BIOLOGY, PEST STATUS AND MANAGEMENT OF JACKFRUIT BORER, *Diaphania caesalis* Walker

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CERTIFICATE

This is to certify that the thesis entitled, "Biology, pest status and management of jackfruit borer. *Diaphania caesolis* Walker" 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 IN ENTOMOLOGY,** embodies the result of a piece of bonafide research work carried out by Sakhaoyad Hossain Mridha, Roll No. 00285**,** Registration No. 25139/00285 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 been duly acknowledged by him.

Dated:

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DEDICATED
TO
MY LATE MOTHER

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ABSTRACT

Experiments were conducted in the farmers orchard of Gazipur district and in the laboratory and Fruit farm of Bangladesh Agriculture Research Institute, Gazipur during January, 2005 to August, 2005 to study Biology, Pest status and management of jackfruit borer, *Diaphania caesalis* Walker. From the study it was found that a female moth laid on an average 31.29 eggs, the incubation period of egg was 4.5 days. The larval period, pupal period, adult stage were on an average 12.01 days, 6.83 days, 4.5 days., the highest fruit infestation was recored in Joydebpur (30.84%) and the lowest was in Sreepur (21.08%). In Joydebpur, farmers were the most conscious about the attract of jackfruit borer (98.5%) and the least in Kapasia. In view of Joydebpur's farmers the highest fruit infestation 53.78%) and the lowest in Sreepur (28.96%). At 30 days after fruit setting (DAFS) the fruit infestation was the lowest while the infestation reached its peak at 30 DAFS. Fruit infestation level declined gradually from 60 DAFS to 120 DAFS. Among the different control measures evaluated against jackfruit borer, the lowest infestation was obtained from bagging treatment (3.18%) and no significant difference was observed between bagging treatment and neem oil treatment.

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LIST OF ABBRIVIATIONS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
cm	=	centimeter
^{0}C	=	Degree Centigrade
DAFS	=	Days After Fruit Settings
EC	=	Emulsiable Concentration
g	=	gram(s)
LSD	=	Least Significant Difference
m	=	million
m ton	=	metric tone
BBS	=	Bangladesh Bureau of Statistics
ml	=	milliliter
No	=	Number
RCBD	=	Randomized Complete Block Design
t/ha	=	ton/hectare
SE	=	Standard Error
%	=	Percent
@	=	at the rate of
r	=	Correlation

CHAPTER 1

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.) is the largest edible fruit in the world (Naik, 1949; Sturrock, 1977). It is one of the most popular and important fruit crop and is the national fruit of Bangladesh (Haque, 1977). It ranks third in area and second in production in Bangladesh. Jackfruit production covers 66,110 acres of land and has an annual production of 267,495 m. tones (BBS 2000). Jackfruit originally native to Indian subcontinent, is now widely cultivated in the tropics of both hemispheres (Ochas *et al*., 1981). It is one of the fruits which the small farmers of tropical Asia, America or Africa can grow with little or almost no care, thereby afforching him a more varied diet as well as a source of income (Anonymous, 1995). In Bangladesh, it is grown in all districts where rain and floodwater does not stand. Although the leading growing regions of the country are Dhaka, Saver, Bhaluca, Madhupur, hilly areas of greater Sylhet distract, Rangamati and Khargrachhari.

Jackfruit has nutritive value and in rich in carbohydrate, proteins and vitamin. A tender jackfruits are also used as vegetable. The pulp of the ripe fruit is eaten fresh and sometimes it is preserved in syrup or dried. The seed is also cooked

and used for cooking. In Greek, Arto means bread and carpus means fruits, therefore, jackfruit is also called Breadfruits. The rink (skin of fruit) and leaves are excellent cattle feed (Anonymous, 1995). Jackfruit wood is valuable for making furniture, the yellow heart wood produces a yellow dye and the latex is used as sealing material. The tree can also be used, to improve the environment of homesteads. So, jackfruit is also called multipurpose fruit tree.

Jackfruit plants *Artocarpus heterophyllus* are attacked by thirty five species of insect pest, among them jackfruit borer, *Diaphania caesalis* (Lepidoptera:Pyralidae) is the major pest of jackfruit (Tandon, 1998). All the three local types of jackfruit viz. khaja, Dorsa and Gola are equally susceptible and frequently infested by jackfruit borer (Khan *et al*, 2003). An average of 27.44% jackfruits are infested by *D. caesalis* in Bangladesh (Khan and Islam, 2004).

Jackfruit borer moth laying eggs singly on the surface of both male and female spikes or on the surface of the spathe and on the tip of the tender shoots of jackfruit (Khan *et al*. 2003). On hatching the reddish brown caterpillar bore into shoots, flowers buds and fruits of all developing stages (Soepadmo, 1991). Early infestation of jackfruit borer results in deformation of fruits and

sometimes dropping off the immature fruits. The larvae bore into the mature fruit and cause damage to the edible part. Later infested fruits frequently get rotten due to entrance of rainwater into the fruits. The entrance hole is easily visible and associated with mass of excreta. (Khan and Islam, 2004).

Jackfruit borer also attacks in nursery. Caterpillar bore into the tip of jackfruit sapling and proceeds towards the base by making tunnel. As a result the affected parts wilt and dry resulting lateral branching of sapling. Caterpillar also attacks the tip of tender shoot of mature plant and collapses the growing tip.

As jackfruit borer can attack different stage of fruits as well as the tender shoots, so it is considered as a major constraint of jackfruit production in Bangladesh. On the other hand it’s damage severity is increasing day by day. But unfortunately very little research works have so far been done on it’s biology, pest status and management in Bangladesh. As it is an internal feeder, so it’s effective control measure is very much difficult. The effectiveness of different pest management approaches has not yet been evaluated properly.

