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Life Cycle of Dried-fruit Beetle, *Carpophilus hemipterus* (L.) (Coleoptera: Nitidulidae) on Peanut and Population Development on Different Processed Nuts

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***Abstract*:** Studies on the biology of dried-fruit beetle *Carpophilus hemipterus* (L.) on peanut and its preference among five different nut kernels were conducted at Post Harvest Technology Centre, Bapatla, Andhra Pradesh, India. The adult is a slightly flattened oblong beetle measures 2 to 5 mm in length. The elytra are short, leaving distal portion of the abdomen exposed. The average time period from egg to adult emergence is 33.6 days during winter and 41.17 days in summer. Pistachios and cashewnuts attracted significantly more insects (9.33 and 8.67, respectively) of dried-fruit beetle adults and the total adult progeny was the highest in pistachios (125.0) which was at par with cashewnuts (114.83). The order of preference of *C. hemipterus* to the processed nuts tested was; pistachios > cashewnuts > walnuts > peanuts > almonds. *C. hemipterus* is a pest of quarantine importance, knowledge on insect biology and its preferences to various nuts is useful to take necessary preventive measures in storage and processing units.

***Keywords*:** Edible nuts, Storage product insects, Nitidulidae, Preference, Quality

Nuts have become an important part of healthy diet as they are rich in proteins, dietary fibres, vitamins, minerals, mono- and poly-unsaturated fatty acids, antioxidants, carotenoids, phytosterols and phenolic compounds (De Souza et al 2015, Tas and Gokmen 2017) and are known to improve metabolic biomarkers (Leila et al 2022). With high calorific value and several nutritional and health benefits, nuts play a very significant role as immunity boosters in prevention of many diseases including cardiovascular risks, arterial pressure, oxidative stress, inflammation and insulin resistance (De Souza et al 2017, Kim et al 2017). Popular edible nuts viz., almonds, hazels, pecans, macadamias, pistachios, walnuts, cashew nuts, peanuts, etc. are traded in the international market. India is the major producer, processor, consumer and exporter of cashew which is the most important commercial crop grown in the coastal belt of India (Karthickumar et al 2014). In India, cashew was cultivated over an area of 1.16 million hectares during 2021-22 with an estimated kernel production of 7.74 lakh metric tonnes (FAOSTAT 2022). India ranks second with 22% of the world's production next to the African countries sharing 45% (ICAR-DCR Annual Report 2021). Walnut and pistachios are grown in temperate regions of northern India. However, nuts like almonds either in the form of raw or kernels are imported from other countries for processing, and marketing within the country. Peanut is another economically important crop grown for edible oil as well as table purposes. During post-harvest processing of nuts, stored product pest problems are becoming major concern. Common pests observed in nut processing industries are insects, mites, rats, microbes, birds, etc., while the insects include, red flour beetle *Tribolium castaneum* (Herbst), red-legged ham beetle *Necrobia rufipes* (De Geer), saw-toothed beetle *Oryzaephilus surinamensis* (L.), dried-fruit beetle *Carpophilus hemipterus* (L.), cadelle *Tenebroides mauritanicus* (L.), almond moth *Ephestia cautella* (Walker), Indian meal moth *Plodia interpunctella* (Hubner), lesser meal worm *Alphitobius piceus* (Olivier), etc (Rajat et al 2020).

Approximately 200 species have been reported under the genus *Carpophilus* which are distributed in tropical and temperate regions mainly by international trade. Many cryptic species like *C. hemipterus*, *C. mutilatus* Erichson, *C. obsoletus* Erichson, *C. ligneous* Murray and *C. dimidiatus* (Fabricius) cause considerable damage to processed and un-processed dried fruits and stored products (Leschen and Marris 2005). The adults and larvae of *Carpophilus* spp. cause damage on poorly dried cereal grains, cocoa, copra, oilseeds, dried fruits, vegetables, herbs and mouldy produce. Louw et al (2009) documented that the dried-fruit beetle breeds prolifically in fermenting fruit, with the adults sheltering under the decaying, moist cladodes those dropped from the cactus pear plant. An event of rain triggered hull rot, *Carpophilus* beetle trap catches, and nut damage in almonds with higher damage levels in wetter areas of Australia (Hossain 2018). Thus, moisture and humidity are very important for the development of dried fruit beetles (Mason

2018). Though the dired-fruit beetle is regarded as a pest of minor importance as it feeds predominantly on rotten, fermented or over ripened fruits in the field, the beetles pose a significant risk to export markets because the infested nuts are difficult to identify and reject during processing and sorting. Moreover, *C. hemipterus* is capable of thriving well even at higher temperatures compared to other species of *Carpophilus* (James and Vogele 2000).

