usually drop. The larval tunnels provide entry points for bacteria and fungi that cause the fruit to rot (Collins *et al.*, 2009). These maggots also attack young seedlings, succulent tap roots, stems and buds of host plants such as mango, guava, cucumber, custard apple and others (Weldon *et al.*, 2008). The full-grown larvae come out of the fruit by making one or two exit holes for pupation in the soil. The larvae pupate in the soil at a depth of 0.5 to 15 cm. The depth up to which the larvae move in the soil for pupation, and survival depend on soil texture and moisture (Jackson *et al.,* 1998).

2.3.3 Pupae

Mature larvae leave infested fruit and enter the soil, usually at the base of affected trees, to pupate. The puparia are 3.80–5.20 mm long and vary in color from tan to brownish-yellow. Pupal development requires about 10.3 days. Narayanan and Batra (1960) recorded that in general, the pupal period lasts for 6 to 9 days during the rainy season, and 15 days during the winter.

2.3.4 Adults

The adult fruit fly has a yellow to orange abdomen marked with a black "T". The thorax is predominantly black but bears two yellow stripes laterally. Oriental fruit fly lacks cross bands on its wings, and therefore is easily differentiated from melon fly. The adult of *B. dorsalis*, which is noticeably larger than a house fly, has a body length of about 8.0 mm; the wing is about 7.30 mm in length and is mostly hyaline. After adults emerge, a period of 6–12 days normally elapses before oviposition can occur. Copulation persists for 2–12 h. Males expel pheromone in a visible form resembling smoke (Anwar *et al.* 1982), similar to pheromone production by melon fly. Mating occurs at dusk in aggregations called "leks". Mating normally occurs at 4–5-day intervals. The adults continue to produce eggs for about two months. The female oriental fruit fly is more fecund than the related tephritids melon fly and Mediterranean fruit fly, and she produces an average of over 1400 eggs per female during a life span of about 80 days (Vargas *et al*. 1984). The oviposition rate is reported to be about 130 eggs per day.

The ovipositor is very slender and sharply pointed. Keys for distinguishing all life stages of these species were provided (Bustos *et al*. 2004, Follett and Armstrong 2004, White and Elson-Harris 1992). Oriental fruit fly can complete a generation in about 30 days. In tropical climates, many overlapping generations per year are reported. Fruit fly abundance typically coincides with availability of ripening fruit, though they tend to be most common in summer and autumn (Vargas *et al*. 1996). Yang *et al*. (1994) reported the net reproductive rate to be 72.9 births per female.

2.4 Nature of damage of mango fruit fly

The damage to crops caused by fruit flies result from oviposition in fruit and soft tissues of vegetative parts of hosts, feeding by the larvae and decomposition of tree tissue by invading secondary microorganisms.

These flies remain active throughout the year on one or the other hosts. During the severe winter months, they conceal and crowd together under dried leaves of bushes and trees. In the hot and dry season, the flies take shelter under humid and shady places and feed on honeydew of aphids infesting the fruit trees (Dhillon *et al.* 2005). Generally, the females of this fly prefer to lay the eggs in soft tender fruit tissues by piercing them with their ovipositor. A watery fluid oozes from the puncture, which becomes slightly concave with leaching of fluid, and transforms into a brown resinous deposit (Gupta and Verma 1978). After egg hatching, the larvae bore into the pulp tissue and make the feeding galleries. The fruit subsequently rotten or becomes distorted. Young larvae present at the necrotic region and move to healthy tissue, where they often introduce various pathogens and hasten fruit decomposition (Arthur *et al*. 1989). Sometimes pseudo-punctures (punctures without eggs) have also been observed on the fruit skin (Bhatti 1970). This reduces the market value of the produce. The full-grown larvae come out of the fruit by making one or two exit holes for pupation in the soil. The larvae pupate in the soil at a depth of 0.5 to 15 cm. The depth up to which the larvae move in the soil for pupation, and survival depend on soil texture and moisture (Pandey and Misra 1999, Jackson *et al.* 1998). Larval feeding damage in fruits is the most damaging (Wadud *et al.* 2005). Mature attacked fruits develop a water-soaked appearance (Calcagno *et al*. 2002). Young fruits become distorted and usually drop. The larval tunnels provide entry points for bacteria and fungi that cause the fruit to rot (Collins *et al*. 2009). These maggots also attack young seedlings, succulent tap roots, stems and buds of host trees such as mango, guava, cucumber, custard apple and others (Weldon *et al*. 2008).

Kapoor (1993) reported that some flies make mines and a few from galls on different Darts of the plants. Singh and Srivastava (1985) reviewed that the maggots bore and feed inside the fruits causing sucken discolored patches, distortion and open cracks. Affected fruits prematurely ripe and drop from the plant. The cracks on fruit serve as the predisposing factor to cause pathogenic infection resulting in decomposition of fruits. The fly has been observed to be active in the field almost throughout the year where the weather is equable (Narayanan and Batra, 1960).

Janjua (1984) observed that the nature of infestation of fruit fly varies with the kinds of fruits. Shah *et al.* (1984) and York (1992) observed the formation of brown resinous deposits on fruits as the symptom of infestation. The insertion of the ovipositor causes wounds on the fruits and vegetables in the form of puncture. The adult female lays eggs just below the epidermis or sometimes a little deeper in the pulp, and/or sometimes on the young leaves or stems of the host plants. After that fluid substance oozes out, which transform into a brown resinous deposit. After hatching, the larva feed into pulpy tissues and make tunnels in fruits causing direct damage.

2.5 Seasonal abundance of fruit fly

Sujit (2005) cited that the population of fruit fly fluctuates throughout the year and the abundance of fruit fly population varies from month to month, season to season, even year to year depending upon various environmental factors. The population of fruit fly fluctuates throughout the year and the abundance of fruit fly population varies from month to month, season to season, even year to year depending upon various environmental factors. The fly has been observed to be active in the field almost throughout the year where the weather is equable (Narayan and Batra, 1960). Narayan and Batra (1960) reported that most of the fruit fly species are more or less active at temperatures ranging between 12°C–15°C and become inactive below 10°C. The peak population of fruit fly in India is attained during July and August in rainy months and

January and February in cold months (Nair, 1986).

2.6 Morphometric detection of different species of fruit fly

Morphometric analyses have been a useful technique in detecting morphological differences among organisms to distinguish closely related species including fruit flies, justify synonymies, demonstrate morphological variation along altitudinal or geographical gradients and propose new species (Reyment *et al.,* 1984; Perero *et al.,* 1984; Willig *et al.,* 1986; McNamee and Dytham, 1993; Selivon, 1996; Adsavakulchai *et al.*, 1999). Indeed, in some frugivorous tephritid fruit fly species, diagnostic morphological characters for the identification of adult flies are now available (Adsavakulchai *et al.*, 1999; De Meyer, 2005; Drew *et al.,* 2006; Drew *et al.*, 2008).

Nakahara *et al.* (2019) conducted two surveys in the dry season and monsoon season to reveal the presence of the *Bactrocera* fruit fly species in Myanmar. In the survey, host fruit sampling and trapping were conducted at four major mango production areas, namely the Yangon, Bago and Mandalay regions and Shan State, and more than seventy thousand *Bactrocera* fruit fly specimens were collected in twenty mango orchards in nine townships. While results of the seasonal occurrence of serious quarantine pest species were previously reported, further analysis was made in this study to determine fruit fly fauna in mango orchards. Based on the morphological research, twenty *Bactocera* species were identified including major serious fruit flies such as *B. dorsalis*, *B. correcta* and *B. cucurbitae*. Out of the twenty species, nine were new findings and not recorded previously in Myanmar. In the fruit sampling, more than two thousand adult flies were detected from mango fruits. As a result of identification, three species were confirmed including *Bactrocera carambolae*, *B. correcta* and *B. dorsalis*. However, *B. zonata,* well known as a species infesting mangoes which was unexpectedly not detected from mango fruits in the survey. *B. latifrons,* not pest of mangoes, were detected from fresh chili (*Capsicum* sp.) cultivated on the premises of the PPD (Plant Protection Division) in Insein, Yangon. In the adult fly traps, more than seventy thousand adult males were collected by the trapping survey. As a result of morphological observation, nineteen species were detected as follows: *B.* (*Asiadacus*) *apicalis*, *B. (Bactrocera) bhutaniae*, *B.* (*Bactrocera*) *carambolae*, *B.* (*Bactrocera*) *correcta*, *B.* (*Bactrocera*) *dorsalis*, *B.* (*Bactrocera*) *nigrifacia*, *B.* (*Bactrocera*) *rubigina*, *B.* (*Bactrocera*) sp. Near *lateritaenia*, *B.* (*Bactrocera*) *tuberculata*, *B.* (*Bactrocera*) *zonata*, *B.* (*Parasinodacus*) *cilifera*, *B.* (*Parasinodacus*) *incisa*, *B.* (*Sinodacus*) *hochii, B.* (*Sinodacus*) sp. near *laterum*, *B.* (*Zeugodacus*) *caudata*, *B.* (*Zeugodacus*) *cucurbitae*, *B.* (*Zeugodacus*) *diversa*, *B.* (*Zeugodacus*) *isolata*, *B.* (*Zeugodacus*) *tau*. Among the species, two species, *B.* sp. near *lateritaenia* and *B.* sp. near *laterum*, could not be identified exactly because there were few samples and a sufficient analysis could not be conducted. Seven species, namely *B. carambolae*, *B. correcta*, *B. dorsalis, B. tuberculata*, *B. zonata, B. cilifera* and *B. cucurbitae,* were detected in all research area regardless of altitude, suggesting widespread distribution in mango cultivation areas. Five species, namely *B. apicalis, B. diversa*, *B. hochii*, *B.* sp. near *lateritaenia* and *B.* sp. near *laterum*, were detected in the Yangon and/or Bago regions only. Three species, namely *B. incisa*, *B. isolata* and *B. bhutaniae,* were detected in Mandalay and Shan State only respectively. In addition, three species, namely *B. caudate*, *B. rubigina* and *B. tau*, were not detected in Shan State. A probable reason is that their habitat depends on host plants and the surrounding environment of mango orchards. This survey was carried out largely in mango orchards and the surrounding area. However, twenty species were found despite the limited research area, suggesting a diversity of fruit fly fauna in Myanmar. This survey should contribute to advancing studies on fruit flies because there is little information on fruit flies in Myanmar.

