LIFE HISTORY TRAITS OF *DERMESTES MACULATUS* DE GEER (COLEOPTERA: DERMESTIDAE) FED ON FRESH WATER AND MARINE DRIED FISH AND ITS MANAGEMENT USING EDIBLE BOTANICALS AND MINERAL POWDER

A THESIS

BY

Farah Ulfat Rahman

Student No. 2205091

Semester: July-December, 2023

Session: 2022-2023

MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

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Submitted to the Department of Entomology
Hajee Mohammad Danesh Science and Technology University, Dinajpur
in partial fulfillment of the requirements for the degree of

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DECEMBER 2023

DEDICATED

TO MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

I acknowledge and express my all praises to the Almighty **"ALLAH"** the merciful and the beneficent to all creations, who has enabled me to complete this piece of research work and submit this thesis successfully in time for the degree of Master of Science (MS) in Entomology.

It is my pleasure to express my sincere appreciation, heartfelt respect and indebtedness to my honorable teacher and Research Supervisor, **Professor Dr. Hasan Fuad El Taj**, Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur-5200 for his constant inspiration, scholastic guidance, instruction and invaluable suggestion during this research work and kind cooperation and affectionate feeling during preparation of the thesis. Heartiest gratitude and deep sense of admiration to my honorable teacher and Co-supervisor **Professor Dr. Alamgir Hossain**, Department of Entomology, HSTU, Dinajpur for his kind help, day to day cooperation, endless encouragement, priceless advice in successfully completing this work.

I express my gratefulness to all the teachers of the Department of Entomology, HSTU, Dinajpur, for their inspiration, encouragement and feelings during the course of M.S. studies.

I would like to express gratefulness and thanks to all staffs and employees of the Department of Entomology, HSTU, Dinajpur for their co-operation during the research.

I express a deep appreciation to my parents for their endless love, support, encouragement and prayer. They have always encouraged me in all of my pursuits and without them the thesis preparation was not possible. I would like to give my thanks whole heartedly to all my relatives, friends and well-wishers for their cooperation, inspirations and affectionate feelings towards the successful completion of the study.

Finally, I acknowledge Almighty **"ALLAH"** for bestowing blessing on me in fulfillment of the requirements for the M. S. degree in Entomology.

The Author

ABSTRACT

The hide beetle, *Dermestes maculatus* De Geer, is a significant pest in dried fish storage worldwide. The objective of this work was to determine the effect of different species of dried fish as Ganges river sprat, Gangetic anchovy, Giant sea perch, Bombay duck, Indian oil sardine as foods of *D. maculatus* on food ability, developing, fecundity, life table parameters and control via edible plant products. The study was conduct of under laboratory conditions at 30±5 ˚C, 80 ±10% R.H. The research investigated diverse aspects of the life cycle and reproductive features of *D. maculatus* De Geer. The results indicated that the incubation periods of various fish species varied; the Indian oil sardine had the longest observed incubation period (2.62 days), while the Ganges river sprat had the shortest (2.23 days). The larval development periods ranged from 24 to 26.92 days for males and 23.01 to 26.47 days for females. Notably, the Ganges River sprat exhibited the shortest pupal developmental time at 5.61 days, while the Giant Sea Perch presented the longest duration at 6.56 days. Ovipositional periods varied, with Gangetic anchovy (29.87 days) and Indian oil sardine (41.06 days) showing the highest and lowest values, respectively. Furthermore, the study observed variations in egg laying rates and adult longevity across different fish species. Generation time (T) was lowest for Ganges river sprat (51.23 days) while highest for Bombay duck (63.98 days). The net reproductive rate(R_0) was highest for Bombay duck (195.13 offspring) but lowest for Ganges river sprat (46.07 offspring). Intrinsic(r_m) and finite(λ) rates of natural increase were lowest for Ganges river sprat (0.075 day-1; 1.07 day-1). Population doubling time (DT) was shortest for Indian oil sardine (8.33) while longest for Ganges river sprat (9.27). The gross reproductive rate (GRR) was highest for Bombay duck (213.27) but lowest for Ganges river sprat (69.10). The maximum infestation rate was found in Indian oil sardine (49.67%), while the minimum was found in Giant sea perch (4.53%). Additionally, in a control experiment involving edible botanicals and minerals, Ajwain powder exhibited the highest efficacy in mortality rates for both adult and larval stages of *D. maculatus*.

Key Words: Hide beetle, Dried fish, Life table parameters, Management

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INTRODUCTION

Dried fish is one of the important popular food items and is widely consumed in Bangladesh. It accounts for the 4th largest share of fish consumed and is the most accessible type of fish for consumers across all income levels and in the livelihoods of actors in fisheries value chains throughout Asia and Africa. Drying is the biggest fish processing activity in both value and volume in coastal region as well as all over Bangladesh. Dried fish has years of storage life, and we use "dried fish" as a catchall term for this category of foods, broadly defined here as any aquatic animal product that has undergone processing that enables it to be stored as food at room temperature for extended periods of time without specialized industrial packaging. The market for safe and hygienic dried fish is expanding and has great potential. In the 2020-21 season, Bangladesh produced 46.21 lakh metric tons of fish, 20% of which was processed as dried fish (The business standard, 2023). Approximately 30% of India's entire fish catch is preserved through curing, which includes salting, drying, smoking, or a combination of those methods (ANNR-cochin, 2016). It is a great source of protein, essential fatty acids, vitamins, and many minerals (Banu *et al.*, 1985). In terms of protein consumption, the crude protein levels are likely to be almost twice in dried fish than those of fresh fish in terms of quantity, if not quality (Pradhan *et al.*, 2017). For many countries in Southeast Asia around 15% protein obtained from fish and fish products (James D., 1984).

Dried fish is of economic, social, and cultural importance for many of the most vulnerable peoples of South and Southeast Asia. Dried fish exports have brought in an impressive amount of foreign currency for Bangladesh. This sector has huge potential to earn foreign exchange and it is also considered an important exportable fishery product (Nowsad, 2007) as many Bangladeshi migrant workers, particularly in the Middle East and Arab countries, have a high demand for dry fish products. Bangladesh has exported

341 metric tons of dried fish during 2008-09 fiscal year which market value was 119.9 million Taka, in 2012-13 fiscal year. It reached to 1278 metric tons and the market value was 360.3 million Taka in fiscal year 2018-19. It became 3144 metric tons and the market value was 425.9 million Taka (DoF, 2019). Presently, Bangladesh exports fish and fish products to over 50 countries and Bangladeshi dry fish is now being exported to the UK, the US, and the Middle East (Illius, 2019). Currently, 20% of Bangladesh's 0.6 million tons of marine fresh catch are preserved as dried fish for later consumption (mostly domestic consumption) and also for exports, fetching only $2.5 million a year – much less than its potential (Dhaka tribune, 2023). However, the fisheries sector of Bangladesh has been experiencing a consistent increase in export, which has significantly contributed to the growth of the sector in recent decades.

So far, dried fishery products frequently suffer severe losses due to infestation by flesh flies (*Sarcophagidae*), beetles (*Dermestes*, *Cornestes*, and *Necrobia* spp.), and mites (*Lardoglyphus* and *Lyrophagus* spp.). These infestations are most common in dried goods that are 7–21% salted and kept in tropical environments with 20–32 °C temperatures and 73–87% relative humidity. Around 2.75 million tons of dry fish are lost annually worldwide, according to a conservative estimate. The invasion of earwigs, hide beetles, and copra beetles causes a significant loss of dried fish in India. Among these, *Dermestes maculatus De Geer*, often known as the hide beetle, is the most devastating insect. It is also known as Leather Beetle, Common Carrion Dermestid, Bacon Beetle. Several species of *Dermestes* have been recorded infesting dried fish like *D. maculatus*, *D. frischii*, *D. carnivorus* Fabr, *D. lardarius*, *D. haemorrhoidalis*, and *D. peruvianus*. Fish crevices are where the females deposit their eggs, and the adults eat dried or drying fish. If the female is able to access water to drink, her rate of egg laying will increase significantly. During their feeding, the larvae dig into the flesh. Fish with infestations frequently contain the cast larval skins, which can be mistaken for the larvae. The final instar larvae burrow into solid material prior to pupation; this material may be the fish's flesh, but more often than not, it is the wood of drying racks or store structures, which may be severely undermined by the tunnelling. The principal pest species have a life cycle that can last anywhere from five to seven weeks, depending on the kind of food and environmental factors. In ideal circumstances, *D. maculatus* have a population growth rate of almost 30 times every month. Adult *Dermestes* are able to fly, which makes it simple for them to spread to new food sources (Singh *et al.*, 2018). Life tables are needed in order to understand the demographic processes and how these processes affect populations on a certain stage and conservation biologists. It is necessary to thoroughly understand the ecology of the pest for an integrated pest management program. The life table generates an integrated and comprehensive description in details of development, survival, fecundity, and life expectancy of a population, and is often used by scientists as a means of projecting the growth of populations. It is an especially useful approach in entomology, where developmental stages are discrete and mortality rates may vary widely from one life stage to another. It is very useful to analyze the mortality of insect population to determine key factors responsible for the highest mortality within population. The construction of several life tables may be possible to prepare a predictive model which can be tested against natural population fluctuations. Life table is an important analytical technique in studying distribution, determination of age and mortality of an organism and individuals can be calculated. However, life table generates simple summary statistics such as life expectancy and reproduction rates. From a pest management standpoint, it is very useful to know when and why a pest population suffers high mortality. This is usually the time when it is the most vulnerable. By knowing such vulnerable stages from life table, we can make time-based application of insecticide for the management of insect pests, to conserve the natural parasites and predators and to reduce the environmental pollution. However, the contamination that occurs throughout various handling stages and negligent application of different insecticides are the other issues with dried fish that are readily apparent (Nowsad, 2005). Increased use of pesticides causes direct toxicity to man and animals and due to entry into the food chain the liver, kidney etc. may be irreversibly damaged and become concentrated by bio-magnification and increased environmental and social costs. Also, the use of insecticides may render the dried fish unattractive and unpalatable to consumers. To prevent these many natural products are currently being investigated. Edible plants and mineral are the alternative to synthetic chemical pesticides since these compounds are bio-degradable and less persistent. Besides, plant and mineral products are also used in cooking dried fish as well as other curries.

