ISSN: **2959-6386** (Online)
Journal of Knowledge Learning and Science Technology, Vol. 1, Issue 1, April 2023
Journal Homepage: http://jklst.org/index.php/home
DOI: https://doi.org/10.60087

PERFORMANCE OF PARASITOID BRACON HEBETOR (SAY.) (HYMENOPTERA: BRACONIDAE) REARING ON TWO LEPIDOPTERAN HOSTPLODIA INTERPUNCTELLAHÜBNER AND CORCYRA CEPHALONICASTAINTON

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| Abstract

Harbobracon hebetor, a parasitic wasp belonging to the Braconidae family, is known for its role in controlling various species of Lepidoptera associated with stored products. This study explores the influence of different photoperiods on H. hebetor reared using the host C. cephalonica. The findings indicate that photoperiod had varying effects on H. hebetor when reared on C. cephalonica. The highest parasitism rate (98.553%) occurred under an 08L:16D photoperiod, followed by 91.110% under a 24L:00D photoperiod and 86.667% under a 00L:24D photoperiod. In contrast, the 12L:12D photoperiod resulted in the lowest parasitism rate at 82.223%. The highest percentage of pupae formation and adult emergence for H. hebetor was achieved at 00L:24D (98.045%) and 08L:16D (98.923%) photoperiods when reared on C. cephalonica. Furthermore, the most significant larval production (86.33) occurred under the 00L:24D photoperiod, while the lowest (20.67) was observed under the 12L:12D photoperiod. Additionally, the 08L:16D photoperiod resulted in the largest male and female body sizes, head width, and wing span length when reared on the host C. cephalonica.

| Keywords

Harbobracon, Hymenoptera gregarious, Lepidoptera, host C. cephalonica.

| Article Information:

Accepted: 20/03/23 **Published:** 01/04/23 **DOI:** https://doi.org/10.60087/vgqyts88

General Introduction

Harbobracon hebetor

Harbobracon hebetor is a tiny wasp belonging to the Braconidae family, known for its role as an ectoparasitoid targeting various species of moth caterpillars. Notable hosts include the larval stage of Plodia interpunctella, commonly known as the Indian meal moth, as well as the late larval stage of the Mediterranean flour moth, the almond moth, and the dried fruit moth. This parasitoid species has gained commercial recognition as an environmentally friendly method for pest control, offering an alternative to chemical insecticides. Harbobracon hebetor (say) is regarded as a promising biological control agent due to its gregarious ectoparasitic behavior, primarily completing its larval development by preying on various species of Lepidoptera host larvae, particularly those of the pyralidae family (Lepidoptera). It has been successfully introduced into integrated pest management (IPM) programs.

Rice Moth

Corcyra cephalonica (Stainton), a pyralid moth belonging to the Galleriidae family within the order Lepidoptera, is a notorious and cosmopolitan storage pest (Neupane, 2000). Its primary target is rice, earning it common names such as the 'rice moth' or 'rice meal moth.' Contrary to its name, C. cephalonica not only infests rice but also poses a threat to wheat, corn, sorghum, groundnut, cotton seeds, coffee, spices, and cocoa beans (Allotey, 1986; Kumar and Kamar, 2001; Ayyar, 1934). The rice moth exhibits a robust, dirty grey appearance, characterized by hairs fringing the lower edges of its fore and hind wings. These moths are nocturnal, and their eggs are deposited indiscriminately on various surfaces within storage areas, including bags, godowns, and walls.

Numerous insecticides have been employed in attempts to control Indian meal moth populations, yet their effectiveness has been limited. A study evaluating the efficacy of an insect growth regulator found that even after treatment with these chemicals, Indian meal moths persisted in corn storage bins. Additionally, resistance to control measures was observed, even with the use of the microbial insecticide Bacillus thuringiensis, where resistance was equally likely with exposure to single strains as with mixtures of the insecticide sequences. As a result, biological control methods have emerged as a promising component of integrated pest management (IPM) strategies for a wide range of stored commodities. These biological control agents encompass pathogens, parasitoids, and predators, making them a valuable alternative for managing stored product pests, as well as agricultural and medical pests (Press et al., 1982; Hujek, 2004; Yu et al., 2003).

Among the diverse array of biocontrol agents, braconoid parasitoids are renowned for their effectiveness in managing various pest insects. The braconoid wasp Bracon hebetor (say) is an ectoparasitoid species that primarily targets larvae of various lepidopteran species, particularly pyralid moths. It stands out as an essential biological control agent for combating moth infestations in stored products across different regions of the world (Brouwer et al., 1996).