Castañeda *et al.* (2015) reported that the West Indian fruit fly, *Anastrepha obliqua*, is one of seven species of quarantine importance of its genus and is one of the most economically important fruit fly pests in Colombia. The taxonomic status of this species is a key issue for further implementation of any pest management program. Several molecular studies have shown enough variability within *A. obliqua* to suggest its taxonomic status could be revised; however, there are no morphological studies supporting this hypothesis. The aim of this work was to describe the morphological variability of Colombian populations of *A. obliqua,* comparing this variability with that of other samples from the Neotropics. Measurements were performed on individuals from 11 populations collected from different geographic Colombian localities and were compared with populations from Mexico (2), Dominica Island (1), Peru (1) and Brazil (2). Linear morphometric analyses were performed using 23 female morphological traits, including seven variables of the aculeus, three of the thoraxes, and six of the wings; seven ratios among them were also considered. Discriminant function analyses showed significant morphological differentiation among the Colombian populations, separating them into two groups. The morphometric analysis of natural populations of *A. obliqua* from Colombia resulted in the separation of individuals into two groups. The Zarzal and La Unión populations had the greatest values for ovipositor width at the end of the oviduct (A2, 0.09–0.11 mm); width at the beginning of the serrated section (A3, 0.08–0.09 mm); length of the tip of the aculeus (A4, 0.12–0.15 mm); length of the apex of the aculeus (A4+A5, 0.18–0.21 mm) and the proportion of the length of the tip of the aculeus and total aculeus length (A10, 0.13–0.15 mm). The remaining populations had smaller values: A2, 0.075–0.083 mm; A3, 0.06–0.08 mm; A4, 0.09–0.12 mm; A4 + A5, 0.14– 0.18 mm and A10, 0.11–0.13 mm. The tip of the aculeus is one of the most important taxonomic characters for species separation within the genus *Anastrepha* (Zucchi, 2000; Hernández-Ortiz *et al*., 2004) and contributed here to separate the Colombian populations into two groups. The usefulness of the linear morphometry was shown for *A. fraterculus* collected from different countries in Latin America (Hernández-Ortiz *et al.* 2004, 2012, 2015). The morphometric analyses of *A. obliqua* females indicate that in Colombia there could be two different morphotypes and also that the external samples could be divergent and several groups may exist. Larger studies should be performed to confirm this hypothesis. Furthermore, in the comparisons between Colombian samples with those from other countries, three clusters were observed.

Khamis *et al.* (2012) reported that in 2003, a new fruit fly pest species was recorded for the first time in Kenya and was subsequently been found in 28 countries across tropical Africa. The insect was described as *Bactrocera invadens*, due to its rapid invasion of the African continent. In this study, the morphometry and DNA Barcoding of different populations of *B. invadens* distributed across the species range of tropical Africa and a sample from the pest's putative aboriginal home of Sri Lanka was investigated. Morphometry using wing veins and tibia length was used to separate *B. invadens* populations from other closely related *Bactrocera* species. The Principal component analysis yielded 15 components which correspond to the 15 morphometric measurements. The first two principal axes contributed to 90.7% of the total variance and showed partial separation of these populations. Canonical discriminant analysis indicated that only the first five canonical variates were statistically significant. The first two canonical variates contributed a total of 80.9% of the total variance clustering *B. invadens* with other members of the *B. dorsalis* complex while distinctly separating *B. correcta*, *B. cucurbitae*, *B. oleae* and *B. zonata*. The largest Mahalanobis squared distance (D^2 = 122.9) was found to be between *B. cucurbitae* and *B. zonata*, while the lowest was observed between *B. invadens* populations against *B. kandiensis* (8.1) and against *B. dorsalis s.s* (11.4). Evolutionary history inferred by the Neighbor-Joining method clustered the *Bactrocera* species populations into four clusters. First cluster consisted of the *B. dorsalis* complex (*B. invadens, B. kandiensis* and *B. dorsalis s.s.*), branching from the same node while the second group was paraphyletic clades of *B. correcta* and *B. zonata*. The last two are monophyletic clades, consisting of *B. cucurbitae* and *B. oleae*, respectively. Principal component analysis using the genetic distances confirmed the clustering inferred by the NJ tree.

Hobololo (2004) reported that two fruit fly species, *Ceratitis capitata* (Wiedemann) and *C. rosa* (Karsch) (Diptera: Tephritidae) were known to attack deciduous fruit in the Western Cape Province of South Africa. The relative abundance of these two pests was studied in different kinds of fruit throughout the year. To facilitate field monitoring, using the immature stages, morphological differences between larval instars of *C. capitata* and *C. rosa* were investigated. Morphological characters of the larvae, such as the spiracles (anterior and posterior), mouth hooks and oral ridges were used. Many of these characters were only suitable to distinguish between the second and third instar larvae as these structures were not yet developed in the first instar larvae. Anterior spiracles were examined in terms of the number of tubules (papillae) and size or shape of the felt chambers. The number of papillae in both species was similar in the second and third instar larvae, but differed between the larvae of the two species (8–10 for *C. capitata* and 10-13 for *C. rosa).* In both species the felt chambers of the second instar larvae were narrow and elongate whilst those of the third instar larvae were broad and short. The major difference between the mouth hooks of the two tephritids was the presence of a sub-apical tooth in the third instar larva of *C. rosa,* being absent in the third instar of *C. capitata.* For the morphometric study, both laboratory-reared and field-collected specimens were examined. Measurements of the body dimensions (length and width) and various parts of the cephalopharyngeal skeleton (CPS) (mandible base, mandible length and distance between the tip and notch) were recorded in all three instars of both *C. capitata* and *C. rosa.* The data were analysed using finite mixture analysis (FMA-N1) and Levene's test was used to test for homogeneity of variances. The results of these analyses were used to estimate the frequency distributions of the larval measurements. In some cases, overlaps in distributions were evident and were resolved using the same program, finite mixture analysis (FMA-N1), based on the probability of the overlapping measurements belonging to the designated instar (i.e. the one with highest probability). Determination of growth ratios suggested an approximate conformation to Dyar's rule thereby disputing the possibility of any hidden instar. However, in most cases measurements of the field samples did not conform to Dyar's rule. For the larval instars of *C. capitata* and *C. rosa* with overlapping morphological features, the morphometric approach as a distinguishing tool was demonstrated. In the field survey, the relative abundance of *C. rosa* at all experimental sites was very low in both orchards and adjacent vines. This suggested that this pest was either not a threat in these sites (crops) or the monitoring procedures applied, should be revised. Trap catches indicated high levels of infestation by *C. capitata* on some sites and low infestation levels at others. On the site with the highest population levels, activity peaks in the orchards did not coincide with those in the adjacent vineyards. This suggested that these vineyards could be alternative hosts for fruit fly after the fruit in the orchards have been harvested. Forced oviposition (*in vitro*) studies indicated that Colombard (grown in Simonsvlei) was the most suitable host for survival of C. *capitata.* Other wine grape cultivars such as Chardonnay were also suitable for the total larval development of *C. capitata.*

CHAPTER III

MATERIALS AND METHODS

The methods which were adopted for morphometric detection of mango fruit fly collected from different mango growing regions of Bangladesh has been discussed under the following subheadings:

3.1 Location of the experiment

The experiment was conducted at the farmer's orchard of Dinajpur and Thakurgaon districts during the period from April to June 2020. Five locations of each Dinajpur and Thakurgaon districts were selected and surveyed for collection of Mango fruit fly that were used in detecting the morphometric similarities/dissimilarities at the Entomology Laboratory of Sher-e-Bangla Agricultural University for further testing. Experimental site at Dinajpur and Thakurgaon districts and relevant information are given below:

Location of the experiment

SI no.	Name of the district	Name of the Upazillas
1	Dinajpur	Biral
2		Bochagonj
3		Kaharole
4		Fulbari
5		Khanshama
6	Thakurgaon	Sadar
7		Pirganj
8		Ranisankail
9		Baliadangi
10		Haripur
Total	**2**	**10**

3.2 Characteristics of soil

The Thakurgaon districts belonging to the Himalayan piedmont plain which is moderately well drained, and dark brown sandy loam soil. The soil is strongly acidic and occurs on highland condition. The majority of soils of Dinajpur district are located in three physiographic types, i.e., Piedmont plain, Tista Floodplain and Barind Tract/Terrace. The soils of Piedmont plain and Tista Floodplain are noncalcareous grey soils (i.e., Gleysols) and Terrace is shallow grey soils (i.e., Planosols) (Huq and Shoaib, 2016). The lands of Dinajpur possess three land types, based on flooding during the monsoon and/or flood season, which are HL (i.e., land above the normal flooding level) and MHL (i.e., land flooded up to 90 cm for at least two weeks) and the remainder is MLL (i.e., land flooded up to 90–180 cm for more than two weeks) (Huq and Shoaib, 2016). The surface soil (i.e., 0–15 cm generally) texture is mainly loam and silt loam, but varies from silt loam to sandy loam and silty clay loam to clay loam (Hassan *et al.,* 2012)

3.3 Climate

An analysis of the agro-climatological data of Thakurgaon regions indicated that the mean daily temperature and mean annual rainfall of this region satisfies the optimum requirements of horticultural crops (Hossain *et al.,* 1999). An analysis of long-term rainfall data and stored soil moisture to one-meter depth indicates that there is a period of moisture shortage or dry period of maximum 50–60 days in this region (Manalo 1975). On the other hand, there is a humid or wet period when the total rainfall is continuously greater than the potential evapotranspiration of crops. During this period, excess water from the soil profile needs to be drained out timely. Dinajpur district lies between 26°4' north latitude and 89°18' east longitude in the North-western region of Bangladesh. The region has a humid, wet and hot subtropical climate with distinct summer, monsoon and winter seasons.

3.4. Trapping of fruit flies through Pheromone Trap (Plastic pot)

The pheromone, ‘methyl eugenol’ or ‘cuelure’, which mimics the scent of female fruit flies, attracts the male flies and traps them in large numbers resulting in mating disruption. Simple plastic containers developed by BARI scientists known as ‘BARI trap’ or popularly known as ‘Magic trap’ were used for deployment of the pheromones. The cylindrical plastic container having 3 liter capacity and 20–22 cm tall was used for this experiment. A triangular hole measuring 10–12 cm height and 10–12 cm base was cut in two opposite sides of the container. The base of the hole was 3 cm above the bottom. Water containing two-three drops of detergent was maintained inside the trap throughout the season. Pheromone soaked cotton or lure was tied inside the trap with thin wire. Fruit fly adults entered the trap and fall into the water and died. Water level was regularly checked to avoid dryness of trap. Pheromone dispenser was continued throughout the cropping season. One pheromone trap was hanged from the lower branches in three distant selected mango trees starting from 15 April before coming full maturity and was continued up to last harvest. The distance between replicates being about 50 meters. The pheromone trap was setup in the mango orchard for 48 hours. After 48 hours the fruit fly sample were collected from trap (Plate 1 and 2).

Plate 1. Sex pheromone trap hanged from the mango branch with captured fruit flies

3.5 Identification and study of the collected specimen

The specimens were kept in a dry state until observation. After the observation, the sample were washed and preserved with ethanol. Morphological identification was made under a stereoscopic microscope. For observation of the terminalia, male abdomens were treated with 10% KOH and transferred to distilled water for dissection as needed. They were placed on double-sided tape and examined under a stereoscopic microscope. Wings were mounted on prepared slides using gum-chloral mounting media and the length was measured under stereoscopic a microscope.

Plate 2. Sex pheromone trap

3.6 Data Collection

Data were collected on following parameters under stereo microscope:

i. Wing pattern
ii. Wing venation
iii. Wing coloration
iv. Head
v. Thorax and
vi. Abdomen

Head, thorax, abdomen and wing were observed under stereomicroscope and photograph of individual sample was captured.

3.7 Statistical analysis of data

The data obtained for different characters were statistically analyzed to find out the significance of effects/impacts. The mean values of all the characters were evaluated, and analysis of variance (ANOVA) performed by the 'F' (variance ratio) test using STATISTICS 10 program. The significance of the difference among the different combinations for different characters will be estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study of morphology was a common means of biological grouping and classification. The different species of fruit flies were identified attacking the mango fruit at different location of Dinajpur and Thakurgaon districts of Bangladesh according to their taxonomy. The morphometric analysis was done at Entomology lab of central laboratory, Sher-e-Bangla Agricultural University. The fruit flies were identified using conventional taxonomy on most morphological characters in adult stages which were the most important stage of detection of any pest for successful management. The fruit fly sample was collected at different location of Bangladesh using pheromone trap (methyl-eugenol). The pheromone trap was setup in the mango orchards for 48 hours. After 48 hours the fruit fly sample were collected from trap then wash and preserve with ethanol. The sample was then study using stereomicroscope.

4.1 Incidence of fruit fly at different location

The fruit fly samples were collected at different locations of Dinajpur and Thakurgaon districts of Bangladesh using pheromone trap (methyl-eugenol) at mango orchard. Four different species were identified using stereomicroscope. The name of the fruit flies were Oriental fruit fly (*Bactrocera dorsalis*), melon fruit fly (*Zeugodacus cucurbitae*), pumpkin fruit fly (*Zeugodacus tau*) and peach fruit fly (*Bactrocera zonata*). (Table 1).

Table 1. Total number of different fruit fly were collected from pheromone trap at different location of Dinajpur and Thakurgaon districts of Bangladesh with (% percentage) value.

District	Upazilla	Fruit fly number /trap	*Bactrocera dorsalis* (%)	*Zeugodacus cucurbitae* (%)	*Zeugodacus tau* (%)	*Bactrocera zonata* (%)
Dinajpur	**Biral**	182	63.19	15.93	8.24	12.64
	Bochagonj	118	66.95	12.71	7.63	12.71
	Kaharole	110	85.46	14.54	0.00	0.00
	Fulbari	258	88.76	7.75	3.49	0.00
	Khanshama	318	90.57	9.43	0.00	0.00
Thakurgaon	**Sadar**	106	82.07	9.44	6.60	1.89
	Pirganj	89	86.52	7.87	5.61	0.00
	Ranisankail	99	87.88	10.10	2.02	0.00
	Baliadangi	107	93.45	3.74	1.87	0.94
	Haripur	293	95.22	2.39	2.39	0.00

Total 85.41% of oriental fruit flies were found in total number of pheromone trap which was the highest number of fruit fly in mango field. However, 2.44 % of peach fruit fly were identified which was the lowest number of fruit fly. Moreover, 8.81 % and 3.34 % percent of melon fruit fly and pumpkin fruit fly were collected from pheromone trap, respectively (Figure 1). Therefore, numbers of oriental fruit fly were highest compare to other fruit fly.

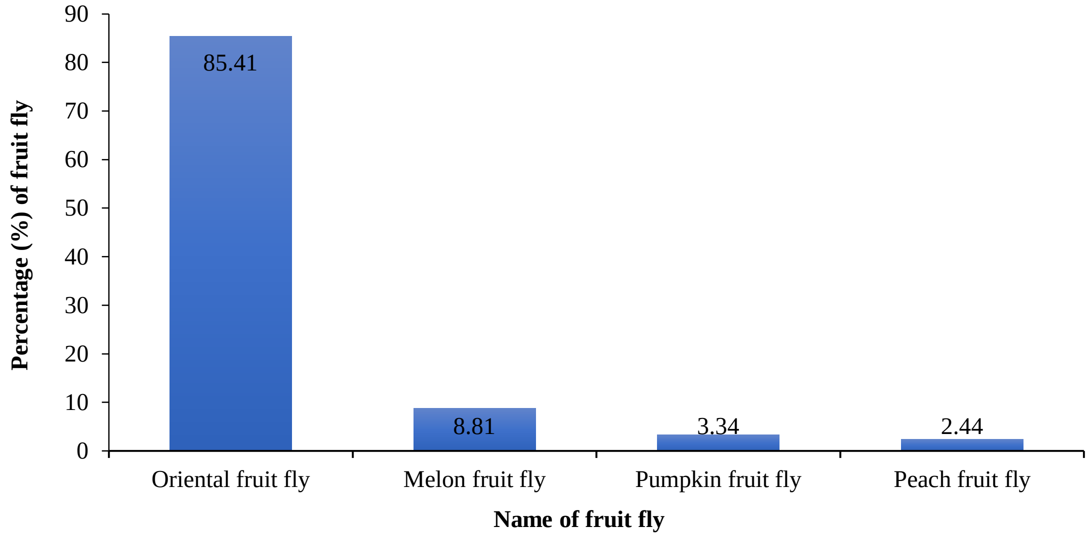


Figure 1. Total percent of different fruit fly were collected from pheromone trap at different location of Dinajpur and Thakurgaon districts of Bangladesh.