The present work determined the effect of different species of dried fish as Ganges river sprat, Gangetic anchovy, Giant sea perch, Bombay duck, Indian oil sardine as foods of *D. maculatus* on food ability, developing, fecundity, life table parameters and control via edible plant products.

REVIEW OF LITERATURE

2.1 Identification And status

Fish on a worldwide basis contributes only about 15 percent of the animal protein in the human diet, but it's more important in terms of its value (James, 1984). Among the fish product dry fish (Locally named as Shutki) is the most popular food items in Bangladesh. Bangladesh has made considerable amounts of foreign exchange from the export of dried fish. Bangladesh has exported 3144 metric ton of dried fish during 2018-19 fiscal year (Table 1) which market value was 425.9 million Taka. (DoF, 2019). From 2012-13 to 2022-23 fiscal year - Bangladesh has exported dried fish worth about 7 crore 17 lakh 19 thousand 263 dollars in these 11 years. According to the Export Promotion Bureau (EPB), Bangladesh earned about USD 2.55 million or approximately Tk 280m from the export of dried fish in the first six months (July-December) of the 2023-24 fiscal (FY24), with December alone witnessing exports of dried fish worth USD 1.43 million.

Table 1: Export of dried fish from Bangladesh

Year	Quantity (Tons)	Value (Crore Tk.)
2008-09	341	11.99
2009-10	622	25.06
2010-11	623	5.57
2011-12	996	9.43
2012-13	1278	36.03
2013-14	2634	29.67
2014-15	2845	36.74
2015-16	2229	30.12
2017-18	2297	30.19
2018-19	3144	42.59

The dry fishes absorbed moisture so rapidly that the fish becomes suitable for infestation by beetles and mites. Therefore, large quantity of dried fish/ fishery products frequently suffers severe losses due to infestation by flesh flies (*Sarcophagidae*), beetles (*Dermestes, Cornestes,* and *Necrobia spp.*), and mites (*Lardoglyphus* and *Lyrophagus spp.*) (Venugopal *et al.,* 1999; Gopakumar *et al*., 1982). The most destructive pest is the hide beetle; *Dermestes maculatus* Deg. Based on a conservative estimate, the loss represents about 2.75mt of dry fish for a year in all over world (Esser *et al*., 1990; Wood, 1982). Insect degradation causes approximately fifty percent of the losses in smoked fish products during storage (lale and Sastawa,1996) (Odeyemi *et al*., 2000).

Species of Dermestes belong to the beetle family Dermestidae. Several species have been recorded infesting dried fish: *D. maculatus, D. frischii, D. carnivorus Fabr, D. lardarius, D. haemorrhoidalis* and *D. peruvianus* (Haines, 1989). *Dermestes maculatus* (hide beetle) has four life stages: adult, egg, larva, and pupa. The length of the life cycle will vary, depending upon the family and species of beetle. In dermestidae, for example, there may be as many as nine instars (Hinton, 1945). Usually, however, there is only one generation of beetles per year. Smith (1986) indicates that the length of the pupal stage of *Dermestes ssp*. can last between 2 weeks and 2 months and that these beetles can overwinter (enter diapause) in a pupal chamber if the weather is not suitable or it is late in the season. The problem of lack of a ready morphological distinction between larval instars in beetles means that other methods to distinguish the instars are needed. *Dermestes maculatus* growth from egg to adult can take 20 - 45 days, although the speed of development depends on the temperature of the habitat. The larvae have characteristic hairs on their body segments and are referred to colloquially as ‘woolly bears’. These hairs occur in tufts at the end of the body or along the sides of each segment and, according to Hinton (1945), can be moved or vibrated when the larva is being threatened.

Adult dermestids show a negative response to light (negative phototaxis) and will, when touched, readily ‘play dead’ (show thanatosis). Dermestids will happily exist in 14 darkness as larvae. These habits mean that they can be kept in the dark but need a reliable food source and pupation site to successfully complete their life cycles.

Dermestid infestation of fish can start during the early stages of drying. *D. maculatus* infesting split Tilapia sp. first laid eggs between the gills of the fish, gaining access through the mouth or opercula (Green, 1967). Osuji (1975) recorded that egg are laid in cracks or cuts (caused by gutting, splitting or dividing the fish into pieces) in the flesh. Each *D. maculatus* female is capable of laying more than 250 eggs and will lay most of them between 3 and 11 days after emergence (Osuji, 1975). Eggs hatch within 1 to 6 days of being laid, depending upon temperature (Azab *et al.*, 1972) and the larvae burrow straight into the flesh of the fish where they remain until they are ready to pupate. There may be up to 10 instars, depending upon the suitability of the fish as food, temperature and humidity (Azab *et al.*, 1972). Under 17 optimum conditions, e.g., on Tilapia sp. at 27 °C and in equilibrium with 75% relative humidity (RH), *D. maculatus* larvae mature within 30 days and pass through 7 instars. The final instar larva excavates a chamber in the fish flesh, in which it pupates. In this case, under optimal conditions, the pupal stage lasts for 10 to 12 days. If, however, the larva has been feeding on ground fish (fish meal) it is unable to pupate as described and goes into a 4 to 7 day long pre-pupal stage during which it becomes quiescent and assumes a shortened and thickened C shape before entering a true pupal stage of only 4 to 7 days duration (Osuji, 1975). Azab *et al.* (1972) studied the longevity of *D. maculatus* adults at various temperatures and relative humidity’s and found that longevity ranges between about 50 days (35 °C and 75% RH) and 173 days (21 °C and 75% RH). Longevity increases with increase in relative humidity or decrease in temperature, and females tend to longer than males. Absence of food or water will shorten the life of the adult.

2.2 Ecology and Regional Distribution

Ecological conditions appear to determine whether dermestid species will be present. Arnoldos *et al.* (2005) showed that the coleopteran profile in south-eastern Spain varied in both distribution and abundance throughout the year. They recorded few dermestid species in the earliest stages of corpse decomposition in spring and summer. Subsequently, numbers of the dermestid species increased as the remains began to dry out. Dermestid larva were characteristic of the dry stage of decay and lots were found in the muscle mass and on bones. In south-eastern Brazil, *Dermestes maculatus* is also recognized as a forensic indicator (Carvalho *et al.*, 2000). Arnaldos *et al.* (2005), in their succession studies in south-eastern Spain, recorded *Nitidulidae* and *Dermestidae* at the same stage of decomposition, linking their presence on the body. Post mortem interval determination is most accurate when based on evidence of the presence of several species of beetles that are normally found in association, rather than on single species of beetle alone.

Majeed (2002) reported a study to determine the effects of temperature and humidity on the development of stored products pest, dried fish beetle (*Dermestes maculatus*). Treatments comprised 28 ± 2, 32 ± 2 and 38 ± 2 °C with 40 ± 5 and 60 ± 5% RH at each level of temperature. Development of adults was more adversely affected by temperature compared to relative humidity. The longest duration of maturation (6.70 + 0.36 days) was obtained at 28 ± 2 °C and 60 ± 5% RH. The shortest duration 4.90 ± 0.97, 23.1 ± 0.72 and 3.70 ± 0.31 days for maturation, oviposition and post-oviposition, respectively, was recorded at 38 ± 2 °C and 40 ± 5% RH. An increase in temperature at constant relative humidity affected the development and decreased the maturation, oviposition, post-oviposition and longevity of adults. Relative humidity, although having no marked effects, is indirectly proportional to the adult development i.e., an increase in relative humidity decreased the rate of maturation, oviposition, post-oviposition and longevity at a particular temperature. The larval survival percentage decreased with temperature increase. At the same temperature, the survival percentage decreased with the increase in relative humidity. The lowest survival percentage (46.1) was observed at 38 ± 2 °C and 60 ± 5% RH. While the highest rate (83.6) was observed at 28 ± 2 °C and 28 ± 5% RH. Temperature and relative humidity affected the larval duration and developmental index. However, the larvae developed faster at higher temperatures and lower humidity. Temperature and humidity affected the pupal period and survival. The pupae developed faster at higher temperature and lower humidity.

Rahaman and Tarafdar (1991) determined the total concentrations of Na, K, Mg and Ca from adult *Dermestes maculatus* by atomic absorption spectrophotometer. They found that Na and K amounts were lower in newly adult insects and then increased with age; Mg and Ca levels showed the reverse trend.

Hill (1990) in India found that egg (1.3mm) laying *Dermestes maculatus* is started a day after copulation, the female laying 200-800 eggs. At 30 °C egg hatch in 2 days, with a 16-survival rate of about 50 percent. Larvae develop through 6 - 7 (up to 11) instars, taking 20 days at 35 °Cand 75 percent relative humidity or 28 days at 27 °C; at lower humidity’s development is prolonged. Fully grown larvae measure 15mm, and are covered with long setae, and there are two terminals curved urogomphi. Pupation at 30 °C takes about 6 days. Adults are elongate to oval and more or less parallel-side, 6 - 10 mm long, with a dark cuticle clothed in black and grey setae dorsally. The life cycle in the tropic (30 °C) is usually completed in about 30 days.