So, considering the importance of jackfruit borer for the production of jackfruit and the necessity to explore the environment friendly management packages for it, a series of research studies were undertaken with the following objectives:

1. To study the biology and morphometries of jackfruit borer.
2. To determine the pest status of jackfruit borer.
3. To develop management packages for sustainable, economic and environmental friendly control measure of the pest.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Host plant

Jackfruit (*Artocarpus heterophyllus* Lam.) is the largest edible fruit in the world (Naik, 1949; Sturrock, 1977). Jackfruit is one of the important fruits widely found in almost all homesteads of Bangladesh. Some relevant literature on jackfruit are being reviewed and described as follows:

2.1.1 Climate and Soils

The jackfruit thrives in the tropical low lands below an elevation of 1000 m. A warm, wet climate is best. It flourishes in humid hill slopes even up to an elevation of 1500m but the quality of fruits deteriorates in higher altitudes. The tree will grow on almost any soil, but prefers a deep, well-drained loam soil. Drainage must be good, on the other hand, the soil moisture content must be kept at a high level (Haque, 1995).

2.1.2 Flowering behavior

In India, Sinha (1975) found that the time of flowering in jackfruit tree varied from last week of November to first week of April. The male spikes were first to appear then the female spikes also join and both appear together since then.

He further postulated that, the spikes in jackfruit tree emerged from the latent buds of the main trunk and main branches. On an average of 41 days required for the development of spike from a tiny bud.

Samaddar (1990) stated that inflorescence of jackfruit generally started appearing in December and continued up to March and fruit ripened in summer. At higher altitude fruit growth might continue up to September. Occasionally, in rare cases off-season flowering in September to October might be noticed.

Sambamurty and Ramalingam (1954) studied floral biology of jackfruit and found that the tree is monoecious. Spikes of staminate and pistillate flowers are enclosed in thick leathery and deciduous spathes when young. Staminate spike are produced in terminal leaf axil of leader and lateral shoots. The tree develops during the flowering season special fruiting branch called footstalk. Footstalks arise mostly on the trunk, on the scaffold limbs and on shoots generally more than two years of age. Pistillate spikes occur only on footstalk arising on the trunk, primary and secondary branches. During the early part of flowering season only male spikes appear either on the footstalk or in the terminal leaf axils of shoots. Pistillate spikes follow this later in the season.

The staminate spikes drop off about a fortnight after their emergence while the pistillate ones that set, developed each into a multiple fruit. The pistillate inflorescence has a number of fertile flowers surrounded by numerous sterile or undeveloped flowers.

2.1.3 Fruiting behaviour

Jackfruit usually produces in footstalk arise from the trunk and branches of plant. Saha (1970) studied fruit set in jackfruit and obtained higher fruit set in primary branches then secondary branches and less in tertiary branches.

Azad (1985) found in jackfruit that fruits of early season were large in weight (7.1 kg) while those in late season were small (4.6 kg). He stated that shapes of the fruits also varied distinctly in different season. Early fruits were mostly regular or uniform in shape but the fruits of late season were mostly irregular.

1.7.4 Fruit drop

Thessy *et al* (1996) carried out a study in Trichur on fruit set, fruit drop and fruit development on Varikka and Koozha types of jackfruit. He reported that the post-set fruit drop ranged from 30 to 40%, the peak period of drop occurred between 60 to 80 days after emergence of spike.

An experiment was conducted at Regional Horticulture Research Station, Akbarpur, BARI (Anonymous, 1991-92) and reported that 0.46% fruit drop was caused by disease, 2.86% due to insect infestation and 7.58% fruit drop due to lack of fertilization.

2.1.5 Fruit type

Two types of jackfruit are commonly recognized, one with firm, sweet pulp and the other softer, more acid pulp (Hayes, 1966). Naik (1949) divides the jackfruit into three types, one with tender, mushy pulp, one with crisp pulp, and the rudrakshi, with fruit only the size of an ordinary pummelo, smoother and less spiny than the other kinds, and pulp of slightly inferior character. Haque (1993) reported three types of jackfruit namely Khaja-hard pulp, Gala-the pulp is very juicy and soft, Dorosa-the pulp is fairly firm and juicy.

2.1.6 Fruit maturity and time of harvesting

In Asian countries the fruits ripen principally from March to June, April to September or June to August, depending on the climatic region. Singh *et al*. (1963) and Naik (1949) reported that some off-season crops from September to December or a few fruits at other times of the year. Anonymous (1969) stated in “Hand Book of Agriculture” that the harvesting season of jackfruit was from

March to June, the season might be extended up to September at higher elevations.

2.2 The insect

Jackfruit borer, *Diaphania caesalis* (Lepidoptera: Pyralidae) is considered as the one of the major pest of Jackfruit, which reduces both the quality and quantity of fruit. It is a very common pest in India and Bangladesh. The incidence of this pest occurs sporadically or in epidemic form every year throughout Bangladesh. In the favorable weather severe infestation may occur and maximum fruits may be infested. Several insect pests cause both qualitative and quantitative losses of this fruit. But published literature on the pest especially on it's biology, pest status and management are scanty. Only a few works on the biology and life history of the pest are available. However, review of the available literatures relevant to the present study is presented below under the following sub-headings.

2.2.1 Taxonomic position

Jackfruit borer, *Diaphania caesalis*, is a destructive lepidoteran insect pest. *Diaphania caesalis* (Walker) was originally described by Walker (1859) as *Glyphodes caesalis* sp. nova; subsequently, it was transferred to genus

Margaronia, then to genus *Palpita* and finally Wang (1963) placed it under genus *Diaphania*. The systematic position of the pest is given below:

Phylum: Arthopoda

Class: Insecta

Sub-class: Pterygota

Division: Endopterygota

Order: Lepidoptera

Family: Pyralidae

Genus: *Diaphania*

Species: *Diaphania caesalis*

2.2.2 Distribution

Jackfruit borer was found almost all the jackfruit growing countries. In India it is found in several states. Fletcher (1914) reported *G. caesalis* as a pest of jackfruit in Karnataka and Maharashtra. It is also recorded from Assam, Sikkim, Bihar, Uttar Pradesh, Andhra Pradesh and Tamil Nadu of India (Chowdhury and Majid, 1954). Outside India, it has been reported from Borneo, Burma and Sri Lanka (Hampson, 1986) and also in Bangladesh (Alam *et al*., 1964).