Andhra Pradesh is located in the coastal region of India and there are several industries involved in the processing of various nuts. Volatiles from food products in combination with aggregation pheromones produced by male adults of *C. hemipterus* play a major role in attracting the insects. Abiotic and host-associated factors such as nutritive values, moisture, temperature, processing methods, storage conditions and control measures determine the survival and development of insect pests on dried fruits and nuts and their economic impact. Since these are high-valued food items and traded in international market, a very low or zero tolerance of live insects is allowed. Particularly during certain processing activities, such as, partial rehydration normally done before packing to avoid breakage, nuts are prone to oviposition by dried-fruit beetle and results in returns of shipments. With this in view, studies on life cycle of *C. hemipterus* and its preference among different nuts were taken up which can help in formulation of necessary preventive measures during processing and storage of various nuts.

MATERIAL AND METHODS

Detailed biology of *C. hemipterus* on peanut and its preference among five different nut kernels was studied in ambient conditions at Post Harvest Technology Centre, Bapatla, Andhra Pradesh, India during 2021 and 2022.

Insect rearing: The *C. hemipterus* insects were cultured on disinfested fresh peanut substrate in the laboratory using few adult insects collected from the peanut samples of local processing units. For this purpose, more than 1 kg of freshly shelled peanut kernels were procured and sterilized in a hot air oven for 3 h maintained at 60 ºC to kill all the insects at different stages, if any. After cooling, the kernels were made into four parts of 250 g each and placed in culture jars (500 ml). Then, 50 adults of *C. hemipterus* were introduced into each jar with the aid of an aspirator. The jars were covered tightly with a perforated lid which was covered with fine mesh to allow aeration and were kept in the laboratory at ambient conditions. After allowing oviposition by females for three days, the introduced insects were removed and the cultures were retained until the emergence of adult progeny. After completion of two generations, freshly emerged adult insects were used for the studies on biology and preference.

Life cycle of *C. hemipterus* on peanut: Insects comprising of both sexes were released into fresh peanut kernels and left overnight for oviposition by female insects. All the insects were removed to ensure that the eggs laid are fresh and of same age. The egg laden individual kernels were observed with the help of an illuminated magnifying lens and isolated into small diet cups. They were observed individually till the emergence of adult while the duration of different stages i.e., egg, larva, pupa, and longevity of adult insects were recorded. Thus, total developmental period from egg to adult emergence was worked out. The mean duration of each stage was calculated based on 30 insect individuals. This study was carried out both during summer and winter months.

Preference of *C. hemipterus* to different nut kernels: The relative preference of *C. hemipterus* for five different nut kernels namely; peanut (*Arachis hypogaea* L.), cashewnut (*Anacardium occidentale* L.), pistachio (*Pistacia vera* L.), almond (*Prunus dulcis* [Mill] D.A. Webb), and walnut (*Juglans regia* L.) was assessed under free-choice conditions. Nut kernels of premium quality were procured from the local market of Bapatla. All five types of nuts (20 g each) were taken in separate polythene paper discs (10 cm diameter) and arranged in a circle in a steel container (45 cm diameter and 10 cm depth) having a lid. The mixed population of twenty four *C. hemipterus* adults was released in the centre so that each individual insect can move into the host material according to its preference. Thus, there were five treatments with three replications arranged in completely randomized design. At five days after release of insects (DAR), the nuts were collected in to individual plastic containers (capacity: 200 ml) along with insects and the number of insects moved into each type of nuts was recorded. Observations on subsequent progeny adult emergence from each nut species were recorded at 40 and 80 DAR and the total progeny adults were worked out. The mean population emerged from the nut samples were suitably transformed and analysed for ANOVA using web based agricultural statistics software package WASP 2.0.