Boxgees and Abdullah (1986) reported the biology of the immature stages of *Dermestes maculatus* studied in the laboratory and in leather stores in Nineveh Province, Iraq. The insect was found to cause considerable damage to stored food (cheese and processed meat) and lamb leather. The average number of eggs laid per female was variable, being higher on untreated leather (413 eggs) than on yeasted dried meat (201) and artificial diet (93.7). The larval stage lasted a mean of 68.5 days on cheese and 48 days on dried meat. The lifespan of adult males was longer on cheese (96 days) than on dried meat (58 days). The pest production all year and had 3 - 4 generations.

2.3 Taxonomic Position of *D. maculatus*

Kingdom: Animalia (Animals)

Phylum: Arthropoda (Arthropods)

Subphylum: Hexapoda (Hexapods)

Class: Insecta (Insects)

Order: Coleoptera (Beetles)

Suborder: Polyphaga

Superfamily: Bostrichoidea

Family: Dermestidae (Carpet Beetles)

Genus: *Dermestes*

Species: *maculatus* (Hide Beetle)

2.4 Life Cycle and Clemet

The life cycle of *D. maculatus* on either a carcass in dry decay or in stored animal products requires approximately five to seven weeks to complete under optimum conditions. The adults consume the remains of the carcass or the animal product (Archer and Elgar 1998, Haines and Rees 1989). Pheromones, secreted by males through a gland on the base of the abdomen, are used to attract females. Males and females will mate multiple times and the female will lay eggs within 24 hours of the first mating (Jones *et al.* 2006). Eggs are laid in cracks of the matter on which they are feeding (Haines and Rees 1989). Females are capable of laying eggs continuously (Jones *et al.* 2006). Taylor (1964) found in his study that the presence of free water improved the oviposition of *D. maculatus*. Larvae will pass through five to 11 instars, the number of instars increasing with unfavorable conditions (Haines and Rees 1989, Hinton 1945). During the last 10 days of the final instar, the larvae will seek out a place to pupate, typically within the meat or a non-food substance such as wood. Exposed pupae that have failed to find a suitable pupal chamber are often cannibalized by larvae. Larvae without a suitable place to pupate can delay pupation by over 20 days, but at the cost of lower adult body mass and increased risk to fatal disease (Archer and Elgar 1998). Survivorship for individuals is the highest between 25 °C and 30 °C (Richardson and Goff 2001). Once adults, the beetles can disperse to other food sources by flying (Haines and Rees 1989). Adult beetles typically live between four to six months.

2.4.1 Egg

Dermestes maculatus eggs are typically laid in batches of three to 20. The number of eggs a single female can lay over a lifetime varies greatly, ranging from 198 to 845 (Hinton 1945). Freshly laid eggs were white in color and oval in shape, being bluntly pointed at both ends. The eggs were laid singly or in batches of 2-8; they measured 3.38±0.44 mm in length (Ezenwaji and Obayi ,2004). Hatching occurred 36-60 hr. (mean 48 hr.) after oviposition. During incubation, each egg darkened considerably in color to a shade of brown (Osuji 1975).

2.4.2 Larva

The bodies of the larvae are covered in rows of hairs of different lengths, called setae. The underside of the abdomen is typically yellowish-brown while the dorsal surface is typically dark brown, usually with a central yellow line. Two long horn-like protrusions are located on the upper surface of the last segment, partially hidden by surrounding hairs (Haines and Rees 1989). The protrusions, called urogomphi, curve upward and away from the tip of the abdomen. This distinguishes the larvae from larvae of *D. lardarius,* which has the urogomphi curving downward toward the tip of the abdomen (Hedges and Lacey 1996).

2.4.3 Pupa

The hairy white larva measured 1.4-1.9 mm on emergence. The body color darkened to light grey within a few hours and then to brown in about 24 hr. The final instar larva attained a body length of 13-15 mm. The only change noticed during larval development in *D. maculatus* was an increase in size from one instar to the next; no morphological differences were observed (Osuji 1975). The last larval skin will usually provide a protective covering for the pupa. The end of the pupal chamber toward the surface can be closed by either debris from the substance which the larvae bore into or from the last larval skin (Hinton 1945). The pupae are an oval shape, usually smaller than the larvae, and do not have the many long hair-like projections (Kulshrestha and Satpathy 2001).

2.4.4 Adult

The adult beetle emerged in four to seven days (mean 5.5 days). The total number of days for the prepupal and pupal development together did not differ significantly from that recorded for individuals pupating within a last instar larval skin inside a piece of fish. Adults' range in size from 5.5 to 10.0 mm. Each side of the thorax has a band of white hairs. The underside of the abdomen is primarily white with black spots at the sides, and a large black patch on the last segment. The elytra are dark brown or black, with hairs that are mostly black, yellow, or white. The antennae are short and segmented with a club at the tip. The edges of the abdominal end of the elytra are serrated and end in a small spine projecting straight out (Haines and Rees 1989, Hinton 1945).

2.5 Losses due to infestation

Dermestid beetle are the most important cause of infestation during storage, although minor pests such as *Necrobia rufipes* (De Geer) and mites have been identified (FAO, 1981). The 22 level of losses due to *Dermestes* infestation has a direct relationship to the length of storage of fish (FAO, 1981). Meynell (1978) reported that infestation was a minor problem in Malawi, since most of the dried fish were consumed within two to three weeks of processing. Long storage periods give insects more time to breed and consume the fish (FAO, 1981). Larvae of *Dermestes* also infest dried fish. The dermestid beetle larvae burrow into the fish flesh in search of pupation sites and reduce the flesh to dust like particles composed mainly of insect excrement (Osuji, 1975a).

Kritzinger (1955) estimated that, before adequate control measures were developed, the annual loss caused by insect attack on hides and skins in South Africa amounted to $ 39430.62. Other estimates include an annual loss of $ 61361.00 to the New Zealand export trade in opossum skins (Clark, 1929), and $ l,OOO,OOO worth of damage per year to hides and skins in the U.S.A. (Howard, 1952).

The most commonly encountered species in traditionally cured fish are *Dermestes frischii* (Kugelann), *Dermestes maculatus* (Degeer), *Dermestes carnivorus* (Degeer) and *Dermestes ater* (Degeer). *D. frischii* is an important pest of marine fish while *D. maculatus* is associated (Proctor, 1972). Losses up to 50% by weight due to *Dermestes spp.* attack on unsalted dried fish, stored for several months have been estimated (FAO, 1981). Although *Dermestes spp.* may attack salted fish over long period of storage (especially Kench-cured fish), the losses are much lower than that of unsalted fish (FAO, 1981).

Smoke does not appear to give any significant protection to dried fish against *Dermestes spp*. Therefore, unsalted smoked fish are also highly susceptible to the beetle attack (FAO, 1981). Levels of losses depend on processing methods used and resultant moisture contents (FAO, 1981). Osuji (1973) showed that smoked fish with a moisture content of below 10% generally showed little or no infestation, but moisture contents between 13 and 16% were very conducive to beetle infestation.

2.6 Management and Control

Larvae of *Dermestes* infest dried fish. There appear to be few published evaluations of the resultant losses, but Rollings and Hayward (1962) estimated that the financial loss from insect damage to dried fish produced on the Nigerian shores of Lake Chad may amount to &500,000 annually. *Dermestes* was responsible for much of this damage, and species of this genus have also been reported as infesting dried fish on the other shores of Lake Chad (Galichet, 1960), and in Aden (Green, 1965)) Formosa (Takahashi, 1937)) Indonesia (Kalshoven, 1937 and 1954), Hawaii (Illingworth, 1918), India (Pillai, 1957), Japan (Kimura and Takakura, 1919, Nonaka, 1952), Norway (Vestergaard, 1960), Russia (Sacharow, 192l), Senegal and Mali (Mallamaire, 1958) and Uganda (Darling, 1946).

2.6.1 Chemical and Fumigation control

Insecticides applied on or near dried fish intended for human consumption must obviously be of low toxicity to mammals. Formulations containing lindane, DDT, pyrethrum or malathion have been used (Mallamaire, 1958; Nonaka, 1952; Pillai, 1957; Galichet, 1960; Green, 1965). The occurrence of dieldrin-resistance in *Dermestes maculatus* attacking skins (Shuttleworth and Galloway 1961), and the recent interest in the greater use of dried fish in countries where protein deficient diets are widespread, have drawn attention to the need for more information on the susceptibility of hide beetles to modern insecticides. The larvae of Dermestids are less readily killed by insecticides than are many other beetles which infest stored products. However, it appears that in other genera of the family, e.g., *Trogoderma Berth*. and *Attagenus Latr*., this relatively low level of susceptibility applies more to organochlorine than to some organophosphorus insecticides (Vincent and Lindgren, 1957; Speirs, 1962). It was considered useful to make comparisons with the susceptibility of a beetle in another family. For this purpose, larvae of the Tenebrionid *Alphitobius laevigatus (F.)* were included in the tests. Mature larvae of this beetle were large enough to retain the topically applied doses used, and have been shown to be suitable for toxicological studies (Hewlett, 1962).