2.2.3 Pest Status

Thirty-five species of insect pests have been recorded on jackfruit from India. However, the important of them are shoot and fruit borer (*Diaphania caesalis*), mealybugs (*Drosicha mangiferae* and *Nipaecoccus viridis*), bark eating caterpillar (*Indarbela tetraonis*), stem borer (*Batocera rufomaculata*), aphid (*Greenidia artocarpi*), scale insect (*Semelaspidus artocarpi*) and spiraling whitetly. The shoot and fruit borer, *D. caesalis*, is one of the major insect pests of jackfruit in India (Tandon, 1998).

Similarly Chowdhury and Majid (1954) recorded it as a major pest in Assam, Nair (1975) reported that the pink caterpillar of *Margaronia caesalis* have black warts and bristly hairs which bores into the tender shoots, flower buds and young fruits in South India.

Alam (1962) reported that the jackfruit borer is an important pest of jackfruit in East Pakistan. It is the major insect pest of jackfruit in Bangladesh (Karim, 1995). Khan *et al. (2003)* observed that all the three local types of jackfruit viz. khaja, Dorsa and Gola are equally susceptible and frequently infested by jackfruit borer. It was also reported that on an average 27.44% jackfruits are infested by *D. caesalis* in Bangladesh (Khan and Islam, 2004).

2.2.4 Biology and Morphometrics

Alam (1962) has described the biology and life history of jackfruit borer. The adult moth is about half-an inch long with black edge bands and pale yellow patches on wings (Plate-12). The adult female moth lays her eggs on leaf, shoot and flower bud. The first instar larva is very tiny. The full-grown caterpillar is pinkish, each segment banded with numerous black flattened horny warts from which arise single short bristly hairs (Plate-10). Head and prothoracic shield become yellow. Pupation takes place in a silken cocoon made by the caterpillar inside the fruit tunnel several inches long, twisted dried of leaf or on the surface of nearest two more fruits. Pupa is red brown in colour(Plate-11) and pupal period is about a week.

Butani (1979) illustrated that the caterpillar posses yellowish head and prothorax with reddish brown body having numerous blacks flattened horny warts each bearing one short bristle like hair. Pupae are reddish-brown. Adults are whitish-brown moths having wings with grayish elliptical patterns and a marginal series of black specks; wing expanse is 26 to 30 mm, females being slightly bigger than males.

2.2.5 Nature and extent of damage

In India the pest is active from May to October. Eggs are laid on tender shoots and flower buds. On hatching the caterpillars bore into tender shoots, flowering buds and developing fruits and tunnel through the same. As a result, the shoots wilt and droop, buds dry and drop down and the fruits start rotting (Butani 1978).

Alam (1962) reported that the young caterpillar bore in to the buds and leaves mining the midribs. The young caterpillar also feed on leaves as well. They generally bore into flower buds and young fruits and sometimes in to the young shoots.

Tendon (1998) illustrated that on hatching the reddish-brown caterpillars bore into shoots, flower buds and fruits. As a result, the affected parts wilt and dry. Severe infestation on fruits may induce drop.

Azad and Haq (1999) described that caterpillar makes tunnels into buds, young shoot and fruit. Infestation during flowering stage causes fruit drop. At mature stage infestation increase and as a result, it fetches less price in the market.

Khan *et al*. (2003) reported that jackfruit borer moth laying eggs singly on the surface of both male and female spikes or on the surface of the spathe and on the tip of the tender shoots of jackfruit. On hatching the reddish brown caterpillar bore into shoots, flowers buds and fruits of all developing stages(Plate-1&2) (Soepadmo, 1991). Early infestation of jackfruit borer results in deformation of fruits and sometimes dropping off the immature fruits(Plate-3). The larvae bore into the mature fruit and cause damage to the edible part(Plate-4,5&6). Later infested fruits frequently get rotten due to entrance of rainwater into the fruits. The entrance hole is easily visible and associated with mass of excreta. (Khan and Islam, 2004).

Khan et al. (2003) also reported that jackfruit borer also attacks in nursery. Larvae bore into the tips of jackfruit saplings and proceeds towards the base by making tunnel(Plate-7). As a result the affected parts wilt and dry resulting lateral branching of sapling. Caterpillar also attacks the tip of tender shoot of mature plant and collapses the growing tip.

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Plate 1: Caterpillar feeding on spike