The Dinajpur district covers around 22% of the mango land area. There is an occurrence of wide genetic variations in plants and insects, both in the wild and cultivated states. Total 58.69 % of fruit flies were found in Dinajpur district which was the highest number of fruit fly. On the other hand, 41.31 % fruit flies were found in Thakurgaon district which was the lowest number of fruit fly (Figure 2).

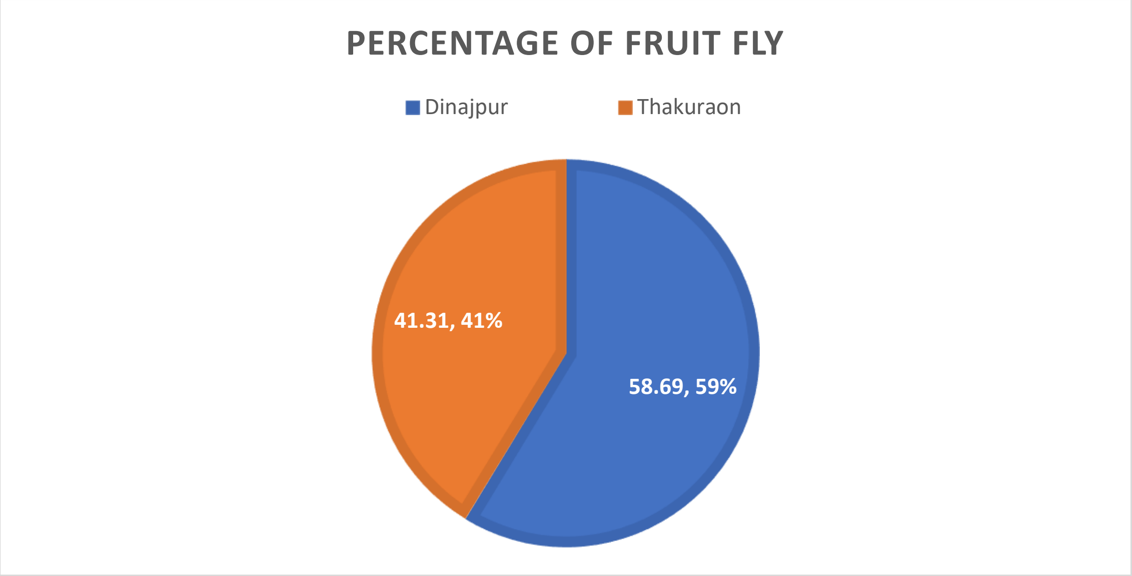


Figure 2. Total percent of different fruit fly were collected from pheromone trap according to Dinajpur and Thakurgaon districts of Bangladesh.

According to Drew and Hancock (1994) distinguish the *B. dorsalis* species complex as follows: *Bactrocera* (*Bactrocera) spp*. with scutum generally black with lateral vittae present and medial vitta absent; yellow scutellum, except for basal band which is usually very narrow (Figure 3.). Abdomen with a medial dark stripe on T3-T5; dark laterally (but form of marking varies from species to species) (Figure 3.). A clear wing membrane, except for a narrow costal band (not reaching R4+5); cells bc and c colourless (except in a few non-pests with a very pale tint) with microtrichia restricted to outer corner of cell c (Figure 3.).

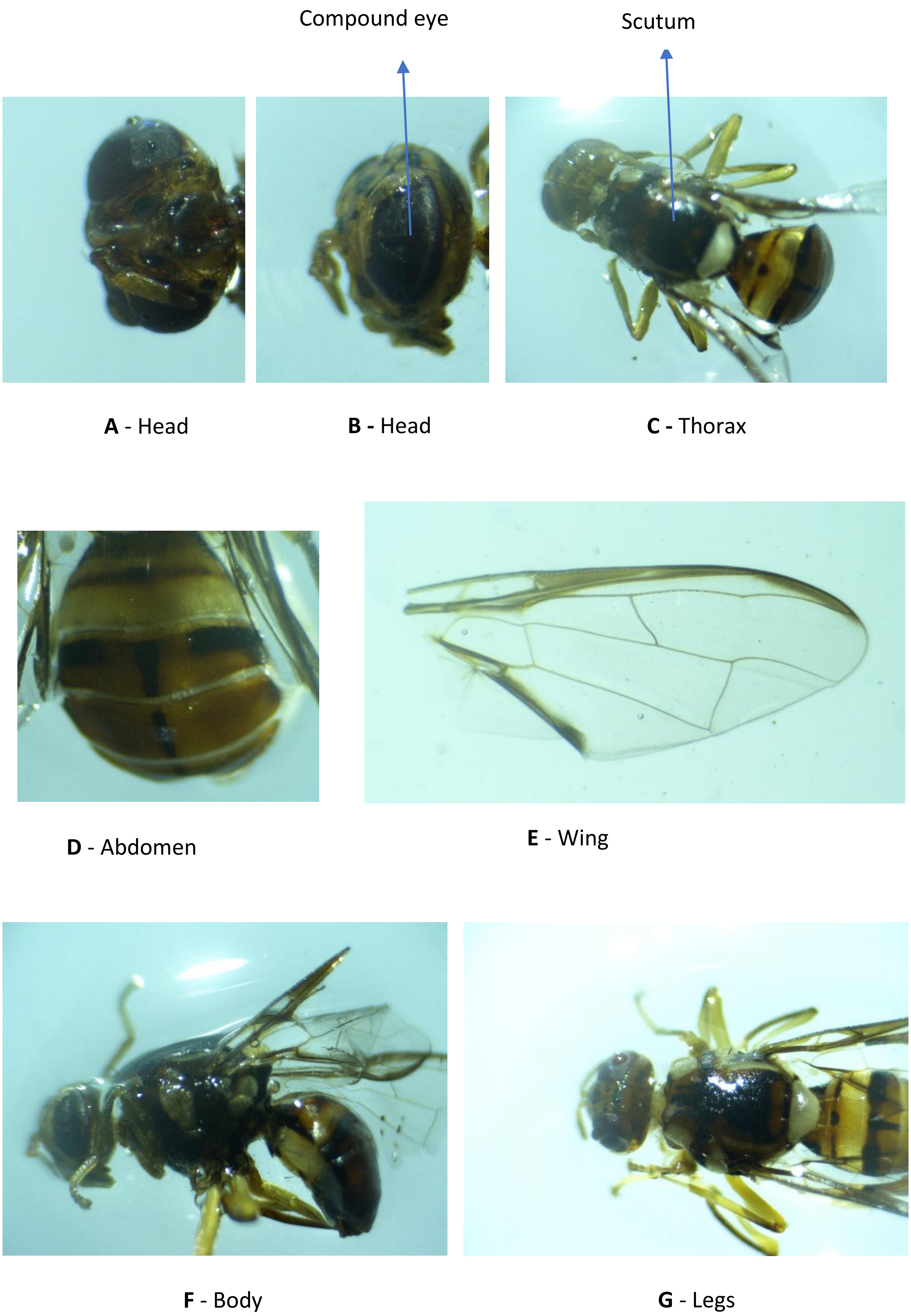


Figure 3. *Bactrocera dorsalis,* habitus and body details.

4.2 Oriental fruit fly

Highest no. of oriental fruit fly four different variables were found in Dinajpur compared to Thakurgaon district. (15.17)mm^2 areas were measured at abdominal part of the oriental fruit fly which was higher in contrast to Thakurgaon district and (12.76)mm^2 were respectively. According to thorax, 14.68 mm^2 areas were measured of the oriental fruit fly which was higher compare to Thakurgaon district and (11.30) mm^2 were respectively. Moreover, lowest 3.41 mm^2 head was measured at Thakurgaon district compare to Dinajpur district. Same observation was observed in case of wing and the 32.58 mm^2 were measured which was highest at Dinajpur district (Figure 4).