Dieldrin and lindane resistance have been suspected in populations from South Africa and Australia, but laboratory tests have failed to reveal any increases in the tolerance level (Shuttleworth and Galloway, 1961; Shaw and Lloyd, 1965).

Insecticidal use should be regarded as a last resort and other improved processing techniques should be considered first. The use of insecticides has escalated so much in recent years that it warrants concern over the potential hazards of their use (UNIFEM, 1988).

Due to continued use of wrong insecticides, it has become necessary to develop and avail insecticides that are safe and easy to use on fish. This would prevent the hazardous consequences of using non-food grade insecticides. Pirimiphos-methyl is an organophosphorus compound with a trade name Actellic. It is one of the safest food grade insecticides, and has been approved for use on cured fish by WHO/ FAO (UNIFEM, 1988). It is currently registered excreted for use in Indonesia and Malawi the insecticide has low toxicity, is by mammals and cheap (Esser, 1988b; UNIFEM, 1988). 26 Pirimiphos-methyl has been found to be very effective in controlling insect infestation of cured fish in Indonesia (Esser, 1988b) and Africa (Golob *et al.*, 1987). Deltamethrin is another effectively is a synthetic pyrethroid insecticide that has control insect infestation compound, which been found to of salted-dried fish during processing and storage, when applied as dips in low concentrations (Rattagool *et al.*, 1988). Deltamethrin is currently used for public health purposes and the protection of stored food products. Its use in protecting dried fish during storage in Africa has been evaluated (Duguet *et al.*, 1985; Golob *et al.*, 1987). Earlier trials in Indonesia had demonstrated that a similar pyrethroid insecticide, Alpha Cypermethrin, (trade name Fastac), was very effective at controlling insect infestation of cured fish at low concentrations (Esser *et al.*, 1985).

The recommended rate of application on maximum residue level of 3 ppm of pyrethrin and 20 ppm of piperonyl butoxide in the fish flesh under consumption. Commercial synergists are chemicals which possess little or no insecticidal activity of their own, but when used with insecticides, increase the insecticidal effectiveness of the whole formulation (Gjerstad, 1986).

Treating fish with salt (sodium chloride) during the drying process is probably the oldest method of improving their keeping quality. The primary effect of salt is bactericidal but there is no doubt that it also retards the development of insect infestations. The degree of attraction of salt treated fish to adult dermestid beetles is inversely related to the amount of initial salting (Green, 1967).

Eggs laid by dermestid beetles on salted fish may hatch but the emerging larvae are slow to develop and suffer high mortality (Osuji, 1975). Well dried and brined marine fish will not be infested for at least six weeks (Green, I967). Heavily salted fish is not a universally acceptable product and, to meet the requirements of some markets (Watanabe and Cabrita, 1971), the salt content has to be limited to 10% or less. At the level, some insect infestation is inevitable (Proctor, 1972). Drying fish over smoky fires is frequently practiced, the product acquiring a flavor which is preferred to that of sun-dried fish. Aref *et al.* (1965) reported from Mali that smoke drying over hardwood sawdust fires appeared to impart some protection against insect infestation. Amorphous silica-based dusts, which are virtually non-toxic to mammals, have been tried on dried fish (Green, 1967; Proctor 1972) but were found to be ineffective because they absorbed oil from the fish.

Aref *et al*. (1965) tried sulphur dipping and fuming with equally poor results. Chemicals in the gaseous state have the 28 capacities to penetrate commodities being treated and so achieve rapid control of all developmental stages of insect pests present.

Fumigation confers no lasting protection and re-infestation can take place immediately should the commodity be re-exposed to insect pests. Two fumigant that are commonly employed to disinfest a wide variety of foodstuffs are methyl bromide and phosphine. Both these chemicals might be considered for the treatment of dried fish in order to reduce losses caused by *Dermestes spp.* Methyl bromide was reported as a successful fumigant of dried fish treated under gas proof sheeting in Angola (Proctor, 1972). Mallamaire (1957) fumigated dried fish with methyl bromide under partial vacuum a dosage rate of 80gm per cubic meter for 2 hours.

Malathion has been shown to give good control of *Dermestes spp.* and subsequent protection, but the minimum effective treatment rate left undesirably high residues of insecticide on the fish (Green, 1967; Proctor, 1972).

McLellan (1964) found that by dipping properly dried fish in a water emulsion containing 0.018% w/ v Pyrethrins and 0.036% w/ v piperonylbutoxide, good control of Dermestes was obtained. If the dipped fish were well drained, they did not become too moist and were acceptable to consumers. The problem of keeping residues within limits is the main difficulty associated with the direct treatment of fish with insecticides.

Guillon (1976) tested the effectiveness of bioresmethrin (a synthetic pyrethroid) and tetrachlorvinphos for the control of Dermestes maculatus attacking dried fish in Mali.

Bioresmethrin was found to be ineffective but tetrachloropiriphos considerably more successful. Further investigations on the insecticidal treatment are necessary but it might prove suitable for use on sacks containing dried fish. Further advantages of permethrin over natural pyrethrins are its higher photostability and its lower mammalian toxicity.

Kordyl (1976) points out that the recommended means of chemical control of infestation in dried fish which can be applied on a commercial scale and which are without health hazard to the consumer are still awaited. With the present state of technology fumigation might be the most effective means of controlling insect pests in dried fish.

2.6.2 Toxic effects of different plant products

Akinwumi (2011) revealed that, the four plant powders, namely: *Dennettia tripetala* Baker, *Eugenia aromatic* Hook, *Monodora myristica* Dunal and *Piper guineense* Schum and Thonn caused significantly high mortality in both the adults and larvae of the *D. maculatus* at 2.5, 5.0, 7.5 and 10.0g/ 100g smoked *Clarias gariepinus* Burchell when compared to the control and was effective in inhibiting progeny development in treated fish.

Egwunyenga *et al.* (1988) rated *Dennettia tripetala* Baker as one of the promising repellents and attributed the repellency of *D. maculatus* from admixed fish to olfactory and gustatorial sensation. Gonzalez-Coloma *et al.* (1994) linked reduced fitness of larvae and consequent suppression of adult emergence to stomach poisons after ingestion of the plant material.

Nwogor *et al.* (2015) stated that the highest mortalities of 83.33% and 76.67% for larva and adult, and the percentage of emergence of larva and adult were 15% and 10.7%, respectively when the smoked catfish (*Clarias gariepinus*) was treated with *Piper guineense* powder at 2.0g doses. Also, the percentage of fish loss in *Piper guineense* powder at 2.0g was 0.88% in adult and larva 1.48%. Insecticidal property of any plant material would depend on the active constituents of the plant material and *P. guineense* contains piperine and chavicine, which are insecticidal including piperidine and alkaloids as the major active components in *P. guineense* seeds (Lale, 1995).

The toxicity has been attributed to their pungent and pepperish taste which could asphyxiate insects by blocking the spiracles and the presence of bioactive ingredients such as alphapinene, limonene and linalool in *P. guineense* (Golob *et al.*, 1999). Adedire and Lajide, (1999) reported that plant materials within the family Piperaceae to which *Piper guineense* belongs have been reported to possess some form of insecticidal properties against eggs of cowpea storage, Bruchid, and also capable of suppressing various developmental instars of *Callosobruchus maculatus*.

MATERIALS AND METHODS

The biological studies of *Dermestes maculatus* provided five dried fish species as food for preparing life table parameters were conducted in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), during June to December 2023. All experiments were carried out under laboratory condition at 30 ± 5 ˚C, 80 ±10% R.H.

3.1 Collection and mass rearing of hide beetle

Hide beetles were collected from the infested dried fish in Saidpur dried fish market in June 2023 for the establishment of a laboratory insect mass culture to provide target insect in all developmental stages required. The fresh dried fish Indian oil sardine, *Sardinella longiceps* was purchased from the Saidpur dried fish market and local market of Dinajpur city. They were placed in 5 plastic boxes (8 cm wide, 11 cm deep). The collected beetles from infested dried fish were transferred into fresh dried fish (*Sardinella longiceps)* which kept in plastic boxes. The culture was maintained at laboratory conditions at 30 ±5 ^{0}C and 80 ±10% R.H. and a light regime of approximately 13h daily. The mass rearing of beetles was continued up to last stage of the experiment to have constant supply of different stages of the insect for the experiment (Plate 1).

3.2 Experiment 1: Life history traits of *Dermestes maculatus* De Geer (Coleoptera: Dermestidae) fed on fresh water and marine dried fish

3.2.1 Tested dried fish species

The biological performances of *Dermestes maculatus* were evaluated on five dried fish species, among them three were fresh water and two were marine water (Plate 2). These dried fish species were collected from the Saidpur dried fish market and local market of Dinajpur city.

Table 2. List of dried fish species assayed

Sl. no.	Common name	Scientific name	Family	Order	Origin
1	Ganges river sprat	*Corica soborna*	Ehiravidae	Clupeiformes	Fresh water
2	Gangetic anchovy	*Setipinna phasa*	Engraulidae	Clupeiformes	Marine water
3	Giant sea perch	*Lates calcarifer*	Latidae	Perciformes	Marine water
4	Bombay duck	*Harpadon nehereus*	Synodontidae	Aulopiformes	Marine water
5	Indian oil sardine	*Sardinella longiceps*	Dorosomatidae	Clupeiformes	Fresh water

3.2.3 Immature development and adult performance

To determine the developmental time of *D. maculatus*, pairs of adults were subsequently placed separately in the specimen plastic boxes previously described. The fecundity of each female was estimated. The gravid females from the mass culture were allowed to oviposit for 24 hours at 30±5 ºC, retaining 80±10% relative humidity. Individual eggs were transferred by fine hair brush (Plate 4) to separate Petri dish maintained thirty replications for each dried fish species. Fresh dried fish of each selected species were offered to the larvae for feeding during the whole larval duration. Pupae were investigated until adult emergence. Fresh fish of same species was supplied regularly until they emerged as adult (Plate 3). The following biological parameters were measured during the study i.e., incubation period, larval and pupal duration. Development from egg to adult was observed at 12 hour intervals to determine stage specific development time under the Trinocular Zoom Stereo Microscope (Model: SM-2TZ LED, AmScope Microscope, Irvine, CA 92606, USA) (Plate 5).