Plate 2: Tunnel in spike formed by jackfruit borer

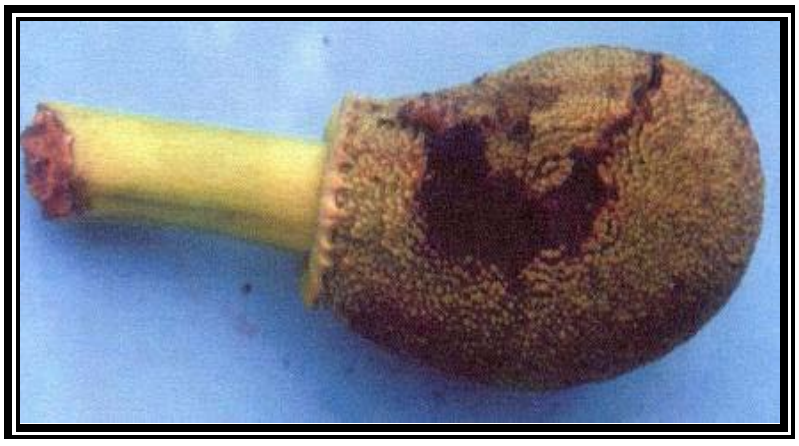

Plate 3: A dropped spike due to jackfruit borer infestation

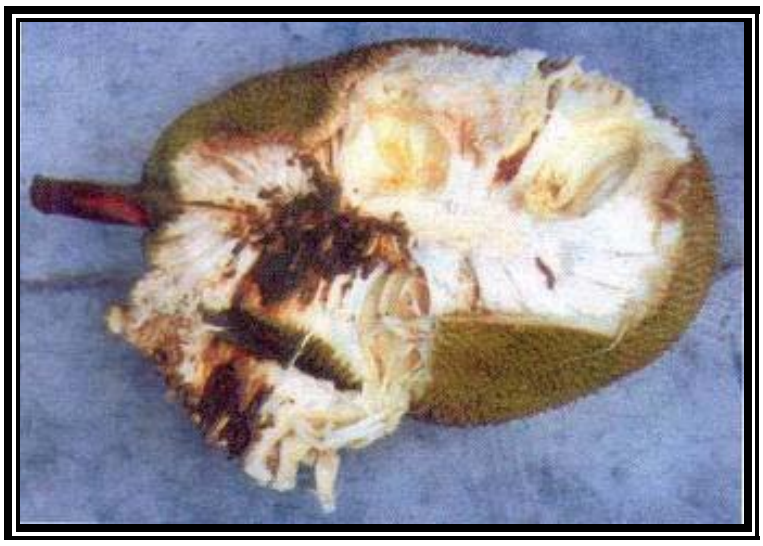

Plate 4. Longitudinal section of mature fruit showing damage by jackfruit borer

Plate 5. Feeding of matured jackfruit by larvae of jackfruit borer

Plate 6. A caterpillar is boring mature fruit

Plate 7. Tunnel of jackfruit borer by feeding internal tissues of shoot

2.2.6 Management

Alam (1962) recommended that during the flowering season spraying of Folidol-M 50 (0.04%) or Dimecron 100 (0.03%) and BHC or DDT (0.02%) for controlling this insect pest. Two treatments are necessary at an interval of 3 weeks during the month of December

Karim (1995) recommended that trees showing the infestation sign at flowring should be sprayed with Cypermethrin (Ripcord/Cymbush/Arrivo /Basathrin/ other) 10 EC or Decis 2.5 EC at the rate of 1.0 ml/liter of water or Fenitrothion (Sumithion/Folithion/others) 50 EC or Diazinon 60 EC at the rate of 2.0 ml/liter of water. A second spray should be given after 15 days of first application where necessary.

To protect the fruits from ravages of this pest covering the fruits with alkathene bags may be practiced (Madhava Rao, 1965). Removal and destruction of the affected shoots, flower buds and fruits in the initial stage of attack should be followed.

Tendon (1998) stated that for the management of shoot borer, the affected parts should be removed and destroyed in the initial stage of attack. To protect from the oviposition, fruit should be covered with alkathene bags.

Hayes (1996) reported that this pest might be controlled by hand picking or spraying with BHC or DDT.

CHAPTER 3

MATERIALS AND METHODS

Series of experiments were undertaken to study "Biology, pest status and management of jackfruit borer. *Diaphania caesalis* Walker." Among them biology and management of the pest were conducted at Fruit orchard of Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, while survey on the fruit infestation through direct count and through farmers' interview at four locations of Gazipur district. On the other hand incidence of fruit infestation was also studied at 10 different jackfruit orchards of Gazipur district. The study area is situated at 24.09° North latitude and 90.26° East Longitudes with an elevation of 8.4 meter from the sea level. All the studies were done during January 2005 to August 2005. The materials and methods adopted in the study are discussed in the following sub-heading:

3.1 Climates

The climatic condition of Gazipur has unimodal rainfall pattern; most of the rainfall occurs during the months of May to September. The average rainfall is usually higher than 200 mm during November to March. The warmer months are April, May and June with mean maximum temperature of 31- 34°c and the

cold months are November, December and January when the temperature ranges from 10-19°C.

3.2 Soil

The area belongs to the Madhupur tract (AEZ-28), clay loam in texture having low organic matter (1.12%) moderately slow permeability and deficient in nitrogen, potassium and sulphur in comparison with the standard nutrient status. The soil is acidic in nature having pH between 5.9 to 6.1.

3.3 Biology and morphometries

This study was carried out at IPM laboratory of Entomology Division, Bangladesh Agricultural Research Institute, Gazipur during February to June 2005. Pupae of *Diaphania caesalis* were collected from the jackfruit plants and kept in petridishes for adult emergence. A pair of freshly emerged male and female adults were caged in fine meshed nylon net with a small jackfruit twig having male and female spikes. The adults were allowed to mate and the female oviposit on the twigs and spikes which were checked carefully everyday at 12.30 PM for egg laying. The number of eggs per batch and per female were counted and allowed to hatch. The incubation period was then recorded. Egg hatching percentage was then calculated. The newly hatched

larvae were reared on the same spike. The larvae were observed daily until pupation to record the larval duration. When feeding stopped, the larvae were kept undisturbed for pupation and the pupal period was recorded. After emergence, the moths were observed daily to determine the longevity of the male and female jackfruit borer. The morphology of different stages of *D. caesalis* was also studied by measuring the size (length and breadth). The behaviour of the insect was noted during the experimental period. Following the same method biology and the morphology of the pest were studied for three generations.

3.4 Infestation status

Infestation status through direct count: One hundred plants were randomly selected from each location of Sreepur, Joydebpur and Kapasia of Gazipur district. A total of 4 observations were made per fruiting season from each location. The first observation was made at 30 days after fruit setting (DAFS), the second at 60 DAFS, the third at 90 DAFS and the fourth at 120 DAFS. Number of healthy and infested fruits were counted and recorded from the selected plants at different observations. Data of four observations were pooled and the mean was calculated. Percent fruit infestation was also calculated.

Infestation status through farmers' interview: A total of randomly selected 25 jackfruit growers were interviewed from each location of Lakhpur of Norsingdi district, Shreepur and Kapasia of Gazipur District to understand their views on the jackfruit borer. One set of objective-oriented questionnaire (Appendix I) was provided to each jackfruit grower to collect his views on the infestation status of jackfruit borer. The survey was done during 2005 fruiting season (February – June 2005). The farmers' interviews were recorded to reflect the farmers' perception about the severity of jackfruit borer.

3.5 Incidence of fruit infestation

Incidence of fruit infestation by the borer was studied from three locations, Kapasia, Sreepur & Joydebpur of Gazipur district. Numbers of healthy and infested fruits were counted and recorded from 25 randomly selected plants of each location by observation each plant carefully at 15 days interval from the first fruit setting till last harvest. The percentages of fruit infestation were calculated and plotted in a graph.