RESULTS AND DISCUSSION

Life cycle of *C. hemipterus* on peanut: The dried-fruit beetle adult is a slightly flattened oblong beetle measures 2 to 5 mm in length. The elytra are short, leaving distal portion of the abdomen exposed (Fig. 1). They are light brown in color with yellow markings on the wing cases. On peanut kernels, the adults prefer to lay eggs beneath the seed coat at points where it is ruptured or damaged. They explore to find out such places on the nuts for egg laying. During winter, the egg period of *C. hemipterus* is 5.25 days ranging from 4 to 6 days

(Table 1). The larval period is 19.3 days and the pupal period is 9.05 days. During summer, the period of the egg stage is 4.93 days and the larval period is 29.93 days followed by the pupal stage which lasted for 8.7 days. Thus, the average time period from egg to adult emergence is 33.6 days during winter and 41.17 days in summer. The adults that emerged during the winter months survived for more than 120 days, whereas, those emerged during summer lived only for about one month. Similarly, an extension in larval duration for about 10 days during the dry-weather period also indicated that this pest prefers high humidity.

Gautam et al (2014) observed that eggs of *C. hemipterus* are white in color and cylindrical in shape with bluntly pointed anterior and posterior ends**.** Burks and Johnson, (2012) described that *C. hemipterus* adult has a distinct yellow colored patches on elytra; the antennomeres 2 and 3 subequal in length; prosternal process expanded laterally behind coxae; mesoventrite with discal carinae; and metaventrite with axillary space very small, reaching to 1/5 the length of metepisternum. Adults feed, and live longer than the larvae. Larvae and adults of *C. hemipterus* beetles cause extensive damage by feeding on the product and contaminate it with frass, cadavers, and cast skins; ultimately causing increased moisture which leads to product spoilage with undesirable mold and bacterial growth (Luttfullah and Hussain 2011).

Table 1. Biology of *C. hemipterus* on peanut

Stage of the insect	Development period (Days)	
	During winter	During summer
	Mean± SD (Range)	Mean± SD (Range)
Egg	5.25 ± 0.79 (4-6)	4.93 ± 0.78 (4-6)
Larva	19.3 ± 1.22 (17-21)	29.93 ± 1.93 (27-33)
Pupa	9.05 ± 1.45 (7-11)	8.7 ± 1.09 (7-11)
Egg to adult emergence	33.6 ± 2.26 (31-37)	41.17 ± 2.02 (36-46)
Adult life span	>120	30

Preference of *C. hemipterus* to different nut kernels: Preference of an insect for some food substrate can be determined by the rate at which the insect multiplies on it. Pistachios and cashewnuts attracted significantly more insects (9.33 and 8.67, respectively) of dried-fruit beetle adults, followed by walnuts (4.50), whereas peanuts and almonds received the minimum numbers (0.67 and 0.50) at 5 DAR (Table 2). At 40 DAR, the highest number of progeny of adults were found in pistachios (40.83) followed by cashewnuts (17.83). Walnuts supported the mean population of 5.0 adults while the peanuts (1.50) and almonds (0.83) supported very negligible population. At 80 DAR, the highest adult progeny buildup was in cashewnuts (97.0) followed by pistachios (84.17). In walnuts, as many as 19.67 adults were observed. Peanut and almonds recorded 3.33 and 1.0 adults of progeny, respectively. Overall, the total adult progeny was the highest in pistachios (125.0) which was at par with cashewnuts (114.83). They were followed by walnuts (24.67), while peanuts and almonds registered the total progeny adults at 4.83 and 1.83, respectively. Among the nuts offered to dried-fruit beetle, pistachios and cashews were highly preferred, whereas, almonds were the least preferred, probably they were hard and possessed intact testa. Thus, the order of preference of *C. hemipterus* to the processed nuts tested was; pistachios > cashewnuts > walnuts > peanuts > almonds. Among peanuts, cashewnuts, pistachios, almonds, and walnuts, *C. hemipterus* affected pistachios heavily producing 125 progeny adults in 80 days. Oladipupo et al. (2018) observed that the peanut supported the highest adult emergence and suffered the greatest damage by the *C. hemipterus* compared to other food materials (cocoa, rice and cowpea) and also highlighted the

