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Taxonomic Description, Distribution, and Control Measures of *Plodia interpunctella* (Hübner, 1813) in Kashmir Valley, India

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ABSTRACT

Pyraloidea moths are economically important as the larvae of most species are pests to several crop plants both internally and externally viz. rice, maize, sugar cane, stored products, legumes, and etc. The larvae are often tabbed as leaf rollers, leaf miners, borers, leaf webbers, root feeders, and seed feeders. *Plodia interpunctella* is a moth belonging to the subfamily Phyctinae, family Pyralidae, in the order Lepidoptera. Hubner first scientifically described the species in 1857. The species is a severe pest of stored food products, mainly dry fruits including walnuts, almonds, and pistachios. In the present study, the pest outbreak of this species was reported from the industrial growth center of the Kashmir valley, damaging stored walnuts and kernels. Besides control measures, the life cycle of species was thoroughly monitored. To help with timely pest management, the taxonomic description, morphological characteristics, and pictures of larvae and mounted adults are provided as well.

Keywords: Indian meal moth, Pyralidae, Stored product pest, Walnuts, Damage, Kashmir.

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INTRODUCTION

The third largest group of moths in the order Lepidoptera is the superfamily Pyraloidea, which comprises two remarkable families of moths, viz., Pyralidae and Crambidae. With more than 16,000 described species, the superfamily Pyraloidea exhibits vast diversity among its families, and many more of its species are still undescribed across the globe [1]. The work on Indian Pyraloidea was initiated by Hampson, in 1896 in the "Fauna of British India" series that includes the distribution and taxonomy of 1136 species. Up to date, a number of authors from India and across the globe have occasionally reported and described many new species and new records from the superfamily Pyraloidea [2-5]. The moth fauna of the northwestern Himalayas, particularly the Kashmir valley, has not been documented well besides being aided by some checklists from British India and a few reports from the recent past.

Pyraloidea moths species are economically important as the larvae of most species are pests to several crop plants both internally and externally viz. rice, maize, sugar cane, stored products, legumes, etc. The larvae are often tabbed as leaf rollers, leaf miners, borers, leaf webbers, root feeders, seed feeders, and so on [6]. In the present study, the taxonomical description, distribution, pest incidence, and control measures of the Indian meal moth along with the photographs of the species and the damage to the stored products are provided to facilitate its easy identification, monitoring, and control.

The majority of the Pyraloidea moth species are economically significant because their larvae are pests to several crop plants, including rice, maize, sugar cane, stored goods, and legumes. The larvae are frequently categorized as seed feeders, borers, root feeders, leaf rollers, leaf miners, and leaf webbers [6]. In order to help with identification, monitoring, and management, the

present study provides information on the taxonomic description, distribution, pest incidence, and control measures of the Indian meal moth along with photos of the species and the damage to stored products.

MATERIALS AND METHODS

The present study monitored the damage to the stored walnuts by the polyphagous caterpillars of *P. interpunctella* at the Nosh Dry Fruits, Industrial Growth Centre, Pulwama, Kashmir, India (33º48'12''N 74º55'46''E, 1686 m). Besides damage to the stored products, the life cycle of the species was also monitored for the timely control of the pest. The photographs were taken using a Redmi Note 8 Pro smartphone with a 20mm macro lens attached. The specimens were kept in the insect museum of Entomology Research Institute, Loyola College, Chennai, Tamil Nadu India.

RESULTS AND DISCUSSION

Species account

Order: Lepidoptera
Superfamily: PYRALOIDEA, Latreille, 1809
Family: PYRALIDAE, Latreille, 1809
Subfamily: PHYCITINAE, Zeller, 1839
Genus: *Plodia* Guenée, 1845; *Ann. Soc. Ent. Fr.* (2) 3: 318;
Species: *P. interpunctella* (Hübner, 1813)
Basionym: *Tinea interpunctella* Hübner, 1813

Synonyms:

=*Ephestia interpunctella* (Hübner, 1813)
=*Phycis interpunctella* (Hübner, 1813)
=*Plodia americana* Piutti, 1920
=*Plodia castaneella* Reutti, 1898
=*Plodia glycinivora* (Matsumura, 1917)
=*Plodia glycinivorella* (Matsumura, 1932)
=*Plodia latercula* (Hampson, 1901)
=*Plodia zeae* (Fitch, 1856)
=*Tinea interpunctella* Hübner, 1813

Distribution and host range

With its wide range of food preferences, the Indian meal moth is a significant stored product pest that results in substantial losses and quality degradation of the products, particularly dry fruits. *P. interpunctella* is undoubtedly the most predominant species of postharvest stored products, as several monitoring studies indicate that the Indian meal moth is globally distributed [7-9] **(Figure 1)**.