3.6 Management

The study was carried out at Fruit orchard of BARI Gazipur during February to August 2005. Five treatments were evaluated to find out the effective management tactics against jackfruit borer. The treatments were as follows:

1) Neem oil: Three sprayings of neem oil @ 10 ml/L of water + soap solution 5 g/L were done at 30, 45 & 60 days after fruit setting (DAFS).
2) Dimethoate (Tafgor 40 EC): Three sprayings of dimethoate (Tafgor 40 EC) @ 2.5 ml/L of water were done at 30, 45 & 60 days after fruit setting (DAFS).
3) Cypermethrin (Ripcord 10 EC): Three sprayings of Cypermethrin (Ripcord 10 EC) @ 1.0 ml/L of water were done at 30, 45 & 60 days after fruit setting (DAFS).
4) Bagging: Three plants are selected for fruit covering. Ten fruits from each plant were randomly covered by polyethylene bag after fruit setting. The size of the polyethylene bag was 55cm x 85cm. Twenty tiny holes were made with an ordinary pin at the bottom of the polyethylene bag for aeration and removal of water (transpiration and rainwater). The open end of polyethylene bag was tied with hard base (gray portion) of footstalk by rope. As the larva is able to penetrate the green soft portion of the footstalk the covering was made up to the base of the stalk.

5) Before covering the fruit a thorough cheek was made so that no infestation or on stage of the pest (egg, larva, pupa) exist on it. If any structure was found the covering of the fruit was made after destruction of it. Fruit remained covered up to harvesting. Data of fruit infestation were recorded both from covered and uncovered fruit of a plant. The weight of covered and uncovered fruit was also recorded.

5) Untreated control.

The spraying was done with the help of foot pump sprayer. The experiment was laid out in a RCB design with 3 replications. Each plant was considered as one replication. The control plants were sprayed with water only. All necessary precautions were taken during application of insecticides.

3.6.1 Data collection and analysis

Data on healthy and infested fruits were recorded from each plant and percent infestation was calculated according to the following formula:

$$\% \text{ fruit infestation} = \frac{Number\ of\ \text{inf}\ ested\ \ fruits / plant}{Total\ number\ of\ \ fruits / plant} \times 100$$

A jackfruit with single bore by fruit borer was considered as infested fruit. No sign of attack was considered as uninfected fruit. All the data were analysed

statistically followed by MSTAT programming and the mean value were judged by LSD ($P>0.05$). Standard error of each parameter was also calculated.

CHAPTER 4

RESULTS AND DISCUSSION

Results of different studies on biology, pest status and management of jackfruit borer. *Diaphania caesolis* Walker have been presented and discussed under the following sub-heading:

4.1. Biology and morphometrics

4.1.1 Egg:

The moth, *Diapharia caesalis* laid eggs singly on the surface of the spikes (Plate-8) or on the surfaces of the spathe and on the tip of the tender shoots of jackfruits. During oviposition period a female moth laid on an average of 31.29 eggs (mean of three generation) in 5 to 6 batches. (Table 1). Eggs were spindles shaped with smooth and shiny surface. The eggs were pale brown to brown in colour. The average length and breath of the eggs were 0.76 mm and 0.567 mm (mean of three generation) (Table 1). Although there was no significant variation in the size of eggs in the three generations. The average incubation period of the eggs was 4.5 days (mean of three generation) (Table 1). However, the difference of incubation period between two generation

depended on environmental factor specially temperature and humidity. Eggs were laid in batches.

Table 1. Egg characteristics of Jackfruit borer

Generations	Egg laid/ female (No.)	Egg length (mm)	Egg breadth (mm)	Incubation period (days)
Generation 1	33.50±2.33	0.80±0.17	0.57±0.11	4.8±0.21
Generation 2	30.26±1.78	0.79±0.12	0.57±0.19	4.4±0.32
Generation 3	30.13±1.14	0.71±0.28	0.56±0.28	4.3±0.65
Mean	31.29	0.76	0.57	4.5

± Standard Error (SE)

4.1.2 Larvae

Newly hatched larvae were very minute with whitish brown body and dark head and the body was covered with sparsely distributed hairs. With the maturity of larvae the body colour changed to pinkish with black spot on both the dorsal and lateral side of the body(Plate-10). The body of larvae was soft and 11 segmented with abdominal prolegs and mature larvae bears a long head of orange colour. The average length breath and weight of mature larvae was

18.47 mm, 2.177 mm and 0.1375 gm (mean of three generation) (Table 2). Larvae of first generation was larger than the consecutive generations. The average total duration of larval period was 12.01 days (mean of three generation) (Table 2). The difference in the larval period may be dependent on sources of food with the variability of different environment factors. Larval stage is the most distractive stage.

Table 2. Larval characteristics (length, breadth, weight & duration of larval period) of Jackfruit borer

Generations	Larval length (mm)	Larval breadth (mm)	Larval weight (mm)	Larval period (days)
Generation 1	19.22±1.98	2.436±0.64	0.149±0.07	12.48±1.12
Generation 2	18.36±1.43	2.122±0.89	0.134±0.05	12.17±1.32
Generation 3	17.84±1.29	1.973±0.92	0.131±0.09	11.37±1.65
Mean	18.47	2.177	0.137	12.01

4.1.3 Pupa

Pupal stage is a non-feeding stage of jackfruit borer. When larva attainted maturity, it stops feeding and spins the pupal case underside of jackfruit leaf or twisted dried leaf or on the surface of nearest two or more fruits or top of the made hole of fruits. Pupation occurred inside the pupal case. The pupa is chocolate in colour and object type(Plate-11). The length, breath and weight of pupa were 13.23 mm, 2.92 mm, 0.11 gm, respectively (mean of three generations) (Table 3). The average duration of the pupa was 6.83 days (mean of three generations) (Table 3).