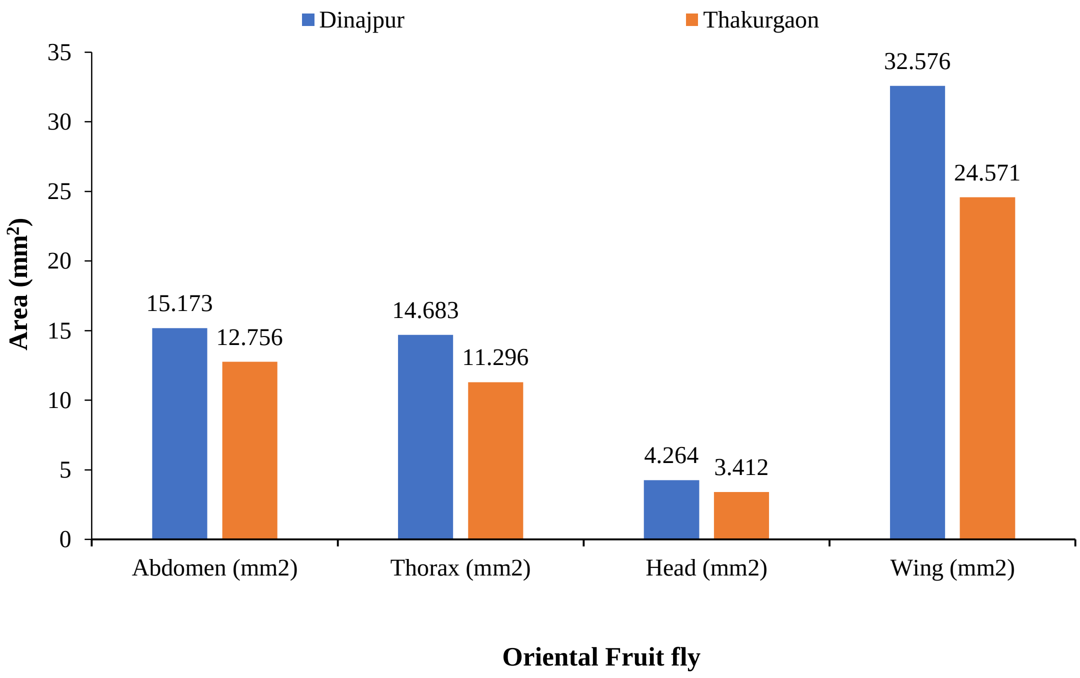


Figure 4. Average area (length × width) of *Bactrocera dorsalis* collected from pheromone trap at Dinajpur and Thakurgaon districts of Bangladesh. (LSD = 2.25, 1.83, 0.56 and 5.92, respectively)

Significant differences were observed in case of oriental fruit flies at two different districts of Bangladesh. Therefore, Dinajpur district oriental fruit fly was larger compare to Thakurgaon district oriental fruit fly.

4.3 Melon fruit fly

According to White and Hancock (1997) melon fruit fly head was like Pedicel+1st flagellomere not longer than ptilinal suture. Face with a dark spot in each antennal furrow; facial spot round to elongate (Figure 5.). Thorax was predominant colour of scutum red-brown. Scutum with parallel sided lateral postsutural vittae (yellow/orange stripes) which extend anterior to suture and posteriorly to level of the intra-alar setae. Medial vitta present; not extended anterior to suture. Scutellum yellow, except for narrow basal band (Figure 5.). Abdomen were predominant colour orange-brown. Tergites not fused. Abdomen not wasp waisted. Pattern distinct; transverse band across tergite 3; tergite 4 dark laterally; medial longitudinal stripe on T3-5 (Figure 5.). Length of wing was 4.2-7.1 mm. With a complete costal band; depth to below R2+3, sometimes reaching R4+5. Costal band expanded into a spot at apex, which extends about half way to M. With an anal streak. Cells bc and c colorless (Figure 5). Legs were all femora pale basally, red-brown apically (Figure 5.).

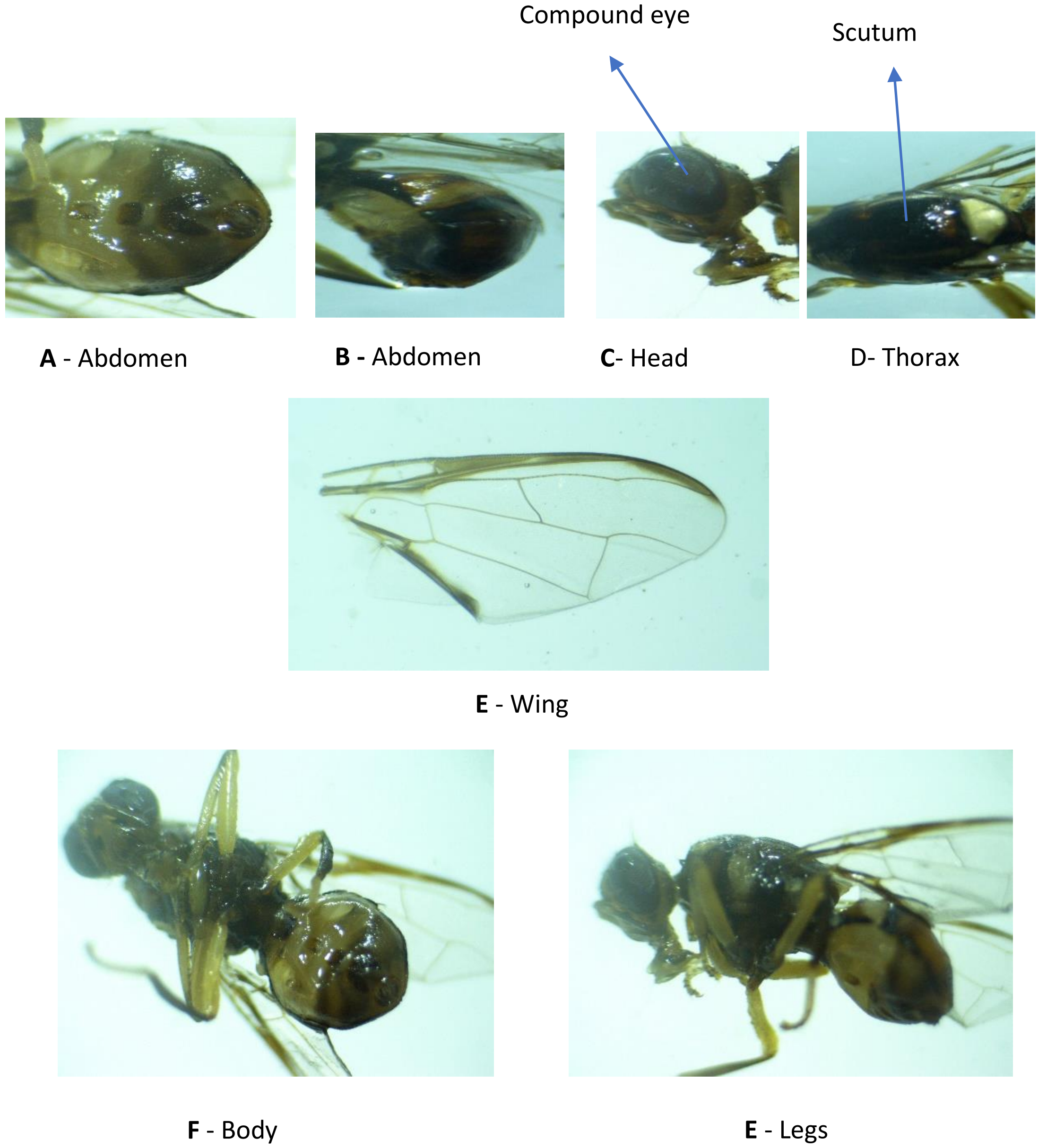


Figure 5. *Zeugodacus cucurbitae*, habitus and body details.

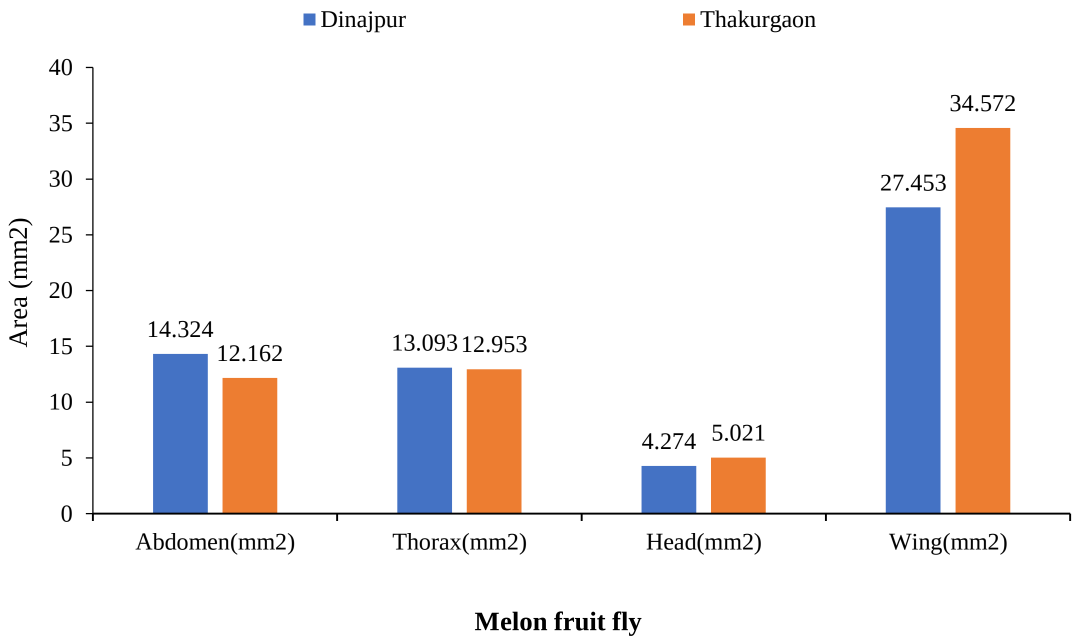


Figure 6. Average area (length × width) of *Zeugodacus cucurbitae* were collected from pheromone trap at Dinajpur and Thakurgaon districts of Bangladesh. (LSD = 1.35, 0.76, 3.57 and 3.26, respectively)