Review of Literature

Photoperiod and temperature represent the most crucial environmental cues influencing diapause. The photoperiodic response plays a vital role in diapause induction, serving as a significant life history trait for temperature-sensitive insects in regulating their seasonal life cycle (Tauber et al., 1986). The critical photoperiod for diapause induction exhibits latitudinal variation due to the evident latitudinal gradient in temperature and day length in the temperate zone (Danks, 1994). Many insect species encounter such latitudinal climatic gradients. They adapt to these gradients primarily through genetic variations and partially through phenotypic changes in diapause and related physiological traits (Higashi, 1999).

In 1936, E. B. Ünning proposed a concept wherein the measurement of time in photoperiodic induction depended on the endogenous diurnal rhythm, known as the circadian rhythm, which provided temporal organization in plants (Bünning, 1936). In his explicit model, Ünning suggested that the 24-hour cycle comprised two half cycles with differing sensitivities to light. The first 12 hours constituted the "photophil" (i.e., subjective day), and the second 12 hours were the "scotophil" (i.e., subjective night). Short-day (or long-night) effects occurred when light was restricted to the photophil half cycle, while long-day (or short-night) effects were observed when light extended into the scotophil half cycle. Thus, light played a dual role: entraining the circadian rhythm and inducing photosensitivity.

Photoperiod serves as one of the most reliable zeitgebers for timekeeping in organisms (Aschoff, 1960; Bünning, 1960; Pittendrigh, 1960). Numerous studies have aimed to unravel the mechanisms underlying this biological chronology (Beck, 1980; Saunders, 2002). Insects often exhibit daily rhythms of activity in their physiology and behavior. To establish a photoperiodic response curve, insects are typically exposed to fixed photoperiodic cycles (Beck, 1980; Saunders, 2002). The determination of the photosensitive phase involves the extensive use of stepwise photoperiodic changes (Zaslavski, 1988).

In addition to photoperiod, thermo-period can also serve as a significant time cue (Zeitgeber) for circadian oscillators. While relatively few studies in insects report the entrainment of circadian rhythms by thermo-period (Saunders, 2002), research on the effects of temperature cycles on the adult eclosion rhythms of lepidopteran species is limited (Hirai, 1972; Doush and Schneider, 1985; Miyata, 1986; Riemann, 1991; Tanaka et al., 2012).

The eclosion rhythm of the adult onion fly Delia antique, a species that pupates in the soil and emerges as an adult under various thermo-periodic conditions, has been extensively studied (Watari, 2002; Tanaka & Watari, 2003, 2001; Watari & Tanaka, 2010). It is suggested that the timing of adult eclosion in this species is regulated by thermo-cycles, with the peak of eclosion advancing as the amplitude of the thermo-cycle decreases. Additionally, research focused on the development of the parasitoid Harbobracon hebetor (Say) (Hymenoptera: Braconidae) at low temperatures aimed to identify rearing conditions that might result in adults entering reproductive diapause (Haoliangchen et al., 2012). Furthermore, studies have explored the optimal photoperiod for larval development, adult emergence, and fecundity of the rice moth Corcyra cephalonica (Chu et al., 199).

Aim of the Work:

The primary objective of this project was to evaluate the impact of photoperiod induction on the parasitoid Harbobracon hebetor (Say) (Hymenoptera: Braconidae) reared using the lepidopteran host Corcyra cephalonica. This experiment encompassed the following aspects:

1. Assessing the parasitism percentage in H. hebetor reared with C. cephalonica due to photoperiodic induction.
2. Estimating the effects of photoperiod on the growth and development of H. hebetor reared with Corcyra cephalonica.

Mass Rearing of Host *Corcyra Cephalanica* and Parasitoid *H. hebetor*

Mass Rearing of Corcyra cephalanica

Mass rearing and laboratory cultivation of insects play crucial roles in various integrated pest management strategies. However, these practices can significantly impact insect performance through phenomena like laboratory adaptation, inbreeding depression, unintentional selection, and direct rearing effects, such as crowding and artificial diets. Consequently, when raising insects intended for release in the field or when research aims to mimic the performance of wild populations, it becomes imperative to establish quality standards under these conditions. In practice, much of the emphasis on controlling mass-reared or laboratory-raised insects revolves around maintaining facility output, such as numbers, with less attention given to individual trait effects like mating competitiveness or field flight performance. This can be attributed to practical constraints, such as time and budget limitations, but also stems from a limited understanding of the relationship between laboratory and field assays and the fundamental biology of the species.

Rearing entomophagous insects for mass production can pose challenges. In cases where these insects have not been reared previously, they often need to be raised on their natural host or prey due to the absence of artificial diets. Consequently, the laboratory rearing of beneficial insects involves managing three distinct entities: the beneficial species itself, the insect host, and the plant host or artificial food source. Maintaining all three levels can be challenging and, in some instances, costly.