The newly emerged female adults were collected, sexed, and individually mated with one active male from the same treatment condition or from the mass culture unit. They were then confined in groups of couples (♀ and ♂) in plastic boxes on the first day of exclusion. If needed, an additional male was added to ensure successful mating. Daily observations were made and life-history traits such as preoviposition, oviposition and post oviposition periods, fecundity and adult longevity were measured. Upon collection of newly-laid eggs by each female were reared up to adulthood to determine the sex ratio.

3.2.3 Dried fish species preference

3.2.3.1 Weight loss determination

About 10 g of dried fish of each species were weighed using an electric balance. Then they were placed in a plastic box and the bottom and top of the box were covered with a muslin cloth for providing good aeration. About 5 pairs of *D. maculatus* were placed in the boxes containing dried fish (Plate 8). The hide beetles were removed from the infested fish and clean the dried fish by sieving. The clean fish in each box were weighted separately. The final weight of dried fish was taken to obtain weight loss. The weight losses of fish were found out by subtracting the final weight from the initial weight. The percentage of weight loss was calculated as follows:

$$\text{Weight loss due to infestation (\%)} = \frac{\text{Initial weight– Final weight of fish}}{\text{Initial weight of fish}} \times 100$$

3.3 Experiment 2: Efficacy of edible plant powders and mineral as protectants of dried fish *Sardinella longiceps* against *Dermestes maculatus* (Coleoptera: Dermestidae)

3.3.1 Tested plant products and mineral

Biologically active plant parts like leaves, fruits, and seeds were collected from sources nearby. The botanicals viz., Bay leaf, Black Cumin, Fenugreek seed, Ajwain and sodium chloride were tested for the management of dried fish beetle, *D. maculatus*.

3.3.1.1 Preparation of plant product powders

The previously collected botanicals viz., Bay leaf (*Laurus nobilis*), seeds of Black cumin (*Nigella sativa*), Fenugreek (*Trigonella foenum-graecum*) and Ajwain (*Trachyspermum ammi*) were washed with running clean tap water and then and then air dried in laboratory for 5 hours. After that, they were ground thoroughly in an electric 1.5HP kitchen grinder and sieved through a 40 holes/mm^2 mesh screen to get fine powder. Each of the plant powders was kept in a separate plastic container with a tightly fitted lid and placed in laboratory for experimental use.

3.3.1.2 Preparation of mineral powder

The table salt/ rock salt sodium chloride was used as mineral and its powder form was prepared with the help of a grinder. The dusts were passed through a 40 holes/ mm^2 sieve to obtain a fine and uniform dust. Then the dusts were preserved in airtight plastic containers till their use in the experiment.

Table 3. List of plant products and mineral powder evaluated against *D. maculatus* on dried fish

Sl. no.	Common name	Scientific name	Family	Plant part used	Active ingredient
1.	Bay leaf	*Laurus nobilis*	Lauraceae	Leaf	Benzaldehyde, Piperidine, and Geraniol
2.	Black cumin	*Nigella sativa*	Ranunculaceae	Seed	Thymoquinone
3.	Fenugreek	*Trigonella foenum-graecum*	Fabaceae	Seed	Flavonoid
4.	Ajwain	*Trachyspermum ammi*	Apiaceae	Seed	Thymol, γ-terpinene, and P-cymene
5.	Rock salt	Sodium chloride	-	-	Sodium and Chloride

Plate: 6 & 7

3.3.2 Insects Bioassay

3.3.2.1 Evaluation of plant powders against *D. maculatus* larva

Toxicities of Bay leaf, Black cumin, Fenugreek, Ajwain and Rock salt (NaCl) powders on *D. maculatus* larvae were assessed by admixing them at concentrations of 4.8 g/40 g dried fish (Indian Oil Sardine) in plastic boxes (Plate 8). Plants and minerals powders were thoroughly mixed with the dried fish. Treated and untreated (control) dried fish were infested with eight (08) newly emerged second instar larvae about 0–6 days old of hide beetle, replicated three times. Larval mortality was assessed and recorded at every 24 h. intervals up to 96 h.

3.3.2.2 Evaluation of plant powders against *D. maculatus* adult

Toxicities of Bay leaf, Black cumin, Fenugreek, Ajwain and Rock salt (NaCl) powders on *D. maculatus* larvae were assessed by admixing them at concentrations of 4.8 g/40 g dried fish in plastic boxes (Plate 8). Plants and minerals powders were thoroughly mixed with the dried fish. Treated and untreated (control) dried fish were infested with four (04) newly emerged adults about 0–3 days old of hide beetle, replicated three times. Larval mortality was assessed and recorded at every 24 h. intervals up to 96 h.

3.4 Life table analysis

Observations on life history, including adult fecundity and longevity, were used to construct a time-specific life table for *D. maculatus* maintained under laboratory conditions. The life table parameters for females held at different dried fish species were estimated using the Birch (1948) equation:

$$\sum e^{-r_m x} l_x m_x = 1$$

Where, x = age in days, l_x = the age-specific survival rate, mx = the age-specific fecundity, the intrinsic rate of natural increase ($r_m = ln (\sum l_x m_x)/T$), the finite rate of increase ($\lambda = e^r$), the net reproductive rate ($R_0 = \sum l_x m_x$), the mean generation time ($T = \sum X l_x m_x / R_0$), and the gross reproductive rate ($GRR = \sum m_x$). Doubling time [$DT = (ln\ 2)/r$] was calculated as described by Mackauer (1983).

3.5 Statistical Analysis

The traits (i.e., developmental time, preoviposition period, oviposition period, postoviposition period, longevity and fecundity) were determined by using analysis of variance (ANOVA), and means were separated by using Duncan's significant difference test (Duncan test) using SPSS statistix 10. The jack-knife technique was used to estimate mean demographic parameters of $l_x m_x$ of the life table and their SE. This method was first applied to life table analysis as proposed by Meyer *et al*. (1986). The jack-knife procedure estimates standard errors for life table parameter estimates by sequentially removing one female and her offspring from the original dataset and recalculating each life table parameter from the truncated dataset.

Plate-1: **M**ass rearing of hide beetle, *Dermestes maculatus*

Corica soborna

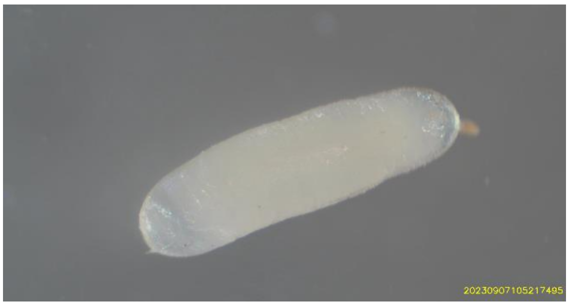
Lates calcarifer

Harpadon nehereus

Sardinella longiceps

Setipinna phasa

Plate-2: Dried fish species tested for the experiment.



Egg

Newly hatched larva

Mature larva

Pupa

Adult (dorsal view)

Adult (ventral view)

Plate-3: Life stages of hide beetle, *Dermestes maculatus*

Plate-4: Camel hair brush for picking larvae

Plate -5: Stereo microscope (model: SM-2TZ LED, AmScope Microscope, Irvine, CA 92606, USA) for observing and counting egg and first instar larva of *D. maculatus*

Ajwain

Fenugreek

Bay leaf

Black cumin

Rock salt

Plate -6: Edible botanicals and mineral used against hide beetle, *D. maculatus*

Ajwain

Fenugreek powder

Black cumin powder

Bay leaf powder

Rock salt powder

Plate-7: Powder form of edible botanicals and mineral used against hide beetle, *D. maculatus*