Dinajpur district melon fruit flies were larger at abdomen area compared to Thakurgaon district. 14.32 mm^2 areas were measured at abdominal part of the melon fruit fly which was higher in contrast to Thakurgaon district and 12.16 mm^2 were respectively. According to thorax, 13.09 mm^2 areas were measured of the melon fruit fly which was higher compare to Thakurgaon district and 12.95 mm^2 were respectively. Moreover, lowest 4.27 mm^2 head was measured at Dinajpur district compare to Thakurgaon district and 5.02 mm^2 area were observed at Thakurgaon district which was the highest. Same observation was observed in case of wing and the 34.57 mm^2 were measured which was highest at Thakurgaon district (Figure 6). No significant differences were observed at two different district of Bangladesh Melon fruit fly. Thakurgaon district melon fruit fly was slightly larger compare to Dinajpur district and Oriental fruit fly were slightly larger compare to Melon fruit fly.

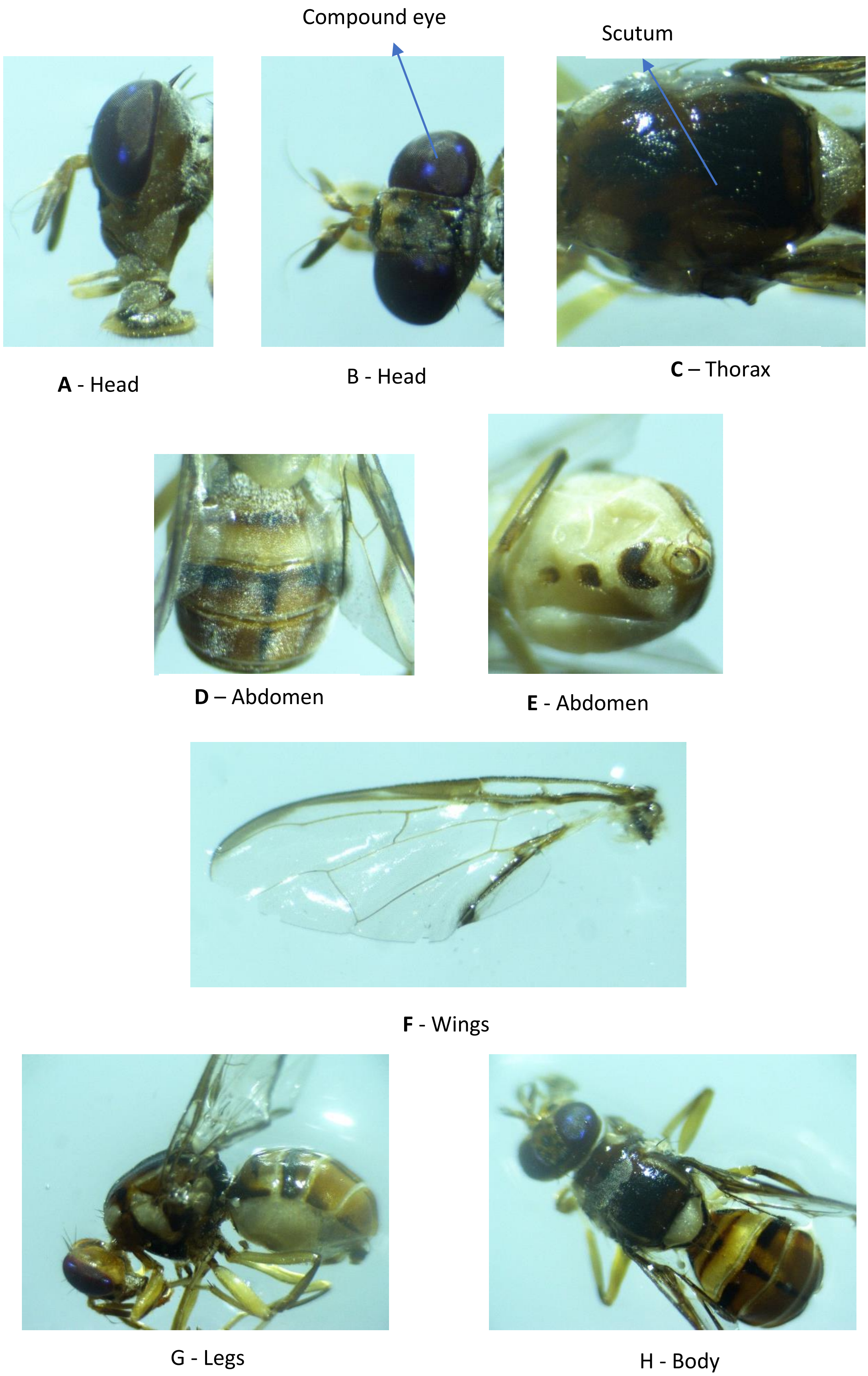


Figure 7. *Zeugodacus tau,* habitus and body details.

4.4 Pumpkin fruit fly

Pumpkin fruit fly adults have orange-brown scutum marked with black stripes contains lateral two and median and yellow stripes. Females have pointed abdomen and male have round and male was smaller than female insect (Figure 7).

12.56 mm^2 areas were measured at abdominal part of the pumpkin fruit fly which was higher at Dinajpur district compare to other district and the lowest value was 9.03 mm^2. According to thorax, 14.57 mm^2 areas were measured of the pumpkin fruit fly which was higher at Dinajpur district to Thakurgaon district and the value was 12.35 mm^2. Moreover, same trend was observed in case of head and wing of the pumpkin fruit fly (Figure 8).

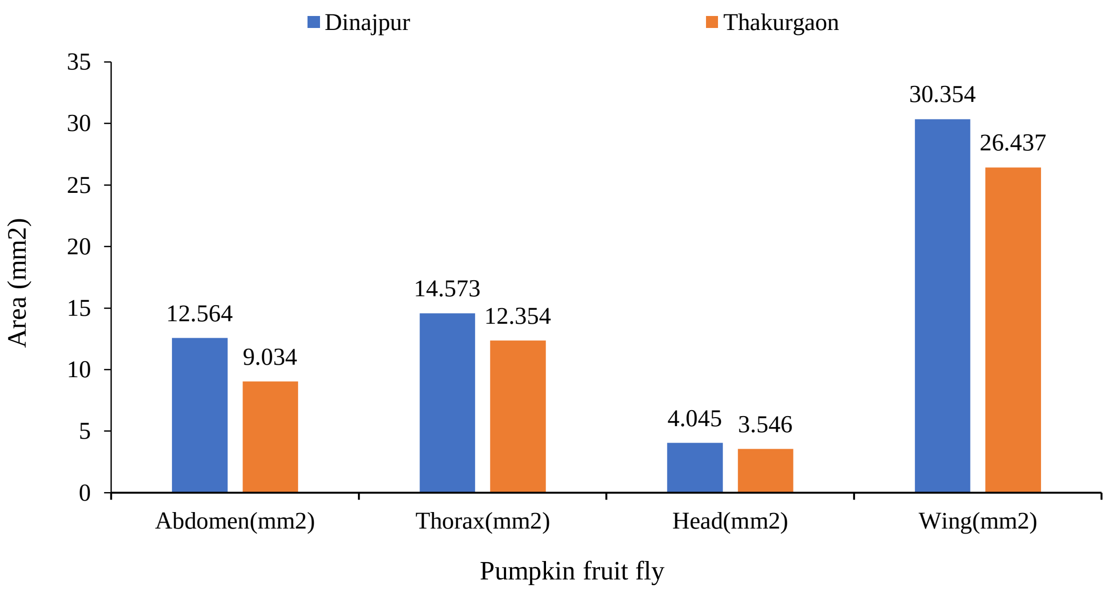


Figure 8. Average area (length × width) of pumpkin fly collected from pheromone trap at Dinajpur and Thakurgaon districts of Bangladesh. (LSD = 4.56, 2.56, 0.61 and 4.75, respectively)

No significant differences were observed of abdominal parts of fruit fly at two different districts of Bangladesh.Pumpkin fruit fly of Dinajpur district was moderately larger in size and shape compare to Thakurgaon district and pumpkin fruit fly were almost similar in size and shape compare to melon fruit fly.