The concept of mass production can be defined as the skillful and highly refined processing of an entomophagous species and its host substrate through a specialized production system, resulting in the cost-effective production of large quantities of beneficial insects. The rearing of beneficial insects involves the synchronization of three biological entities: the beneficial species, the host species, and the host plant or food source. The objective of a mass production program is to maximize efficiency while minimizing labor, space, and costs. This can be achieved through the standardization of procedures, mechanization of processes, efficient production methods, quality control maintenance, effective sanitation, and microbial contamination control in the rearing laboratory (Singh, 1982).
Key qualities required in a laboratory-reared insect include a short life cycle, high biotic potential, simple dietary requirements, and adaptability to alternative hosts. Quality control for mass-produced insects currently encompasses various interrelated concepts. While entomophagous insects have been reared in large numbers for some time, true mass production commenced approximately 36 years ago following the introduction of genetic control concepts. During the early 1970s, comprehensive concepts for evaluating and enhancing the quality of insects produced at minimal costs were virtually nonexistent. It wasn't until the late 1970s that quality control principles began to emerge. Generally, the quality of mass-reared insects is defined and assessed in terms of how effectively the insect population functions in its intended role, whether in the field or laboratory (Huttel, 1976).
Numerous traits related to the quality of laboratory-reared insects are considered, including vigor, activity, reproductive potential, and biotic potential. Quality can be influenced by various factors, such as alterations in metabolic functions, nutritional reserve content, temperature tolerance, and responses to toxins. Other crucial aspects include fertility, fecundity, longevity, and changes in biological characteristics like mating behavior rhythms and host specificity (Singh, 1982). The present study has been initiated to develop a mass rearing protocol for the rice moth, C. cephalonica, under laboratory conditions.

Materials and Methods

Host Insect Culture

Insect Colony: We initiated our study with a laboratory culture of *Corcyra cephalonica* (C. cephalonica) obtained from the Post-Harvest Entomology laboratory, Department of Zoology at Rajshahi University. The source population was comprised of adults collected from local food facilities in Rajshahi metropolitan city. These insects were reared on maize flour under controlled laboratory conditions, maintaining a temperature of 27°C and relative humidity levels between 70% to 75%.

Culture Boxes: Plastic boxes measuring L-14.0 cm, W-11.2 cm, and H-8.50 cm were employed for this experiment. The boxes were procured from local markets and featured small-meshed netting as lids to facilitate proper gaseous exchange. The lids were securely fitted to ensure that no larvae could escape from the culture boxes.

Diet: We utilized maize flour as the primary food source for *C. cephalonica*. Maize seeds were acquired from the market, sun-dried, and subsequently ground into flour. To ensure hygiene, the flour was heated at 50 degrees Celsius for 24 hours in an incubator. Once cooled, this flour was utilized as the food source in the mass culture boxes, with a food thickness of 2 inches.

Adult Release: In each mass culture box, 50 pairs of fresh, newly hatched adult *C. cephalonica* (comprising 950 males and 50 females) were introduced. Tissue papers were provided within the boxes to facilitate egg laying by the adult moths. Each female laid eggs over a span of 3 days. After mating, males perished, followed by the eventual death of the females. Deceased adult moths were carefully removed from the mass culture boxes once the last one had expired.

Experimental Procedures for Cellulae and Egg Collection: Newly emerged virgin males (less than one hour old) were paired with 1–3-day-old virgin females. Each of these treatment groups (treatments 4–6) was replicated 10 times, with moths placed in glass jars measuring 10×5 cm. The jars were covered with small pieces of muslin cloth post-pairing. Daily observations were conducted to count the number of eggs laid by females, which were subsequently sieved from the diet. Adult longevity was recorded until all individuals had perished.

Egg Collection: Eggs were collected daily and placed in Petri dishes sized 25×10 mm, along with the rearing diet. Eggs of the Indian meal moth appeared greyish-white and ranged in length from 0.3 to 0.5 mm. These eggs were laid either individually or in clusters, typically directly on the larval food source.

Larval Collection: *C. cephalonica* larvae typically undergo five to seven instars. Their coloration varied from off-white to pink, brown, or even slightly greenish, depending on their diet. These larvae possessed five pairs of well-developed pro-legs, enabling them to move considerable distances to pupate. After 25 days from the release of adults in the mass culture boxes, mature larvae were harvested from the food, and their weights were measured. To calculate the total number of larvae statistically, each spot measured 2 inches in size.

Pupae: The larvae pupated either within silken cocoons or without protection. These pupae ranged from 1/4 to 2/5 inches long (6 to 11 mm) and displayed a pale brown coloration. Pupation occurred away from the infested material. Late-instar larvae were known to travel significant distances, often leading to misconceptions about the source of infestations within pantries.