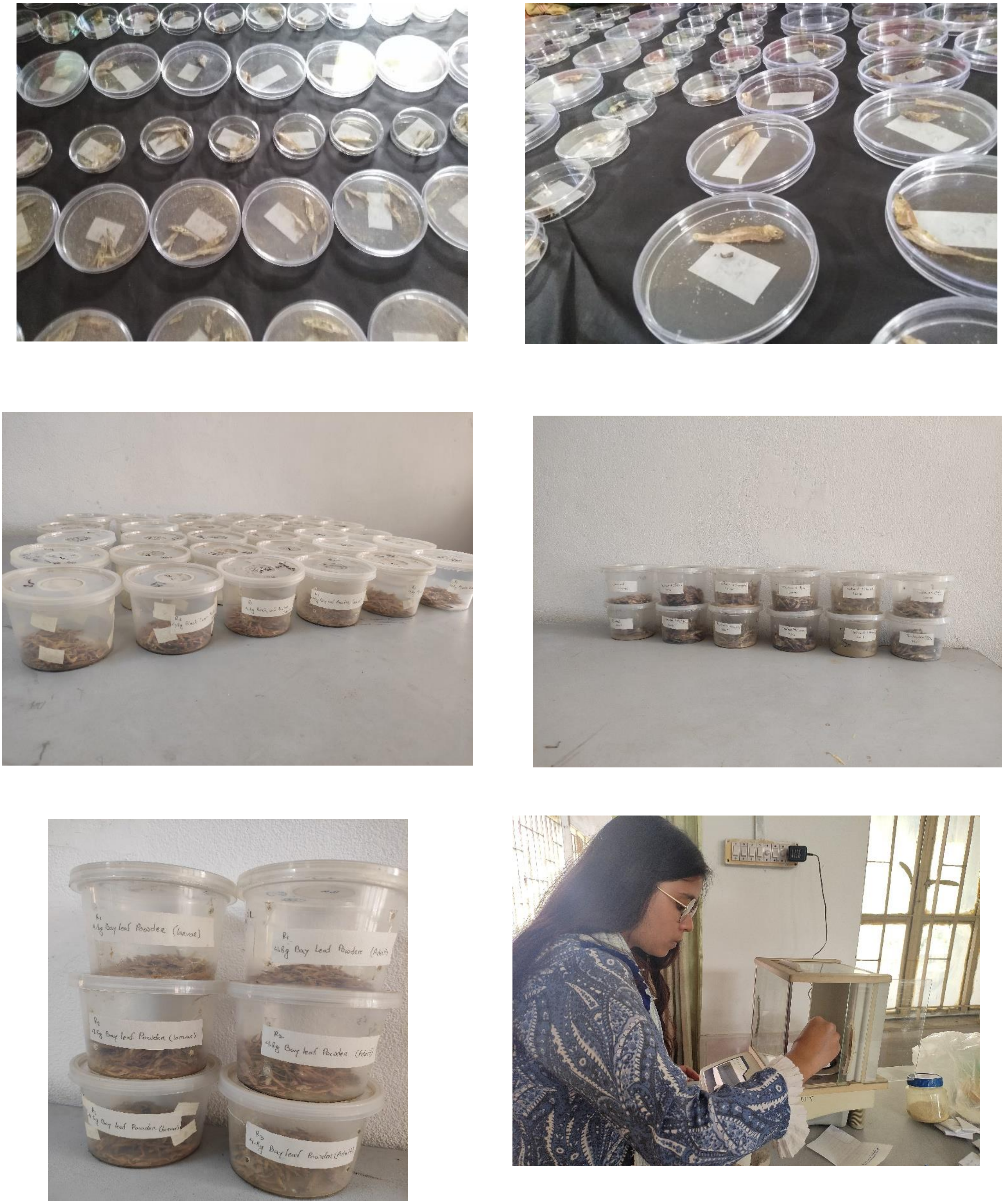


Plate- 8: Experimental arenas used for the research

RESULTS AND DISCUSSION

4.1 Experiment 1: Life history traits of *Dermestes maculatus* De Geer (Coleoptera: Dermestidae) fed on fresh water and marine dried fish

4.1.1. Immature Development

The female and male immature developmental time (egg to adult emergence) and adult longevity *D. maculatus* are shown in Table 1.

There was a significant variation observed in egg, egg to adult and adult longevity period while the hide beetle fed on five dried fish species. Significant differences were observed among dried fish species for the egg developmental period of both sexes. The duration of egg stage ranged from 2.23 to 2.62 days in females (*df*- 4, 65; F- 3.09; P < 0.05) and 2.29 to 2.71 days in males (*df*- 4, 51; F- 4.11; P < 0.05) at 30±5 ˚C when fed the five dried fish varieties as food. Female egg developmental time was the longest (2.62 days) on Indian oil sardine species while the shortest (2.23 days) on Ganges River sprat species. Male egg developmental time was the longest (2.71 days) on Giant Sea perch species but the shortest (2.29 days) found in Ganges River sprat. Azab (1972) found that eggs hatch within 1 to 6 days, depending upon temperature. Again, Hill (1990) revealed that egg hatch in 2 days at 30°C. Osuji (1975) showed that hatching occurred 36-60 hours (about 2 days) after oviposition at a temperature of 31°C to 34°C (mean 33°C). This is in line with the work of Azeb (1973) that eggs took 1 – 2 days at 30°C and 10 – 11 days at 16°C to hatch.

The female and male larval developmental periods ranged from 23.01 to 26.47 days and 24 to 26.92 days respectively at 30±5°C and among the periods statistically considerable variations are found (Female: df- 4, 65; F- 27.53, P < 0.05; Male: df- 4, 51; F- 30.12; P < 0.05). And go through 6 instars. Female larval developmental time was the highest (26.47 days) on Indian oil sardine species which was significantly different from Ganges

River sprat species which was the lowest (23.01 days). Male larval developmental time was the longest (26.92 days) on Indian oil sardine species which was significantly different from other species while the shortest (24 days) found in Ganges River sprat. Hill (1990) observed that larvae develop through 6 - 7 (up to 11) instars, taking 20 days at 35 °C and 75% relative humidity or 28 days at 27 °C; at lower humidity's development is prolonged. Azab *et al.* (1972) observed that the larval development was affected by both temperature and relative humidity. At 21 °C, 27 °C and 35 °C (at 75% relative humidity), development lasted an average of 53, 28 and 20 days respectively while at 27 °C with lower relative humidity of 55%, the period was increased to 35 days. Larval development of *D. maculatus* was shown by Osuji (1975) to be much more rapid in dried fish than in synthetic media. He further showed that moderate salting (3.2% - 10.2% sodium chloride content) when accompanied by effective dehydration of fish (6.2% - 9.2% moisture content) significantly prolonged the larval development period of *D. maculatus*.

The duration of pupal stage ranged from 5.61 to 6.56 days in females (df- 4, 65; F-9.21; $P<0.05$) and 5.58 to 6.5 days in males (df- 4, 51; F- 5.42; $P<0.05$) at 30±5 ˚C and the periods of all species were significantly different. Female pupae developmental time was the longest (6.56 days) on Giant Sea perch species but the shortest (5.61 days) on Ganges River sprat species. Male pupae developmental time was the highest (6.5 days) on Giant Sea perch species while the lowest (5.58 days) found in Ganges River sprat species which were also significantly different from each other. Azeb *et al.* (1973) reported the pupal duration of *D. maculatus* on smoked dried fish lasted at 5.1 days (ranging from 2 – 11 days) at 29 °C.

The time ranges elapsed from egg stage to adult emergence while fed on five dried fish species were 31.65 to 35.29 days for female (df- 4, 65; F- 33.07; $P<0.05$) and 33.10 to

35.71 days for male (df- 4, 51; F- 40.56; $P<0.05$) which were significantly different from each other. The longest time (35.29 days) was observed on Indian oil sardine but the shortest (31.65 days) on Ganges River sprat for female. For male, the highest result occurred on Giant sea perch (35.71 days) and the lowest on Ganges river sprat (31.87days).

4.1.2 Adult Longevity

The adult longevity of hide beetle occurred in different dried fish species shown in Table 1.

The female beetle survived longer (58.31days) on Bombay duck and shorter (49.18 days) on Indian oil sardine. The male beetle survived 51.25 days on Ganges River sprat which was longest period while 46 days on Gangetic anchovy which was shortest period. There was a significant difference found in the period of male and female adult longevity (Male: df- 3, 45; F- 4.49; $P < 0.05$ and Female: df- 3, 57, F-127.48, $P > 0.05$). Azab *et al.* (1972) studied the longevity of *D. maculatus* adults at various temperatures and relative humidity's and found that longevity ranged between about 50 days (35 °C and 75% RH) and 173 days (21 °C and 75% RH)

Table 4. Mean (±SE) developmental time and adult longevity (days) of *D. maculatus* on five different dried fish species

Species	Sexes*	N**	Egg	Larva	Pupa	Egg to Adult	Adult longevity
Ganges River sprat	F	13	2.23± 0.12 b	23.01±0.22 d	5.61±0.14c	31.65±0.27 d	51.31±0.25 b
	M	12	2.29±0.09 B	24±0.31 D	5.58±0.16 C	31.87±0.27D	51.25±0.41 A
Gangetic anchovy	F	15	2.53±0.09 a	24.83±0.25 c	5.8±0.11c	33.17±0.30 c	49.47±0.47 c
	M	10	2.45±0.08 AB	24.85±0.24 C	5.8±0.1 BC	33.10±0.24C	46±0.35 C
Indian oil sardine	F	17	2.62±0.04 a	26.47±0.09 a	6.20±0.08b	35.29±0.15a	49.18±0.31 c
	M	13	2.61±0.06 A	26.92±0.13 A	6.04±0.14 B	35.58±0.24A	50.92±1.19 AB
Bombay duck	F	16	2.47±0.07 ab	25.72±0.11 b	6.15±0.06b	34.25±0.16b	58.31±0.29 a
	M	14	2.32±0.08 B	25.96±0.11 B	6.18±0.08 AB	34.46±0.16 B	48.5±1.02 BC
Giant Sea perch	F	9	2.61±0.07 a	26.05±0.28ab	6.56±0.09a	35.22±0.34a	-
	M	7	2.71±0.09 A	26.5±0.22 AB	6.5±0.17 A	35.71±0.31 A	-

*F females, M males

** Number of individuals tested

Means of the same sex within a column followed by different letters are significantly different (Duncan test: $P < 0.05$)

4.1.3 Fecundity

Reproductive phases and fecundity of *D. maculatus* are presented in Table 2. Dried fish species had a significant effect on preoviposition, oviposition and postoviposition periods (Preoviposition: df- 3,57; F- 7.27; $P < 0.05$, Oviposition: df- 3, 57; F- 296.64; $P < 0.05$ and Postoviposition: df- 3, 57; F- 19.09; $P<0.05$) of hide beetle while fed on four dried fish species. The time between the date of adult emergence and the first egg deposition was considered as pre-oviposition period. The longest preoviposition period (4.71 days) was observed on Indian oil sardine while the shortest period (4.46 days) found on Ganges River sprat. Azab (1973) observed that the pre-oviposition period was 3 days at 35 ˚C and 19 days at 21 ˚C. Hossain (2016) stated that the pre-oviposition period was shorter in 24h dark period (3.7±0.48 days) and 12h light 12h dark period was (4.0±0.47 days) regime but it was longer in 24h light period (5.6±0.84 days) regime.