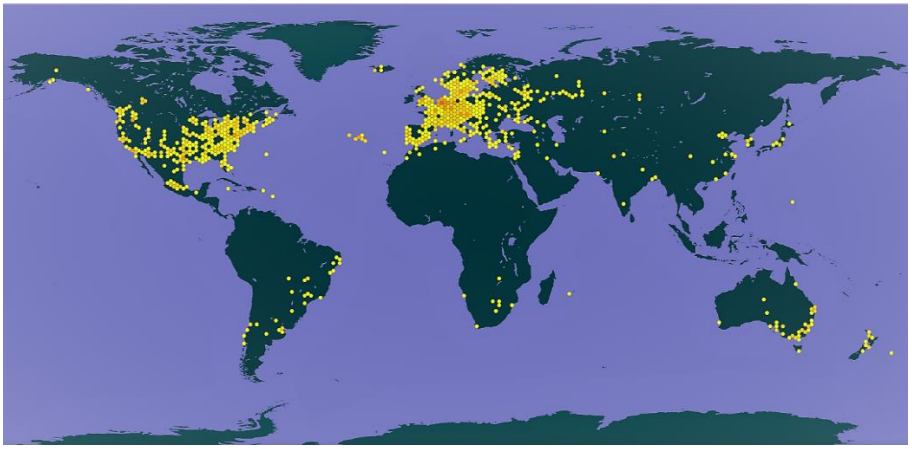


Figure 1. Global Distribution of *Plodia interpunctella* (Source: GBIF, 2022).

Species description

The Indian meal moth is quite distinctive in appearance with a wingspan of 10 to 15 mm **(Figure 2)**. The hindwings are greyish white, whereas the forewings are purplish brown with faint yellowish buff bases **(Figures 3a-3d)**. The heads of the larvae are reddish brown or yellowish brown, and body of the larvae vary in color from white to yellow **(Figure 4)**. The first indication of an infestation is typically the development of silken webbing formed by the larvae. Sometimes adult species may seem black in certain lighting circumstances since many adults can be rather dark.

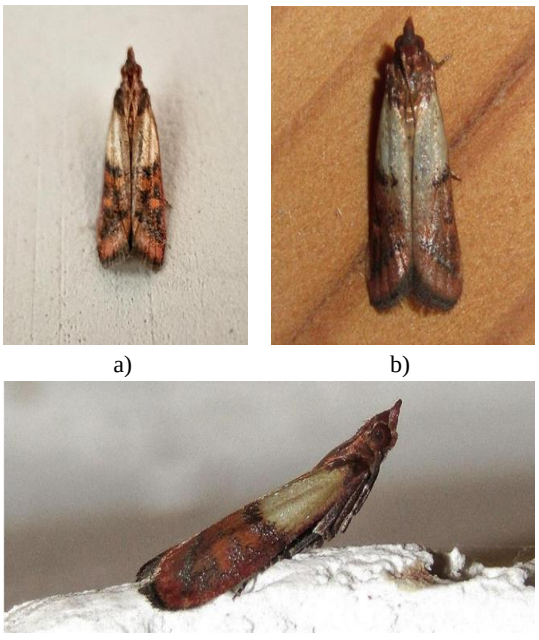
Five to seven larval instars are present. Their colour is typically off-white, but depending on the food source, it has been seen to be pink, brown, or nearly green. The adult larvae approximately 1.27 cm long with five pairs of well-developed prolegs on each limb enable them to migrate

across long distances to pupate. The Indian meal moth's eggs have a greyish white appearance and are between 0.3 and 0.5 mm in length.

Eggs are often oviposited directly on the larval f ood source, often individually or in clusters.

Either without covering or in a silken cocoon, the larvae pupate. The pupae have a light brown hue and vary in length from 6 to 11 mm. Pupation occurs far away from the infested material. Late instar larvae may well travel very long distances, so they are easily mistaken for pests of garments. Prior to pupating, small larvae frequently, migrate to nearby closet racks, which can be confusing for the people trying to determine the infestation's origin.