Table 3. Pupal characteristics (length, breadth, weight & duration of pupal period) of Jackfruit borer

Generations	Pupal length (mm)	Pupal breadth (mm)	Pupal weight (mm)	Pupal period (days)
Generation 1	13.6±2.08	3.08±0.56	0.12±0.02	7.12±0.86
Generation 2	13.2±1.65	2.87±0.76	0.11±0.03	6.45±0.82
Generation 3	12.9±1.16	2.81±0.94	0.10±0.06	6.92±0.54
Mean	13.23	2.177	0.11	6.83

± Standard Error (SE)

4.1.4 Adult

The adult moth comes out from the pupa through the opening of cocoon. Newly emerge moth is pale brown in colour which after a few hours changes to cream colour. The adults after emergence remain quite silent and they do not take any food and rarely fly. The female is sightly larger than male. The body is covered with cream colours scales. It bears compound eyes. Antennae are segmented and covered with scales. The wings colour is combination of cream and brown. Semi-circular brown spots present on the surface of the wings. Both the front and hind pairs of wings are covered with scales and fringed with hairs at the edge(Plate-12). The legs are walking type and more or less equal in size and shape. The average length, breath and wings spread of the adult are 14.34 mm, 3.33 mm and 26.08 mm (mean of three generations) (Table 4). Average longevity of the adult was 4.67 days (mean of three generations) (Table 4).

Table 4. Adult characteristics (length, breadth, wing spread & longevity) of jackfruit borer

Generations	Adult length (mm)	Adult breadth (mm)	Wing spread (mm)	Longevity (days)
Generation 1	14.59±1.12	3.5±0.96	26.28±0.07	5.2±0.86
Generation 2	14.31±1.76	3.3±0.83	26.12±0.05	4.5±0.94
Generation 3	14.12±0.87	3.2±0.76	25.84±0.09	4.3±0.46
Mean	18.47	3.33	26.08	4.67

± Standard Error (SE)

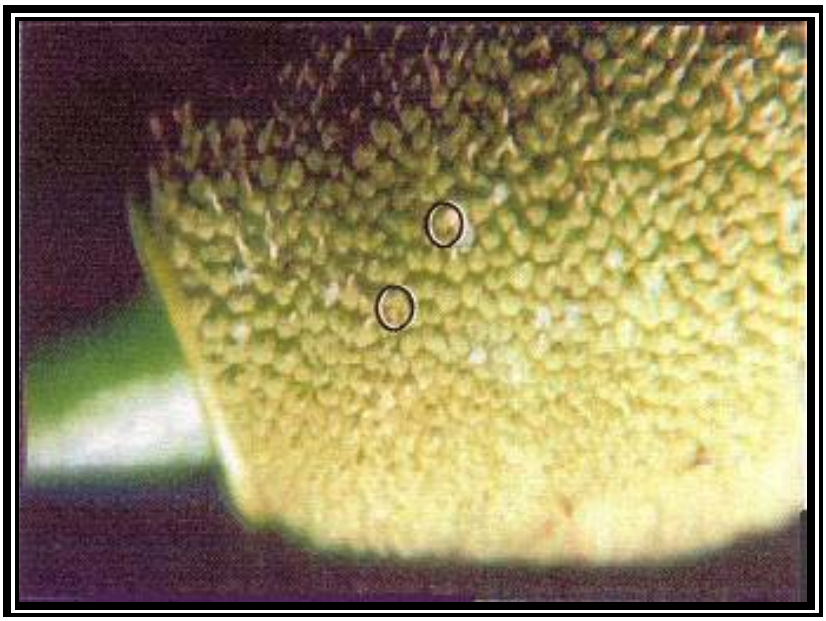

Plate 8. Eggs of jackfruit borer on female spikes

Plate 9. First instar larvae of jackfruit borer

Plate 10. A mature larva of jackfruit borer

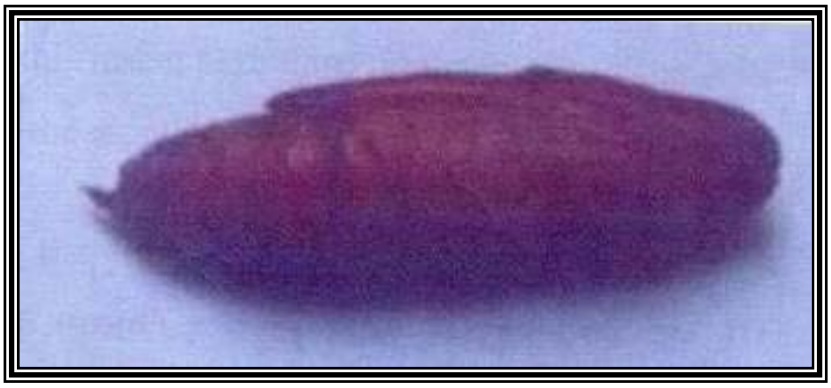

Plate 11. Pupa of jackfruit borer, *D. caesalis*

Plate 12. Adult jackfruit borer, *D. caesalis*

4.2 Infestation status

4.2.1 Percent fruit infestation as per direct count: In case of direct count, data on healthy and infested fruits were collected from total fruits of each plant. It is revealed from the Table 5 that the height fruit infestation was recorded at Joydebpuer (30.64%), followed by Kapasia (24.05%).

Fruits of Sreepur had the lowest infestation (21.08%). Rasel (2004) conducted a survey at three villages (Niluapara, Vhanaipur and Kewa Paschim, Khanda) of Joydebpur and reported that the maximum fruit infestation by jackfruit borer was 28.8% and the lowest was 21.6%.

4.2.2 Percent fruit infestation as per farmers view: Results of direct count for fruit borer infestation was also reflected in farmers' view. It is observed from the Table 5 that Joydebpur farmers' viewed the highest fruit infestation (53.78%) followed by the farmers' of Kapasia (32.84%) and Sreepur (28.96%).

4.2.3 Farmers' awareness on jackfruit borer: Joydebpur farmers were also found as the most conscious about the attack of jackfruit borer among the three studied locations. Around 98.5% farmers' knows about the seriousness of the borer infestation at Joydebpur followed by 68.5% farmers' of Sreepur. On the other hand Kapasaia farmer's were less conscious about the matter.

Table 5. Infestation status of jackfruit borer at different locations of Gazipur district during fruiting season 2005

Locations	% fruit infestation through direct count *	% fruit infestation through farmers' view *	% Farmers' awareness on jackfruit borer *
Joydebpur	30.64±4.33	53.78±3.76	95.5±1.22
Sreepur	21.28±3.01	28.96±4.36	68.5±1.85
Kapasia	24.05±3.41	32.54±3.24	48.4±2.87

± Standard Error (SE)

* Infested & healthy fruits data were collected from total fruits of each plant

4.3 Incidence of fruit infestation

It is revealed from the figure 1 that at 30 days after fruit setting (DAFS) highest fruit infestation happened at all the locations, 18.35% at Joydebpur, 10.36% at Sreepur and 13.20% at Kapasia. Lowest infestation occurred at 15 DAFS, which gradually increased to the peak within 45 days (at 60 DAFS). Infestation of borer then gradually decreased. Although even at 120 DAFS infestation of jackfruit borer was observed, which means that the borer can infest the matured fruits also.