Adult Collection: Adult *C. cephalonica* measured approximately 1/2 inch (12.7 mm) in length, with a wing span of about 5/8 inch (16 to 20 mm). The forewings of these moths exhibited a reddish-brown hue with a coppery sheen on the outer two-thirds and grey coloring on the inner third. When at rest, the wings formed a roof-like structure over the body. The head and thorax appeared grey, while the posterior displayed a brown coloration with a coppery sheen. Adults were collected upon emergence, with this process being repeated 20 times to record the developmental time period from egg to adult emergence for *C. cephalonica*.

Plate-1: Egg

Plate-2: Larvae

Plate-3:Pupal Formation

Plate-4: Pupa

Plate-5: Culture Box

Plate-6:Cellulae

Mass Rearing of Parasitoid H. hebetor

Introduction

Habracon hebetor Say (Hymenoptera: Braconidae) is an ecto-parasitoid known for its ability to target the 4th and 5th instar larvae of pyralid moths, including the greater wax moth (*Galleria mellonella*) (L.) (Lepidoptera: Pyralidae) (Awadallah et al., 1985). It also parasitizes other economically significant species such as *Plodia interpunctella* (Hübner) (Milonas, 2005), *Corcyra cephalonica* (Stainton) (Krombein et al., 1979), *Ephestia kuehniella* Zeller (Darwish et al., 2003), *Helicoverpa armigera* Hübner, and *Heliothis virescens* (F.) (Attaran, 1996). These pests infest both field crops and stored products (Benson, 1974). *H. hebetor* is regarded as a potential biological control agent for lepidopteran pests in stored products (Brower et al., 1996) and certain field insect pests.

Traditionally, the management of lepidopteran pests has heavily relied on chemical insecticides, including fumigants and aerosols. However, these moths have developed resistance to insecticides (Zettler et al., 1973). Furthermore, the presence of insecticide residues in food products and processing facilities poses direct risks to human health and the environment (Fields and White, 2002).

In recent years, there has been a growing interest in non-chemical strategies for insect control, encompassing cultural, physical, biological, varietal, bio-rational, and genetic control methods, as alternatives to conventional pesticides for managing stored product insects and field pests (Subramanyam and Hagstrum, 2000; Phillips, 2006). Among these approaches, the utilization of natural enemies, including parasitoids and predators, has gained prominence in integrated pest management (IPM) due to its numerous advantages over chemical control (Scholler et al., 1997; Scholler and Flinn, 2000).

H. hebetor females employ a strategy of paralyzing their host larvae through stinging, followed by the deposition of variable numbers of eggs on or near the surface of the paralyzed hosts (Antoline et al., 1995). These paralyzed host larvae serve as nourishment for developing larvae and adult females alike (Doten, 1911; Richards and Thompson, 1932). Ghimire and Phillips (2010) conducted a study on the mass rearing of *B. hebetor* on *P. interpunctella* to investigate the impacts of host density, parasitoid density, and rearing container size on adult progeny production and sex ratio. Their findings revealed that host density, parasitoid density, and rearing container size significantly affected adult progeny production, but had no influence on the sex ratio.

Given the increasing emphasis on environmental safety and the global demand for pesticide-free food, the search for eco-friendly pest management methods has intensified. Biological control methods have garnered heightened attention as a response to the adverse effects of pesticides on the environment, aligning with new international trends that favor the conservation and sustainable use of biological resources.

Researchers in the field of biological control have recognized the importance of interactions between parasitoids and their hosts to ensure the success of biological control programs. *Bracon hebetor* (Say) is considered one of the potential biological control agents. It is a gregarious ecto-parasitoid species that completes its larval development on various species of Lepidoptera host larvae, especially those of the Pyralidae family, which includes agricultural pests infesting field crops and stored products. Key species among these pests include *Ephestia kuehniella*, *E. cautella*, *Galleria mellonella*, *Achroia grisella*, *Helocoverpa armigera*, *Corcyra cephalonica*, and *Plodia interpunctella* (Calderon et al., 197; Brower et al., 1996).

The efficiency of biological control hinges on the cost-effective production of biological control agents, particularly parasitoids. In recent years, substantial progress has been made in the production of beneficial insects. Life tables are essential tools for quantitative analysis and population estimation. Therefore, this study primarily focuses on evaluating the impact of different hosts on the developmental time, longevity, fecundity, and life table parameters of *B. hebetor*. The aim is to identify the most suitable hosts for rearing *B. hebetor* to effectively deploy it as a biological control agent.

Materials and Methods

Insect colony: A laboratory culture of *Bracon hebetor* was used for this experiment. Our initial *B. hebetor*culture was obtained from the post-harvest Entomology laboratory, Department of zoology, Rajshahi University. This laboratory culture was from adults collected from BARI at Joydevpur, Dhaka. They werereared on Indian meal moth larvae under laboratory condition at 25°C degree Celsius and 70-75% RH at the Post Harvest Entomology laboratory, Department of Zoology, Rajshahi University.