The oviposition periods ranged from 29.87 to 41.06 days. The longest period was found on Bombay duck and the shortest period was on Gangetic anchovy. The oviposition period of hide beetle lasted 31.62±0.13, 29.87±0.52, 30.29±0.19 and 41.06±0.14 days when they fed on Ganges river sprat, Gangetic anchovy, Indian oil sardine and Bombay duck, respectively. The daily oviposition was highest (6.25±0.2 eggs) while the beetle fed by dried fish species Bombay duck whereas it was lowest (4.12±0.11 eggs) on the Ganges river sprat. Total number of eggs laid by individual female in its life span ranged from 256.56±8.51 eggs (Bombay duck) to 130.39±3.87 eggs (Ganges river sprat). Hasan (2016) found that the oviposition period of *D. maculates* was 42.4±4.22 days at 12h light 12h dark period, 41.8±3.33 at 24h light period and 35.0±5.50 days at 24h dark period photoperiodic conditions.

There were significant differences found in postoviposition period of hide beetle (df-3, 57; F- 19.09; $P<0.05$) while fed four dried fish species. The highest postoviposition period (15.23

days) was recorded on Ganges river sprat whereas the lowest period (12.88 days) was on Bombay duck.

Table 5. Reproductive phases (days) and fecundity (number of eggs) of *D. maculatus* on four different dried fish species

Species	Preoviposition period (days)	Oviposition period (days)	Postoviposition period (days)	No. of eggs /female/day	Lifetime fecundity/female
Ganges river sprat	4.46±0.21 a	31.62±0.13 b	15.23±0.27 a	4.12±0.11 c	130.39±3.87 d
Gangetic anchovy	4.6±0.16 a	29.87±0.52 c	14.93±0.26 a	5.06±0.13 b	150.47±2.96 c
Indian oil sardine	3.71±0.09 b	30.29±0.19 c	15.18±0.21 a	5.82±0.09 a	176.24±2.49 b
Bombay duck	4.38±0.10 a	41.06±0.14 a	12.88±0.21 b	6.25±0.2 a	256.56±8.51 a
Giant Sea perch	-	-	-	-	-

Means in the same column followed by different letters are significantly different (Duncan test P<0.05)

4.1.4 Life Table Parameters

Data presented in Table 3 show the changes in the estimated life table parameters of hide beetle when larvae were fed on 4 species of dried fish like Ganges River sprat, Gangetic anchovy, Indian oil sardine and Bombay duck. The net reproductive rate (R_o) (df- 3, 57; F- 15273.86; P < 0.05) was highest (195.13) while fed on Bombay duck species while lowest (46.07) on Ganges River sprat. Intrinsic rate of population increase (r_m) (df- 3, 57; F- 2671.85; P < 0.05) was maximum (0.08) on both Indian oil sardine and Bombay duck but minimum (0.075) on Ganges river sprat. Mean generation time, T (df- 3, 57; F- 67384.55; P < 0.05) was longest (63.98 days) while fed Bombay duck but shortest (51.23 days) on Ganges River sprat. The finite rate of increase (λ) (df-3, 57; F- 2658.62; P > 0.05) was found to be the lowest (1.07) when the subjects were fed on Ganges River sprat, whereas the highest value (1.09) was observed on Indian oil sardine. Population doubling time, DT (df- 3, 57; F- 3005.43; P < 0.05) was the longest (9.27) on Ganges River sprat and shortest (8.33) while fed on Indian oil sardine. The gross reproductive rate (GRR) (df- 3, 57; F- 10732.61; P < 0.05) was highest (213.27) for the host Bombay duck while lowest (69.10) for the host Ganges River sprat.

In many cases, when a pest species is at its most vulnerable stage of growth and development, it can be optimally controlled. An analysis of its life table represents one of the most effective methods for identifying this stage. In addition, this can be used to gather useful information concerning the fertility, developmental period, and survival of the specified pests (Metcalf and Luckman, 1994; Ozgokce and Atlihan, 2005). Under certain conditions, the components of the life table serve as reliable estimates of population growth (El Taj and Jung, 2012).

Table 6. Mean (±SE) life table parameters of *D. maculatus* on four different dried fish species

Species	R_o	r_m	T	Λ	DT	GRR
Ganges river sprat	46.07±0.11 d	0.075±0.00 d	51.23±0.02 d	1.07±0.00 d	9.27±0.01 a	69.10±0.17 d
Gangetic anchovy	112.60±0.28 c	0.079±0.00 c	59.41±0.03 c	1.08±0.00 c	8.71 ±0.01 b	154.85±0.6 c
Indian oil sardine	141.61±0.36 b	0.08±0.00 a	59.52 ±0.01 b	1.09±0.00 a	8.33 ±0.01 d	147.83±0.26 b
Bombay duck	195.13±0.76 a	0.08±0.00 b	63.98±0.02 a	1.085±0.00 b	8.41±0.01 c	213.27±0.80 a

Means in a column followed by different letters are significantly different (Duncan test: P<0.05) Ro net reproductive rate, rm intrinsic rate of natural increase per day, T mean generation.

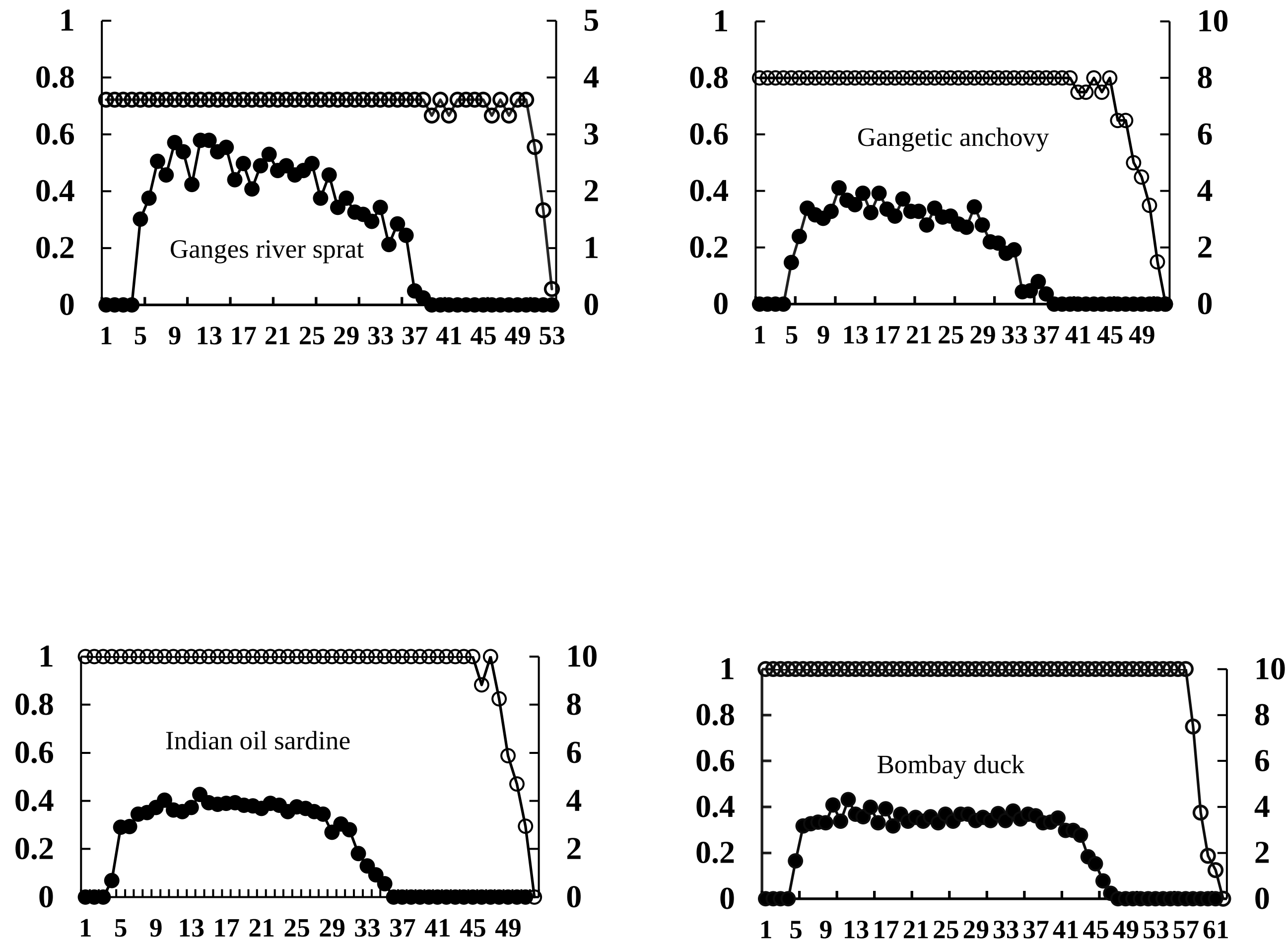


Fig. 1: Age-specific survivorship (lx) and age specific fecundity (mx) *of D. maculatus* female on four different dried fish Species. lx = proportion of females alive at age x. mx = (proportion of females) × (age specific oviposition).