Table 2. Preference and progeny development of *C. hemipterus* on different processed nuts

Nuts	Insects moved into (No.)	Progeny adult emergence (No.)		
	5 DAR	40 DAR	80 DAR	Total
Peanuts	0.67 (1.05)^{c}	1.50 (1.28)^{d}	3.33 (1.95)^{d}	4.83 (2.31)^{c}
Cashewnuts	8.67 (3.0)^{a}	17.83 (4.27)^{b}	97.0 (9.85)^{a}	114.83 (10.72)^{a}
Pistachios	9.33 (3.12)^{a}	40.83 (6.42)^{a}	84.17 (9.19)^{b}	125.0 (11.19)^{a}
Almonds	0.50 (0.97)^{c}	0.83 (1.12)^{d}	1.0 (1.18)^{e}	1.83 (1.42)^{d}
Walnuts	4.50 (2.19)^{b}	5.0 (2.32)^{c}	19.67 (4.47)^{c}	24.67 (5.01)^{b}
CD (p=0.05)	0.43	0.33	0.65	0.58

Values in parentheses are square root transformed values; DAR: Days after insect release. In each column values with similar letter do not vary significantly at P=0.05

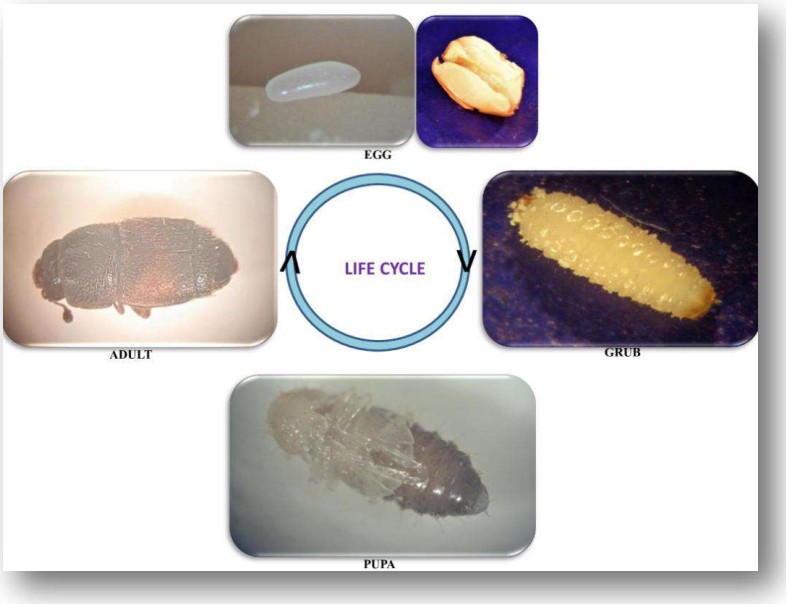

Fig. 1. Biology of dried-fruit beetle *C. hemipterus* on peanut

innate ability of *C. hemipterus* to survive even on less preferred food materials. Despite the strict quarantine and preventive measures, introduced invasive insect species challenge the sustainable pest management due to their fast acclimatization and establishment in new areas. Benedetta et al (2022) reported the invasiveness of *C. truncatus* which is capable of acclimatizing to the walnut and almond production areas of the world and also opined that it is to be considered as a quarantine pest. Thus, their presence itself is of a great concern for those involved in nut processing. Nagaraju et al (2022) reported that some exotic storage pests including *Carpophilus* sp. were intercepted in raw cashew nuts shipments imported into India. Moreover, Carpophiline species are known to tolerate high tropical temperatures. Thus, any sort of poor management and negligence in this regard involves huge costs in terms of salvage as well as exporting country's reputation.

CONCLUSION

Insect infestations at nut processing units are of particular concern as they interfere with international trade and pest-free conditions in the processing and storage facilities should be given much more importance. The dried-fruit beetle preferred processed pistachios and cashews compared to peanuts, walnuts and almonds. Since *C. hemipterus* has been found associated with several nut processing centers, the information on its preference to various nuts is of much relevance in management of this quarantine pest. By adopting simple practices and regular sanitation of process equipment and the premises, the populations of stored-product insects can be prevented from reaching unacceptable levels.

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