Culture box: For this experiment plastic boxes were used which were obtained from the local market. The height and width of the boxes were 9.50 cm and 15 cm respectively. Middle portion of the lid of the boxes were cut down and very small mesh size net was used there. This system allowed easy to gaseous exchange. The gap between lid and net were sealed very carefully so that a single larva will notcome out outside from the culture box.

Diet: Indian meal moth larvae were used as the food of *B. hebetor*. The maize seed was collected from thelaboratory. The larvae should be separated from the maize flour. It should be clean and free from net which is made by the Indian meal moth larvae.

Adult release: At least 7-10 pairs (7-10 males and 7-10 females of *B. hebetor*) were released in each massculture box which was carrying at least 100 Indian meal moth larvae. All the adults were fresh and newly hatched. In the box, baspata papers were placed on the box so that adults female can easily sit and lay eggs on it. Each female laid eggs till 5-7 days or more till they death. Males were died soon after mating and females were died after finishing the egg laying. When the last adult died in the mass culture box thenwe removed the dead bodies carefully from the boxes.

Emergence of*Bracon* Larva: After 3-4 days of releasing adults in the mass culture box, matured larvaewere found in the culture box. The larvae of *Bracon* take food from the infested larvae of Indian meal moth. The larvae of *Bracon* take at least 1-2 days to reach in pupal stage.

Pupae: The larvae pupate either in a silken cocoon or unprotected. The pupae are 1.5 to 2.5mm in lengthand white in color. Pupation takes place away from the infested material. In fact, late instar larvae can travel such distances that they are often mistaken for clothing pests. The pupal stage lasts for 5-6days.

Adult collection: Adults are about 1/2 inch (12.7 mm) long with a wing span of about 5/8 inch (16 to 20 mm). The forewings of this moth are reddish brown with a copper sheen on the outer two thirds and greyon the inner third. At rest the wings are held roof-like over the body. The head and thorax of the moth appears grey and the posterior brown, with a coppery sheen. When the adults emerged then they were collected. This was made for 20 times development time period from egg to adult emergence for *P. interpunctella* was recorded.

Plate-1: Male Bracon

Plate-2: Female Bracon

Plate-3: Bracon culture

Plate-4:Bracon larvae

Plate-5:Braconpupae

Plate-6:Bracon adult

Effect of Photoperiod Regimes on the Biological Traits of Parasitoid *Habrobraconhebetor*(Say)(Hymenoptera: Braconidae) Rearing on Rice Moth *Corcyra cephalonica*(Stainton)
Introduction

The rice moth *Corcyra cephalonica* is an important insect pest of different stored products in tropics. It isthe major pest of rice, wheat, sorghum, corn (maize), cocoa, peanuts, almonds, dates, groundnut, cotton seeds, coffee, spices and cocoa beans, cashews, raisins and millet (Cox et al., 1981; Trematerra, 1983; Allotey and kumar, 1985; Mbata, 1989; Allotey, 199la; Johnson et al., 1992; Locatelli and Limuata, 1988;Harita et al., 2000).
Habrobracon hebetor is an ectoparasitaid of the larvae of many pyralid pest-species, that attack stored grains. The parasitoid is considered to have a potential for the biological control, of many other lepidopterous pests, of various crops, because it is highly aggressive It occurs, naturally, throughout the world. There is a growing evidence that B. hcbctor can also be an important bio-control agent of *Helicoverpa armigera*. It is used in Turkmenistan, on cotton and to a lesser extent, in Uzbekistan, where,theyrely more on *Trichogramm apintoi*. It attacks the larval stage of stored gainpyralid moths, such as Plodia interpunctella Hilbner.

The biology of *H, hebeto r*has been intensively studied because of its importance as a biological control agent of the moths and also it is easy to rear in the laboratory (Benson, 1973, Taylor, 1988: Brower and press, 1990; Heimpel et al, 1997; baker nad Fabric, 2000; Darwish et al., 2003; Giindiiz and Giilel, 2005;Milonas, 2005; Margo et al., 2006; Giindiiz et al., 2008). Many researchers have been studied on the effects of host quality and or quantity on biology and ecology of//, *hebetor*(Ullyett, 1945; Doutt, 1959; Taylor, 1988; Yu et al, 2003).

Materials and Methods

Host Culture

The adult Indian meal moths (*C. cephalonica*) were sourced from local food facilities in Rajshahi Metropolitan City. A laboratory culture of *C. cephalonica* was employed for this study, initially obtained from the Post-Harvest Entomology Laboratory within the Department of Zoology at Rajshahi University. These moths were reared on maize flour under controlled laboratory conditions, maintained at 25°C and with a relative humidity (RH) of 70-75%.

Parasitoid Culture

Larval parasitoids (*H. hebetor*) were collected from the Bangladesh Agriculture Research Institute (BARI) in Gazipur, Dhaka. These parasitoids were subsequently reared within a laboratory room under conditions of 25-27°C and 60-70% relative humidity (RH) at the Post-Harvest Entomology Laboratory within the Department of Zoology at Rajshahi University.