Bactrocera zonata adults was about 6 mm long and reddish brown with yellowish thoracic markings. Head higher than long and chaetotaxy reduced. Dark round spots in each antennal furrow (Figure 9.). In thorax, anterior supra-alar bristles present. Scutum orange brown, or red brown. Scutum has two pale-whitish to yellow lateral post sutural stripes (vittae), they extending to intra-alar bristles or beyond. Scutum without blackish dorsoventral stripe (Figure 9). Abdomen ovate or parallel sided and yellow to orange brown color. Abdominal tergites with medial dark stripe usually on T5; not brown with medial T-shaped yellow mark (Figure 9.). Wings are sub-costal vein (Sc), which bends abruptly to the wing edge, combined with the presence of setulae along the dorsal side of vein R1 and yellowish and brownish in color (Figure 9.). Femora legs of *Bactrocera zonata* are slender. Fore femur with regular bristles and mid femur and hind femur without spine bristles. Middle leg of male without feathering. Femora all entirely yellow without dark mark (Figure 9.).

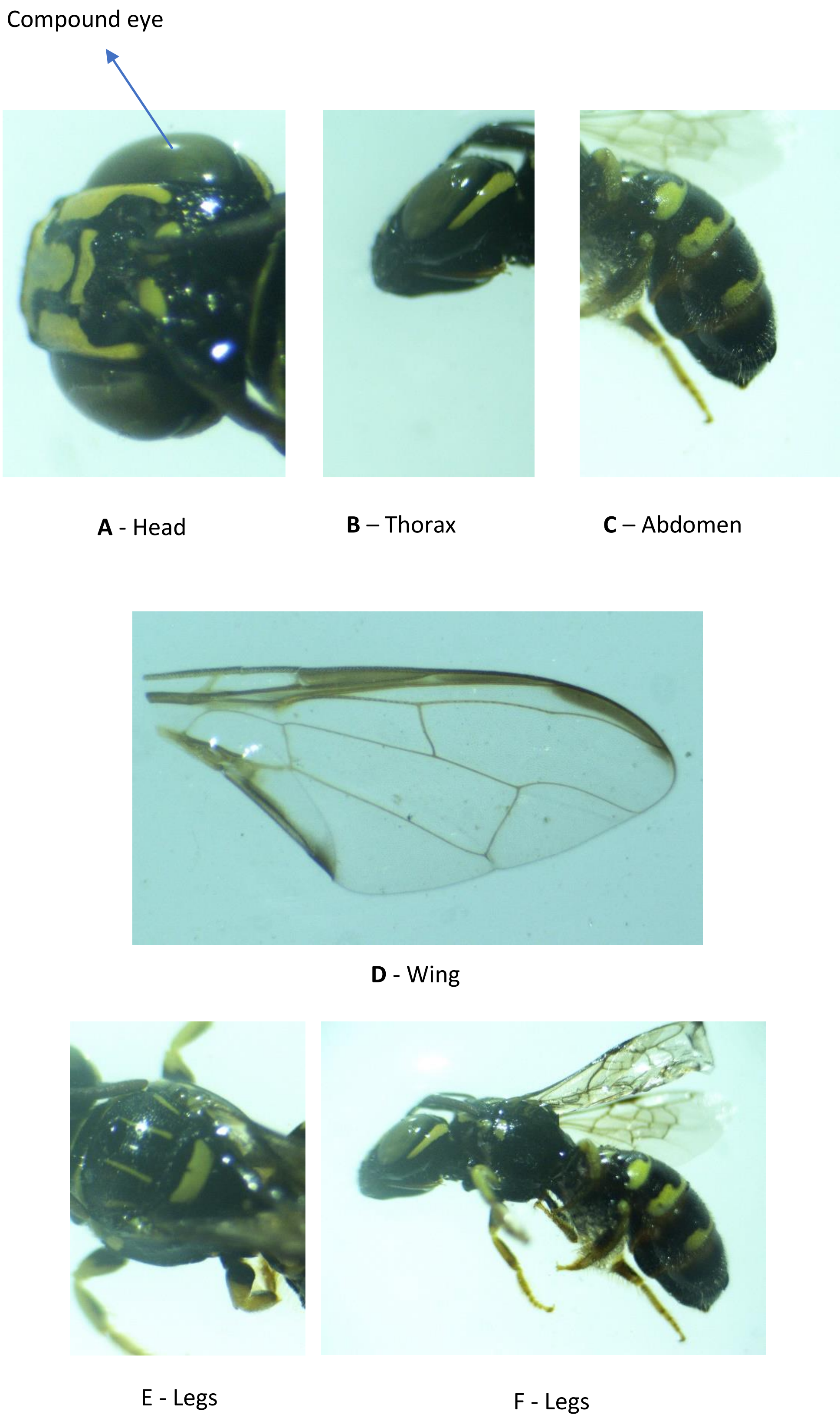


Figure 9. *Bactrocera zonata*, habitus and body details.

4.5 Peach fruit fly

11.55 mm^2 area were measured at abdominal part of the peach fruit fly which was higher at Dinajpur district compare to Thakurgaon district and the lowest value was 9.95 mm^2. According to thorax, 14.07 mm^2 area were measured of the peach fruit fly which was higher at Dinajpur district compare to Thakurgaon district and the value was 11.29 mm^2. Moreover, same trend was observed in case of head and wing of the peach fruit fly of Bangladesh (Figure 10).

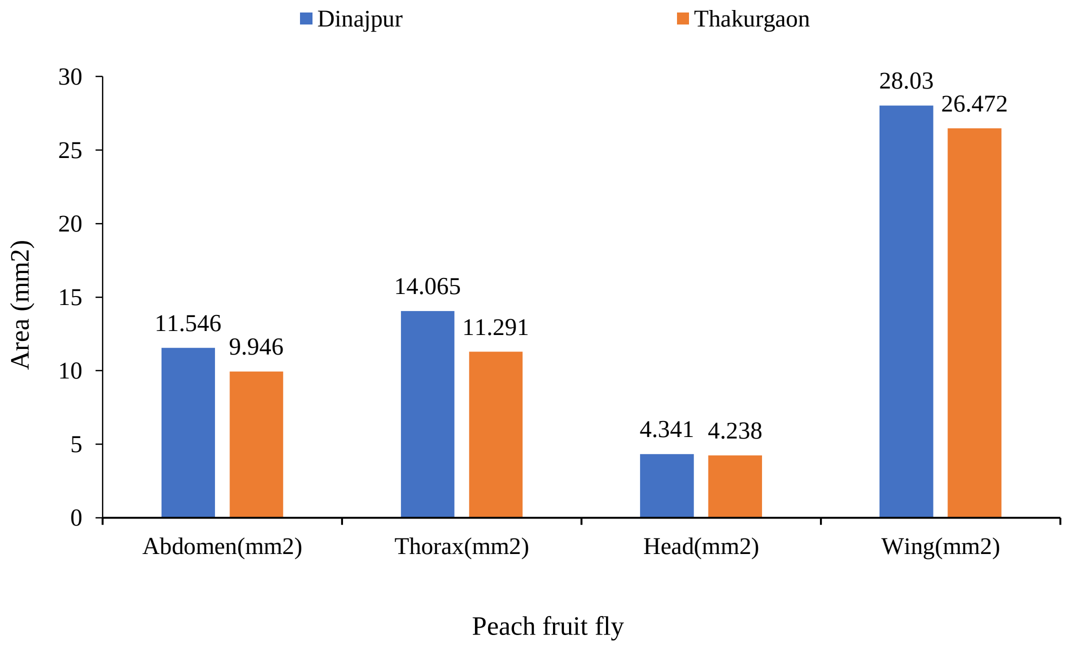


Figure 10. Average area (length × width) of *Bactrocera zonata* collected from pheromone trap at Dinajpur and Thakurgaon districts of Bangladesh. (LSD = 0.93, 2.05, 0.35 and 1.41, respectively)

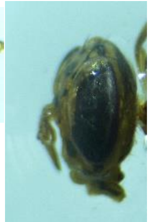
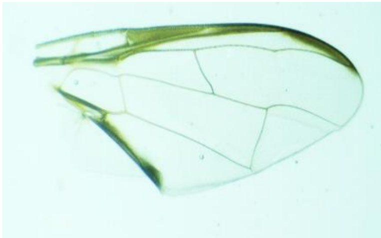
Significant difference was observed at two different district of Bangladesh peach fruit fly at abdominal body part. Therefore, Dinajpur district's peach fruit fly was prominent compare to other district and peach fruit fly were almost same in size and shape with melon fruit fly.