Among the three locations, lowest infestation was consistently recorded at Sreepur and highest infestation at Joydebpur (Figure 1). On the other hand Kapasia had the medium infestation rate among the three locations.

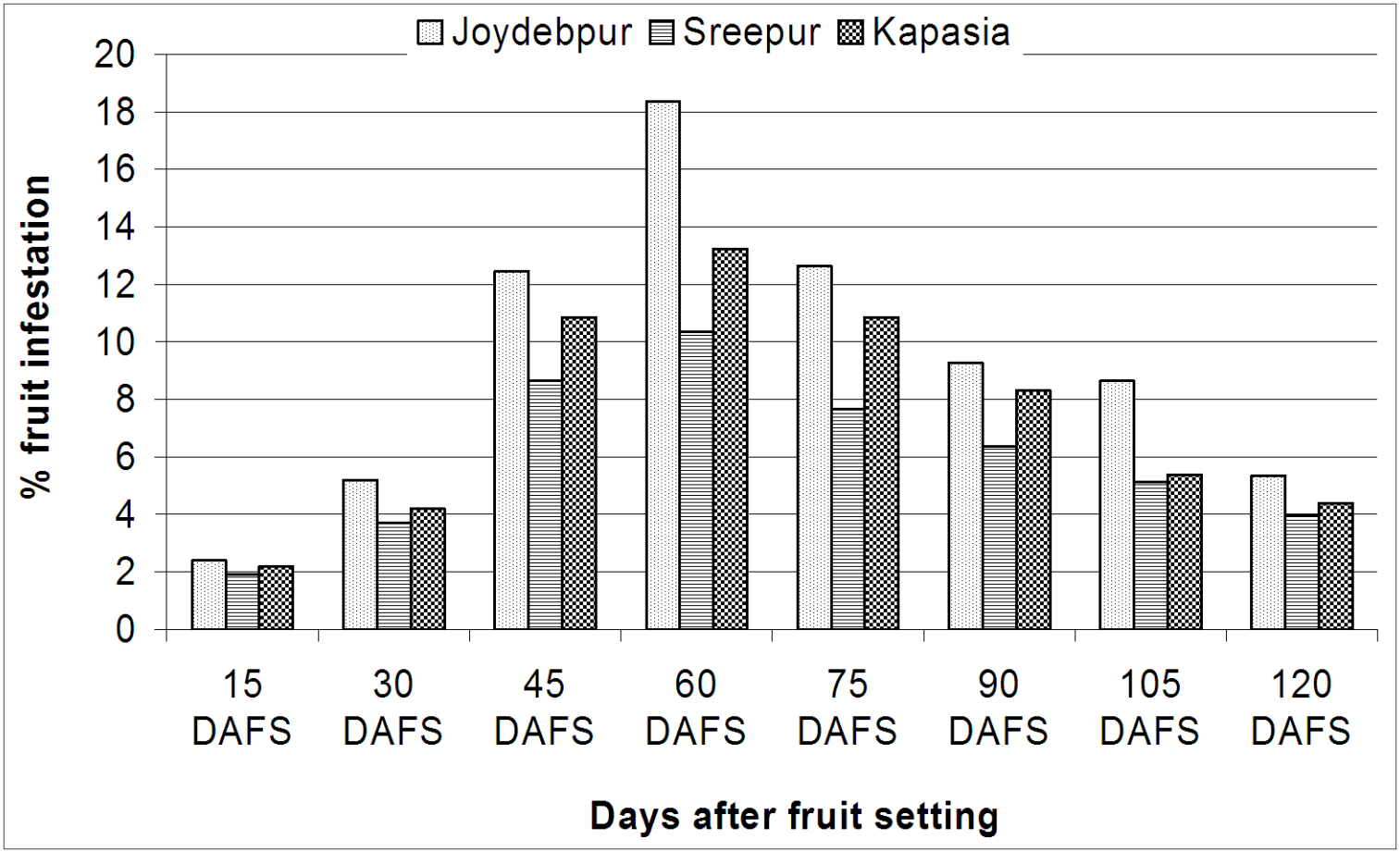

Fig. 1. Incidence of jackfruit borer at different days after fruit setting during 2005 fruit year at three different locations of Gazipur district

4.4 Management

Study on the jackfruit borer management was done at Fruit Farm, Horticulture Research Center, BARI, Gazipur during 2005 fruiting season. Five treatments, viz. spraying of neem oil 10 ml/L of water + soap solution 5 g/L of water, spraying of Dimethoate (Tafgor 40 EC) @ 2.5 ml/L of water, spraying of Cypermethrin (Ripcord 10 EC) @ 2.5 ml/L of water, Bagging of fruits were evaluated for jackfruit borer control along with a untreated control.

Table 6. Effect of different treatments on the management of jackfruit borer at

Fruit Farm, BARI, Gazipur during 2005 fruiting season

Treatments	% Jackfruit borer infestation	% reduction over control
Spraying of neem oil (@ 10 ml/L of water + soap solution 5 g/L)	3.94±0.86 d	78.98
Spraying of Tafgor 40 EC (Dimethoate) (@2.5ml/L of water)	5.64±0.98 cd	69.92
Spraying of Ripcord 10 EC (Cypermethrin) (@1.0 ml/L of water)	9.23±1.02 b	50.77
Bagging of fruits	3.18±0.79 d	83.04
Untreated control	18.75±1.74 a	

* Means of 3 replications, Means followed by the same letter did not differ significantly by LSD ($p<0.05$)

It is revealed from the Table 6 that the lowest infestation was obtained from bagging treatment (3.18%) followed by neem oil treated plants (3.94%). Although there was no significant difference among them. Between the two insecticides tested against jackfruit borer, Tafgor 40 EC gave the highest protection against jackfruit borer than Ripcord 10 EC. The percent fruit infestation of Tafgor 10 EC treated plants were also not significantly differed with that of bagging and neem oil treatment. Highest infestation was happened in the untreated control plants (18.75%).