Experimental Procedure

The experiments were conducted under constant laboratory conditions with normal temperature and relative humidity. Three distinct photoperiods were selected as follows:

- **B. 24 L: 24D:** This regimen entailed 24 hours of daylight followed by 24 hours of darkness.
- **C. 8L: 16D:** In this scenario, there were 8 hours of daylight followed by 16 hours of darkness.
- **D. 12L: 12D:** This photoperiod consisted of 12 hours of daylight followed by 12 hours of darkness.

To provide illumination, 12-watt fluorescent bulbs were used for each photoperiod regime. The trial with continuous darkness was conducted in an incubator by covering it with foil paper, while the other trials were conducted in an incubator adjusted to simulate the appropriate photoperiod lighting conditions.

In the experiment, 15 mature *C. cephalonica* larvae, sourced from the rearing facility, were separately placed into three containers. Subsequently, one pair of newly emerged adult *H. hebetor* was introduced into each of these containers. The containers were then sealed with lids and covered with black cloths to facilitate infestation of host larvae by *H. hebetor*.

After 2 days, the number of parasitized host larvae was recorded, and regular checks were made for the number and date of pupae formation among *H. hebetor*. The total number of parasitoid pupae in each container was tallied, and the number of adult parasitoids in each container was also counted. Additionally, the dimensions (total length, head width, thorax length, abdominal length, and wing span in millimeters) of deceased *H. hebetor* parents were measured using a microscope and a 1/10 millimeter scale.

Results

Figure 1 illustrates the impact of photoperiod on the percentage of parasitism in *H. hebetor* reared on its host, the rice moth *C. cephalonica*. The highest percentage (95.553%) of parasitism occurred in the 08L:16D photoperiod, followed by 91.110% in 24L:00D, and 86.667% in 00L:24D. The lowest percentage (82.223%) was recorded in the 12L:12D photoperiod. Notably, the effect of photoperiod on the percentage of parasitism did not exhibit significant variations (see Appendix Table 1 for details).

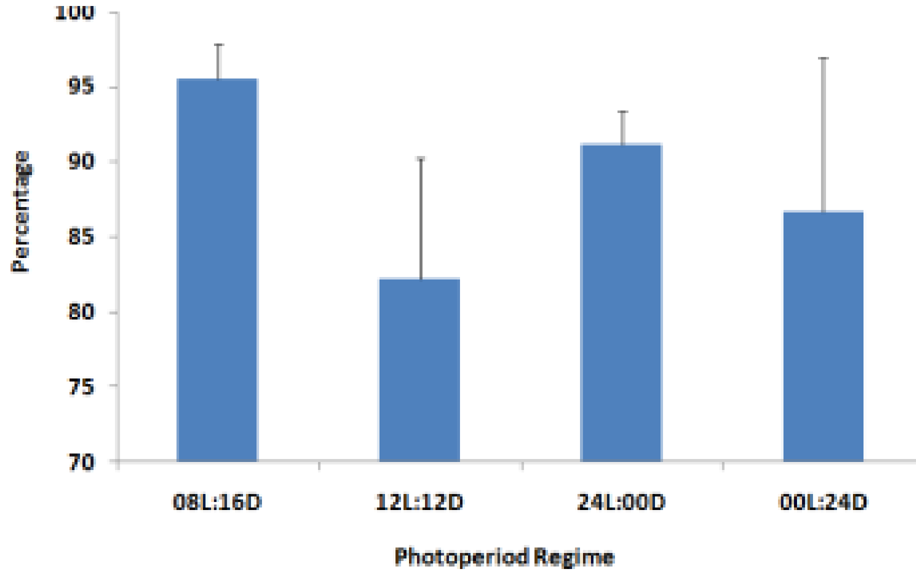

Fig. 1: Effect of photoperiod regimes on the percent parasitism in H. hebetor rearing on the host rice moth C. cephalonica

The fig 2 showed the effect of photoperiod regimes on the production of larvae of *H. hebetor* rearing on the host rice moth *C. cephalonica* the highest larval rate 86.33 was recorded for 00L:24D photoperiod followed by 62, 45.67, 20.67 for 24L:00D, 08L:16D, 12L:12D respectively. As Appendix Table 2 shows,there was no significant effect of photperiod on the production of larvae of *H. hebetor* rearing on the hostrice moth *C. cephalonica.*