4.6 Comparison of different fruit fly species

Table 2. Length and width of different fruit fly collected from pheromone trap at Dinajpur and Thakurgaon districts of Bangladesh with (± SE) value

Species	Abdomen (± SE)	Scutum (± SE)	Head (± SE)	Wing (± SE)
Bactrocera dorsalis	L = 4.97±0.46 W = 4.77±0.29	L = 4.51±0.08 W = 3.23±0.15	L = 1.70±0.23 W = 2.94±0.16	L = 9.33±0.37 W = 3.57±0.47
Zeugodacus cucurbitae	L = 4.36±0.05 W = 3.85±0.19	L = 3.95±0.09 W = 3.25±0.05	L = 1.56±0.05 W = 2.57±0.04	L = 9.53±0.11 W = 3.65±0.01
Zeugodacus tau	L = 2.97±0.37 W = 2.72±0.33	L = 4.46±0.26 W = 2.81±0.06	L = 1.26±0.05 W = 2.46±0.03	L = 8.26±0.42 W = 3.05±0.04
Bactrocera zonata	L = 3.72±0.04 W = 3.54±0.03	L = 4.23±0.15 W = 3.11±0.15	L = 1.60±0.3 W = 2.69±0.17	L = 9.35±0.04 W = 3.47±0.03

Table 3. Abdomen, scutum, head and wing of different fruit fly collected from pheromone trap at Dinajpur and Thakurgaon districts of Bangladesh.

Species	Abdomen	Scutum	Head	Wing
Bactrocera dorsalis				
Zeugodacus cucurbitae				
Zeugodacus tau				
Bactrocera zonata				

Four different species were identified using stereomicroscope. The name of the fruit flies were Oriental fruit fly (*Bactrocera dorsalis*), melon fruit fly (*Zeugodacus* *cucurbitae*), pumpkin fruit fly (*Zeugodacus tau*) and peach fruit fly (*Bactrocera zonata*). The numbers of oriental fruit fly were the highest compare to other fruit fly. The highest infestations were observed at Dinajpur district compared to Thakurgaon district in mango orchard. The Oriental fruit fly of Dinajpur district was larger compare to oriental fruit flies of Thakurgaon district. Dinajpur district oriental fruit flies' abdominal part was distinguished compare to Thakurgaon district.

Table 4. Comperative representation of morphometric data on four fruit fly species

Species	**Area of Abdomen**		**Area of Thorax**		**Area of Head**		**Area of Wing**	
	Dinajpur (mm^2)	Thakurgaon (mm^2)	Dinajpur (mm^2)	Thakurgaon (mm^2)	Dinajpur (mm^2)	Thakurgaon (mm^2)	Dinajpur (mm^2)	Thakurgaon (mm^2)
Bactrocera dorsalis	15.173	12.756	14.683	11.296	4.264	3.412	32.576	24.571
Zeugodacus cucurbitae	14.324	12.162	13.093	12.953	4.274	5.021	27.463	34.572
Zeogodacus tau	12.564	9.034	14.573	12.354	4.045	3.546	30.354	26.437
Bactrocera zonata	11.546	9.946	14.065	11.291	4.341	4.238	28.030	26.472
Average	13.402	10.974	14.104	11.973	4.231	4.054	29.603	28.013

There are significant difference area of abdomen between Oriental fruit of Dinajpur districts and peach fruit fly of Thakurgaon District. Area of thorax Oriental Fruit fly of Dinajpur district is larger compare to Peach fruit fly of Dinajpur fruit fly. Dinajpur district oriental fruit flies area of head is slightly lower than Melon fruit fly od Thakurgaon district. Area of Wings of Oriental fruit flies are larger compare to thakurgaon oriental fruit fly.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The experiment was conducted at the farmer's orchard of Dinajpur and Thakurgaon districts during the period from April to June 2020 for morphometric detection of mango fruit fly collected from different mango growing regions of Bangladesh. Five locations of each Dinajpur and Thakurgaon districts were selected and surveyed for collection of Mango fruit fly. The samples were used in detecting the morphometric similarities/dissimilarities at the Entomology Laboratory of Sher-e-Bangla Agricultural University for further testing. The location for collection of the samples in Dinajpur were Biral, Bochagonj, Kaharole, Fulbari and Khanshama and in Thakurgaon were Sadar, Pirganj, Ranisankail, Baliadangi and Haripur. Data were collected on wing, head, thorax and abdomen of fruit flies and further study was ensured.

The fruit fly samples were collected at different location of Dinajpur and Thakurgaon districts of Bangladesh using pheromone trap (methyl-eugenol) at mango field. Four different species were identified using stereomicroscope. The name of the fruit flies were Oriental fruit fly (*Bactrocera dorsalis*), melon fruit fly (*Zeugodacus cucurbitae*), pumpkin fruit fly (*Zeugodacus tau*) and peach fruit fly (*Bactrocera zonata*).

Total 85.41% of oriental fruit flies were found in total number of pheromone trap which was the highest number of fruit fly in mango field. However, 2.44 % of peach fruit fly were identified which was the lowest number of fruit fly. Moreover, 8.81% and 3.34% percent of melon fruit fly and pumpkin fruit fly were collected from pheromone trap respectively. Therefore, numbers of oriental fruit fly were highest compare to other fruit fly. The Dinajpur district covers around 22% of the mongo land area. There is an occurrence of wide genetic variations in plants and insects, both in the wild and cultivated states. Total 58.69 % of fruit flies were found in Dinajpur district which was the highest number of fruit fly. On the other hand, 41.31 % fruit flies were found in Thakurgaon district which was the lowest number of fruit fly.

Oriental fruit flies of Dinajpur district was larger considering four different variables compared to Thakurgaon district. 15.17 mm^2 areas were measured at abdominal part of the oriental fruit fly which was higher in contrast to Thakurgaon district and 12.76 mm^2 were respectively. According to thorax, 14.68 mm^2 areas were measured of the oriental fruit fly which was higher compare to Thakurgaon district and 11.30 mm^2 were respectively. Moreover, lowest 3.41 mm^2 head was measured at Thakurgaon district compare to Dinajpur district. Same observation was observed in case of wing and the 32.58 mm^2 were measured which was the highest at Dinajpur district. Significant differences were observed at two different districts of Bangladesh oriental fruit flies. Therefore, Dinajpur district oriental fruit fly was larger compare to Thakurgaon district oriental fruit fly.

Melon fruit flies of Dinajpur district were larger at abdomen area compared to Thakurgaon district. 14.32 mm^2 areas were measured at abdominal part of the melon fruit fly which was higher in contrast to Thakurgaon district and 12.16 mm^2 were respectively. According to thorax, 13.09 mm^2 areas were measured of the melon fruit fly which was higher compare to Thakurgaon district and 12.95 mm^2 were respectively. Moreover, lowest 4.27 mm^2 head was measured at Dinajpur district compare to Thakurgaon district and highest 5.02 mm^2 area were observed at Thakurgaon district which is highest. Same observation was observed in case of wing and the 34.57 mm^2 were measured which was highest at Thakurgaon district. No significant differences were observed in melon fruit flies at two different districts of Bangladesh. Thakurgaon district melon fruit fly was slightly larger compare to Dinajpur district and oriental fruit fly were slightly larger compare to melon fruit fly.

Pumpkin fruit fly adults have orange-brown scutum marked with black stripes contains lateral two and median and yellow stripes. Females have pointed abdomen and male have round and male was smaller than female insect. 12.56 mm^2 areas were measured at abdominal part of the pumpkin fruit fly which was higher at Dinajpur district compare to other district and the lowest value was 9.03 mm^2. According to thorax, 14.57 mm^2 areas were measured of the pumpkin fruit fly which was higher at Dinajpur district to Thakurgaon district and the value was 12.35 $mm^{2.}$ Moreover, same trend was observed head and wing of the pumpkin fruit fly. No significant differences were observed at two different districts of Bangladesh pumpkin fruit fly at abdominal body part. Dinajpur district pumpkin fruit fly was moderately larger in size and shape compare to Thakurgaon district and pumpkin fruit fly were almost similar in size and shape compare to melon fruit fly.

Significant difference was observed at two different district of Bangladesh peach fruit fly at abdominal body part. Therefore, Dinajpur district's peach fruit fly was prominent compare to other district and peach fruit fly were almost same in size and shape with melon fruit fly.

CONCLUSION

The fruit flies which were collected from Dinajpur and Thakurgaon districts identified were Oriental fruit fly (*Bactrocera dorsalis*), melon fruit fly (*Zeugodacus cucurbitae*), pumpkin fruit fly (*Zeugodacus tau*) and peach fruit fly (*Bactrocera zonata*). The numbers of oriental fruit fly were the highest compare to other fruit fly. The highest infestations were observed at Dinajpur district compared to Thakurgaon district in mango orchard. Dinajpur district oriental fruit fly was larger compare to Thakurgaon district oriental fruit fly. Thakurgaon district melon fruit fly was slightly larger compare to Dinajpur district and oriental fruit fly were slightly larger compare to melon fruit fly.

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