Bagging of fruits also have highest percent reduction of infestation over control (83.04%) followed by neem oil (78.98%), Tafgor 40 EC (69.92%) and Ripcord 10 EC (50.77%). So, from this study it indicates that fruit covering could protect the fruit from the damaging activity of jackfruit borer (Plate-13). Weight of covered fruit was higher than the uncovered one but difference was insignificant. Color of the covered fruit was bright greenish-yellow and looked better than uncovered fruit. The covering not only protects the fruit from the attack of jackfruit borer but also from other insect pests. Better appearance of covered fruit may have higher market price. Madhava Rao (1965) described that protection of the fruits from the ravages of this pest was due to covering of the fruits with alkathene bags. Tendon

(1998) stated that to protect from the oviposition, fruits should be covered with alkathene bags. Fruit covering increases yield of fruit, reduces pest problem and could contribute to sell with

Plate 13. Jackfruit covered by polyethylene bag

higher market price due to attractive appearance. Following the method jackfruit growers can avoid use of insecticides and would be able to produce organic fruits for better markets in home and abroad.

On the other hand growers can also effectively control the pest with neem oil as well as with insecticide Tafgor 40 EC. Rahman et al. 2005 also observed lowest infestation from neem oil (@ 10 ml/L + Trix 5ml/L of water) treated fruits and no significant difference was observed from Dimethoate (Tafgor 40 EC) treated fruits.

It was also reported that trees showing the infestation at flowering stage should be sprayed with Cypermethrin (Ripcord/Cymbush/Basuthrin 10EC) @1.0 ml/L or Desis 2.5 EC @ 1.0 ml/L or Fentriothion (Sumithion/Follithion/others) 50 EC. A second spray application should be given after 15 days of first application where necessary (Annonymous, 1995).

CHAPTER 5

SUMMARY AND CONCLUSION

Several studies were undertaken to study "Biology, pest status and management of jackfruit borer. *Diaphania caesalis* Walker" in the farmers' orchard of Gazipur district and in the laboratory and Fruit Farm of Bangladesh Agricultural Research Institute, Gazipur during January 2005 to August 2005.

In the biology and morphometrics experiment of jackfruit borer the characteristics of eggs, larvae, pupae and adult were studied. During oviposition period a female moth laid on an average of 31.29 eggs (mean of three generation) in 5 to 6 batches. Eggs were spindles shaped with smooth and shiny surface. The average length and breath of the eggs were 0.76 mm and 0.567 mm (mean of three generation) The average incubation period of the eggs was 4.5 days (mean of three generation). Newly hatched larvae were very minute with whitish brown body and dark head and the body was covered with sparsely distributed hairs. Matured larvae were soft and 11 segmented with abdominal prolegs and mature larvae bears a long head of orange colour. The average length breath and weight of mature larvae was 18.47 mm, 2.177 mm and 0.1375 gm (mean of three generation). The

average total duration of larval period was 12.01 days (mean of three generation). When larva attainted maturity, it stops feeding and spins the pupal case underside of jackfruit leaf or twisted dried leaf or on the surface of nearest two or more fruits or top of the made hole of fruits. The pupa is chocolate in colour and obtect type. The length, breath and weight of pupa were 13.23 mm, 2.92 mm, 0.11 gm, respectively (mean of three generations). The average duration of the pupa was 6.83 days (mean of three generations). The adult moth comes out from the pupa through the opening of cocoon.. Newly emerge moth is pale brown in colour which after a few hours changes to cream colour. The body of adult moth is covered with cream colours scales. The wings colour is combination of cream and brown. semi-circular brown spots present on the surface of the wings. Both the front and hind pairs of wings are covered with scales and fringed with hairs at the edge. The average length, breath and wings spread of the adult are 14.34 mm, 3.33 mm and 26.08 mm (mean of three generations). Average longevity of the adult was 4.67 days (mean of three generations).

Infestation status of jackfruit borer was determined by direct count and as per farmers' view. In case of direct count it was observed that the height fruit infestation was recorded at Joydebpuer (30.64%), followed by Kapasia

(24.05%). Fruits of Sreepur had the lowest infestation (21.08%). Results of direct count for fruit borer infestation were also reflected in farmers' view. Joydebpur farmers' viewed the highest fruit infestation (53.78%) followed by the farmers' of Kapasia (32.84%) and Sreepur (28.96%). Joydebpur farmers were also found as the most conscious about the attack of jackfruit borer among the three studied locations. Around 98.5% farmers' knows about the seriousness of the borer infestation at Joydebpur followed by 68.5% farmers' of Sreepur. On the other hand Kapasaia farmer's were less conscious about the matter.

It was reported that at 30 days after fruit setting (DAFS) highest fruit infestation happened while lowest infestation occurred at 15 DAFS, which gradually increased to the peak within 45 days (at 60 DAFS). Infestation of borer then gradually decreased. although even at 120 DAFS infestation of jackfruit borer was observed, which means that the borer can infest the matured fruits also. Among the three locations, lowest infestation was consistently recorded at Sreepur and highest infestation at Joydebpur. On the other hand Kapasia had the medium infestation rate among the three locations.

Among the different control measures evaluated against jackfruit borer, lowest

infestation was obtained from bagging treatment (3.18%) followed by neem oil treated plants (3.94%). Although there was no significant difference among them. Between the two insecticides tested against jackfruit borer, Tafgor 40 EC gave the highest protection against jackfruit borer than Ripcord 10 EC. The percent fruit infestations of Tafgor 10 EC treated plants were also not significantly differed with that of bagging and neem oil treatment. Highest infestation was happened in the untreated control plants (18.75%).

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Appendix I: Incidence of jackfruit borer at different location of Bangladesh

District :

Upazilla :

Village :

Sample no.

Parameter	Plant						
	P1	P2	P3	P4	P5	Total	Average
Total Fruit							
Infested fruit							
No. of bore /infested fruit							
Weight of fruit							
Weight of damage portion							