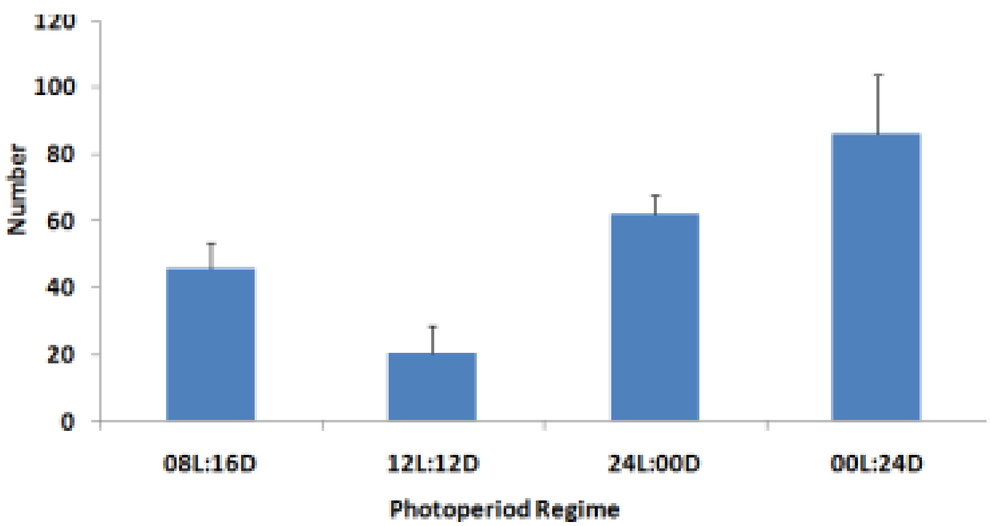

Fig. 2: Effect of photoperiod regimes on the production of larvae ofH. hebetor rearing on the host ricemoth C. cephalonica

The fig. 3 showed the effect of photoperiod regimes on the percent pupae formed and adult emergence in *H. hebetor* rearing on the host rice math *C. cepholonica*. The highest percentage (98.045%) pupae formedwas recorded for 00L:24D and adult emergence (98.923%) for 08L:16D photoperiod and lowest was (91.128%) for 12L:12D and (82.683%) for 00L:24D (Appendix table 3 and 4). The effect of photoperiod regimes on the percent pupae formed and adult emergence are not significantly varied in *H. Hebetor* rearing on the host rice moth *C. cephalonica*.

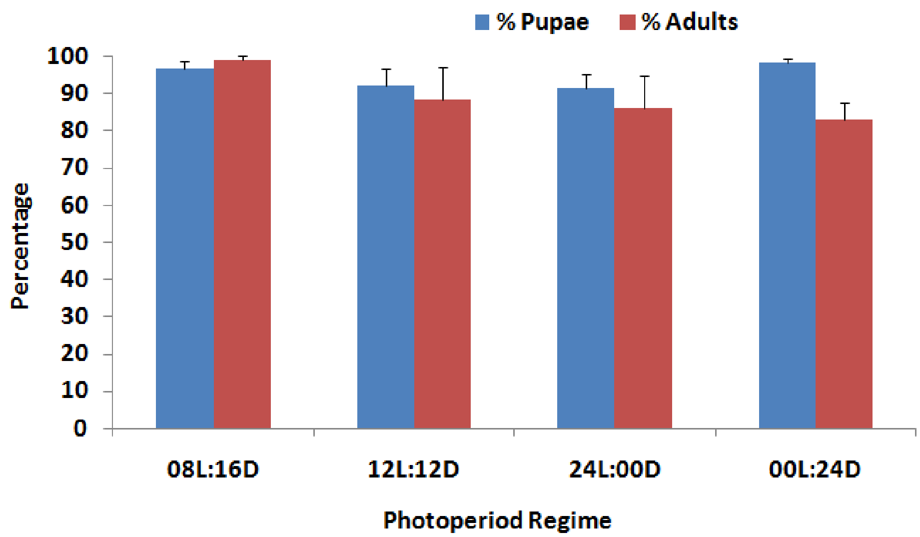

Fig. 3: Effect of photoperiod regimes on the percent pupae formed and adult emergence in H. hebetor rearing on the host rice moth C. cephalonica

The fig 4 showed that the effect of photoperiod on the female ratio in *H. hebetor* rearing on the host rice moth *C. cepholonica*. The female ratio sequence of photoperiod was 08L: 16D> 24L:00D>00L:24D> 12L:12D. As ANOVA showed, there was significant difference among the photoperiods for female ratio(Appendix Table 5).