4.1.5 Infestation

Figure 2 represents the infestation rate of hide beetle on different dried fish species. These data are statistically different within the species. Ganges River Sprat experienced a 27.07% weight decrease, while the Giant Sea Perch showed a smaller decrease of 4.53%. Bombay Duck, Gangetic Anchovy, and Indian Oil Sardine exhibited notable decreases in infestation rates, recorded at 35.33%, 39.23%, and 49.67%, respectively. These infestation rates imply a decrease in weight, signaling potential concerns such as infestation or processing losses for these particular fish species.

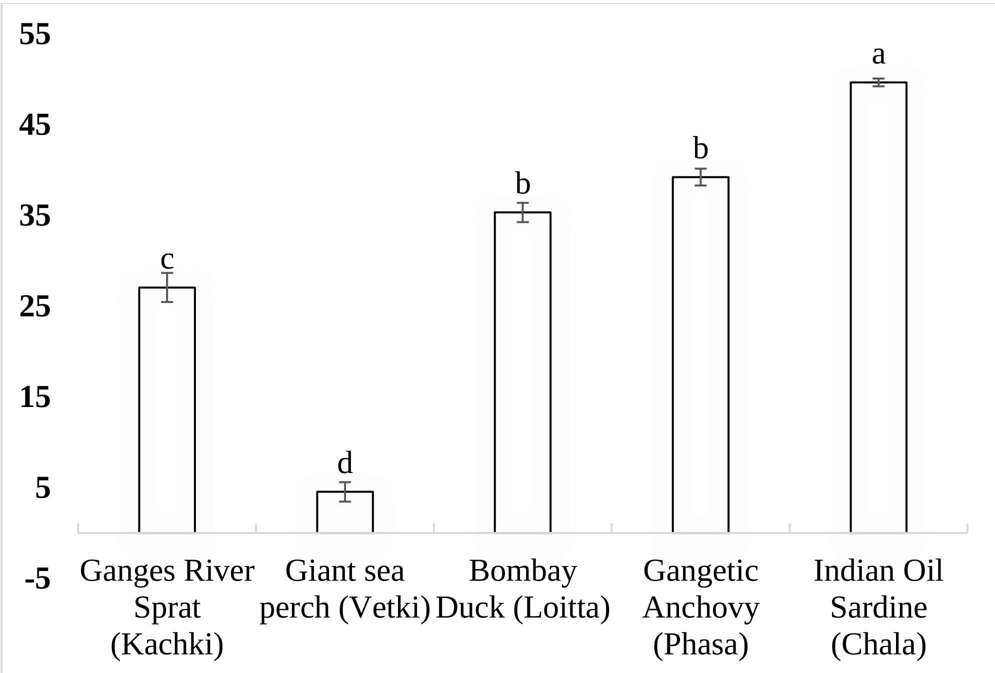


Fig. 2: Infestation rate of five different species of dried fish caused by *D. maculatus*

4.2 Experiment 2: Efficacy of edible plant powders and mineral as protectants of dried fish *Sardinella longiceps* against *Dermestes maculatus* (Coleoptera: Dermestidae)

4.2.1 Mortality of edible plant powders and mineral against *D. maculatus*

The toxicities of edible plant powders and mineral were concentration and exposure time-dependent. The toxicity of Ajwain powder was the most potent against both adult and larvae of *Dermestes maculatus*. All the botanicals, minerals, and controls showed 0% mortality of *D. maculatus* after a 24-hour exposure period at a concentration of 4.8g/40g dried fish (*Sardinella longiceps*) in both adult s and larvae. Only Ajwain powder (*Trachyspermum ammi*) exhibited a 25% mortality rate in adult *D. maculatus* at 48h, 72h, and 96h of exposure, respectively.

The larval mortality of *D. maculatus* was observed in Ajwain powder at a concentration of 4.8g/40g Sardinella longiceps, with rates of 8.33%, 25%, and 25% at 48h, 72h, and 96h, respectively. The mortality rates in larvae of different treatments can be shown as follows: Ajwain > Bay leaf > Black cumin, Fenugreek, Rocksalt.

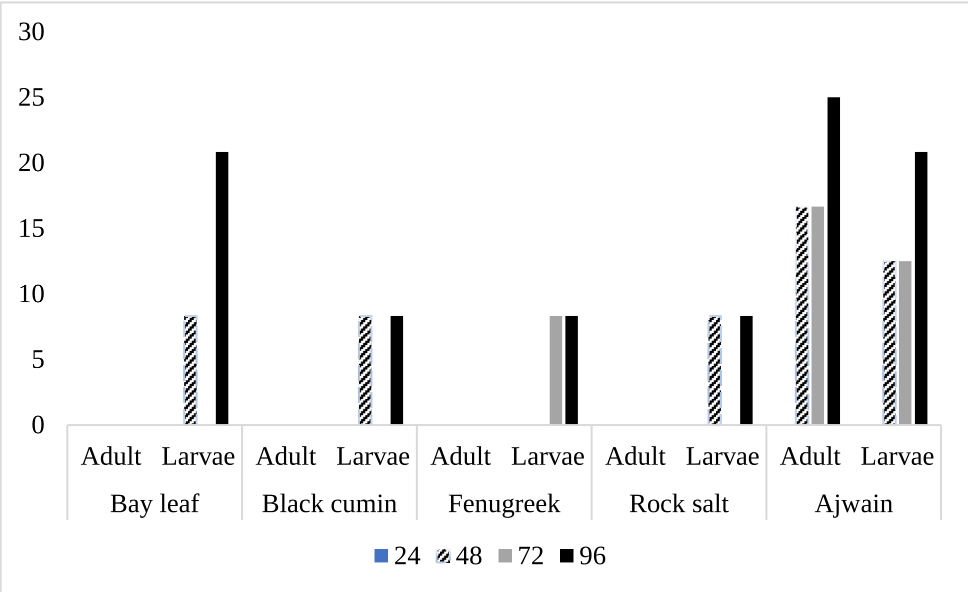


Fig.2: Percentage mortality of *D. maculatus* while treated with edible botanicals and mineral powder

SUMMARY AND CONCLUSION

The present study was conducted in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), during June 2023 to December 2023. All experiments were carried out under laboratory condition at 30±5 ˚C, 80±10% RH. The hide beetle *Dermestes maculatus* De Geer (Coleoptera: Dermestidae) constitutes one of the major pests of dried fish in Bangladesh. The present work aims to determine the effect of different species of dried fish (Ganges River sprat, Gangetic anchovy, Giant sea perch, Bombay duck, Indian oil sardine) as foods of *D. maculatus* on food ability, developing, fecundity, life table parameters and control via edible plant products. Life table parameters of *D. maculatus* were conducted at laboratory conditions in 30 ±5 ˚C, 80 ±10% RH. The study revealed that the maximum incubation period of female was recorded 2.62 days in Indian oil sardine while minimum 2.23 days on Ganges River sprat. The range of the larval development periods for the male and female was 24 to 26.92 days and 23.01 to 26.47 days, respectively. The Ganges River sprat species had the shortest pupae developmental time (5.61 days) while the Giant Sea perch species had the longest (6.56 days). Highest and lowest ovipositional period were 29.87 days) Gangetic anchovy) and 41.06 days (Indian oil sardine) respectively. Moreover, maximum number of eggs laid by individual female was 4.12 per day on Ganges River sprat but minimum 6.25 on Bombay duck. The longest female and male adult longevity were observed 58.31 days on Bombay duck and 49.18 days on Indian oil sardine while the shortest female and male longevity were recorded 51.25 days on Ganges River sprat and 46 days on Gangetic anchovy, respectively. Generation time (T) was lowest (51.23 days) on Ganges River sprat and highest (63.98 days) on Bombay duck. Net reproductive rate (R_o) was highest (195.13 offspring) on Bombay duck and lowest (46.07 offspring) on Ganges River sprat. Both the intrinsic rate of natural increase (r_m) (0.075 day-1) and finite rate of increase (λ) (1.07 day-1) were lowest on Ganges river sprat but the highest r_m was 0.08 day-1 on both Indian oil sardine and Bombay duck whereas highest λ was 1.09 day-1 observed on Indian oil sardine. Population doubling time (DT) was lowest 8.33 days on Indian oil sardine and highest 9.27 days on Ganges river sprat. The gross reproductive rate (GRR) was highest (213.27) while fed Bombay duck and lowest (69.10) on Ganges River sprat. Maximum rate of infestation was found in Indian oil sardine (49.67%) and minimum in Giant Sea perch (4.53%). In the control experiment utilizing edible botanicals and minerals, it was found that Ajwain powder resulted in the highest mortality percentage for both the adult and larval stages of *D. maculatus*. From this study, significant insights were gained into the life cycle dynamics and population parameters of *Dermestes maculatus*, a prominent pest affecting dried fish in Bangladesh. Variations in developmental times, fecundity rates, and longevity were observed across different dried fish species, shedding light on their susceptibility to infestation. Moreover, the efficacy of Ajwain powder as a control measure against *D. maculatus* infestation was established, highlighting its potential as a practical solution for pest management in the dried fish industry.

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