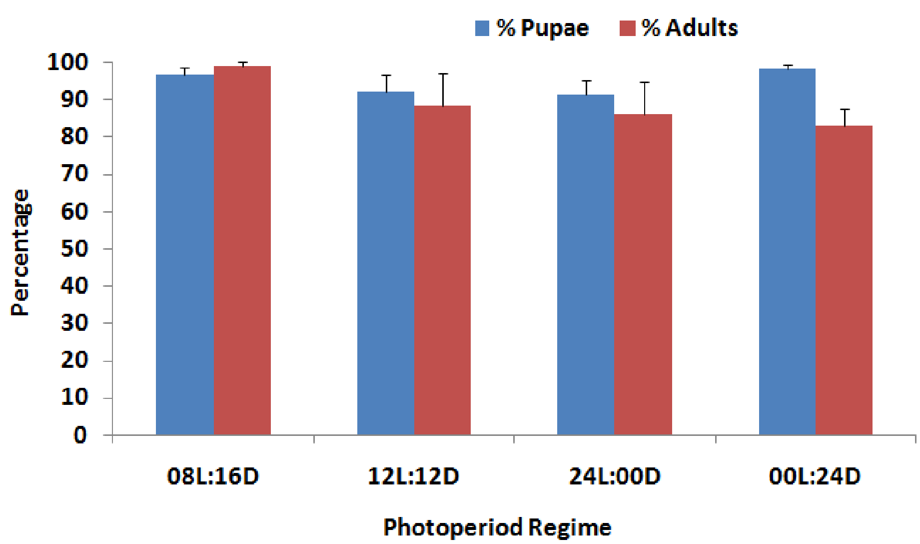

Fig. 4: Effect of photoperiod regimes on the female ratio in H. hebetor rearing on the host rice moth C.cephalonica

Table-1: Effect of photo period regimes on the sizes (Mean±SE) a adult parasitoid H. Hebetor.

Photoperiod regimes	Male length			Female length		
	Headwidth (mm)	Body(mm)	Wing span (mm)	Headwidth (mm)	Body(mm)	Wing span(mm)

08L:16D	0.32±0.012	1.76±0.040	2.00±0.03	0.32±0.012	1.8±0.055	2.02±0.058
12L:12D	0.31±0.010	1.74±0.060	1.96±0.051	0.32±0.012	1.72±0.066	1.9±0.089
00L:24D	0.31±0.010	1.62±0.073	1.92±0.073	0.31±0.010	1.5±0.055	1.9±0.045
24L:00D	0.31±0.010	1.64±0.051	1.88±0.066	0.32±0.012	1.68±0.066	1.9±0.063

The table 1 shows that the effect of photoperiod on the adult body length of *H. hebetor* rearing on the ricemoth *C. cephalanica*. The highest male body length was 1.76mm in 08L:16D photoperiod and lowest was1.62mm in 24L:00D photoperiod.
The highest female body length was 1.8 in O8L:16D photoperiod and lowest was 1.5mm in 24L:00D photoperiod. However, there was not significant effect of photoperiod on the adult body length of *H.hebetor*. The highest and lowest male and female head width length was 0.32 mm and 0.31mm in 08L:16D and 24L:00D photoperiod respectively. There was not significant effect of photoperiod on thehead width length of *H. hebetor*.
The highest male wing span and female wing span length was 2.00 mm in 08L:16D photoperiod, 2.02mm in 08L:16D photoperiod and the lowest male and female was 1.88mm in 00L:24D photoperiod, 1.9mm in 00L:24D photoperiod. There was not significant effect of photoperiod on the length of wingspan of *H. hebetor* rearing host rice moth *C. cephalonica*.

Discussion

Development and Physiological Factors Influencing Insects

Various factors, including temperature, humidity, photoperiod, and the quality and quantity of food, can significantly impact the development and physiological processes of insects (Na and Ryoo, 2000; Musa and Ren, 2005; Bouayad et al., 2008). Photoperiod and dietary diversity play crucial roles in the development and viability of these organisms (Shojaaddini et al., 2005). Photoperiod influences a wide range of activities in living creatures, such as hatching, pupation, sex ratio, lifespan, and nutritional behaviors (Macedo et al., 2003; Saunders and Bertossa, 2011; Workman et al., 2011; Fonken et al., 2012; Saunders, 2014). Many insect species exhibit differential developmental rates under varying day lengths, with some progressing faster under shorter days and others under longer days (Saunders, 2002).

Impact of Host Component on Parasitoid Reproductive Parameters

The findings of the present study underscore the substantial influence of the host component on various reproductive parameters of parasitoids, including parasitism percentage, larval count, pupation percentage, adult emergence, and progeny size (body, head, wing span). Importantly, *H. hebetor* is capable of completing a photoperiodic cycle when reared on its host, *C. cephalonica*.

Effect of Photoperiod on Parasitoid Rearing

In our experiment, the highest percentage of parasitism was observed in the 08L:16D photoperiod, while the lowest occurred in the 24L:00D photoperiod when rearing *H. hebetor* on its host, the rice moth *C. cephalonica*. The photoperiod with 00L:24D and 08L:16D yielded the highest percentage of pupae formation and adult emergence, as well as the largest body size and head and wing span lengths in both male and female adults. These results suggest that *C. cephalonica* is the most favorable host for rearing *H. hebetor* under photoperiodic conditions.

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