Figure 2. Mounted specimen of *Plodia interpunctella* ♀ with wingspan 15 mm (Mounted and Photographed by Muzafar Riyaz).



a) b) c)

Figure 3. Live photograph of *Plodia interpunctella* (a) Female (b) Male (c) Female resting on the abdomen while thorax and head suspended. (Photos by Muzafar Riyaz)

Figure 4. Last instar larva of Plodia interpunctella (Photo by Muzafar Riyaz)

Life cycle

The Indian Meal Moth can complete its life cycle in 27 to 305 days. Three days or so after adult emergence, the females mate and lay their eggs. Following mating, a single female can lay up to 400 eggs. The larval food supply is typically immediately adjacent to where the eggs are oviposited, and they can be deposited individually or in clusters. At 20°C, the eggs hatch in 7–8 days, but at 30°C, they do so in 3–4 days. The larvae start to spread out as soon as they hatch, and after a few hours, they can settle down on a food source. At temperatures ranging from 18 to 35° C, the larvae can complete their development in six to eight weeks. Depending on the food supply and the environmental conditions, there can be five to seven larval instars in the life cycle of the Indian meal moth. At 20°C, the pupal stage can last 15–20 days, whereas, at 30°C, it can survive seven-eight days.

Pest incidence

The Indian meal moth (*Plodia interpunctella*) is a common pest of stored food products. Although the larvae (grubs or caterpillars) devour a wide range of food products like cereals, nuts, seeds, and dried fruits, where they are most frequently reported **(Figure 5)**. Fecundity and other biological characteristics are profoundly affected by the source of food. In contrast to the mean fecundities of 258, 275, and 280 when the juvenile larvae were raised on walnuts, almonds, and wheat bran, respectively, Allotey and Goswami (1990) found mean fecundities of 96.8 on wheat and 174.2 on broken maize [10]. The percentage of eggs that hatch in diagnostic procedures also varies depending on the kind of feedstock used to raise juvenile stages [11]. Egg hatch rates on pistachios and almonds were 88

and 96 percent, respectively, while up to 98.6 percent of the eggs came from adults whose earlier stages were raised on various products [10].

a)

b)

Figure 5. Damage to stored walnuts by Indian meal moth larvae inside the storage facility of Nosh Dry Fruits

As the newly larvae hatch (first instars), they can swiftly disperse to locate food and can penetrate food-containing cans through pinholes of 0.39 to 0.45 millimeters in diameter [12, 13]. However, even when the food source was placed up to 38 cm from the release site, a significant number of the larvae have still been observed inside the food. As the distance from the food source increased, the invasion decreased [14]. Temperature plays an important role in the life cycle of the Indian meal moth [15]. The type of foodstuff or feeding source also has a significant impact on how quickly *P. interpunctella* requires completing its life cycle [16-19].

Control measures

Previously, applying insecticidal sprays, fumigants, and fogs to warehouses and retail outlets has been the primary method of managing and controlling *P. interpunctella* [20]. However, the availability of pesticides for use in preserved food has been constrained by new insecticide laws brought about by the Food Quality and Protection Act as well as customer worries about pesticide residues [21]. Regular sanitation and packaging that is insect-resistant are other crucial management strategies. However, these sources of insect infestation endure because spills and broken packaging are frequent. Since finished stored items cannot grow or rebound like crops can, managing pests on them presents a special difficulty. A single insect infestation can also result in the loss of a product due to customer complaints, lost future sales, and even legal action [22]. As a result, goods sold in warehouses and retail establishments have a relatively low economic threshold. The following are the conventional techniques that are employed in the case of Indian meal moth pest outbreaks.

Physical/mechanical control

The two main strategies for managing this moth's pest populations are elimination and exclusion. If a population is found, all contaminated food must be thrown away or sanitized. Any vulnerable food supply ought to be stored in airtight containers. Often ignored as potential infection locations include dog food and bird seed, both of which should be stored in sealed containers. The "white worms" and webbing should be checked on all stored food items brought home from the grocery shop; otherwise, the infestation will spread to other stored items. Most of the time, infested objects should be thrown away and swiftly removed from the area, especially little amounts.

Freezing the product for a few days has shown to be a successful control method when an infestation is found. Until the cold penetrates all regions of the container, infested items should be stored at 0°F (-18°C). If temperatures in infected facilities are kept at 130°F to 150°F (54°C to 66°C) for 24 hours, pests that live on stored products will also be killed by heat. Small amounts of the infected items can be treated in their original packaging or the loose material can be put in a shallow pan. The material should then be heated for 20 minutes at 150°F (66°C). To prevent the oven from becoming too hot, one source suggests propping open the door [23].

Biological control

In retail and warehouse environments, biological control employing hymenopteran parasitoids is an appealing prospect for synthetic insecticides for reducing infestations and damage caused by

the Indian meal moth. Although the packaging may protect the bulk of the stored goods, there are frequently places in the storage landscape with inadequate cleanliness. In order to prevent *P. interpunctella* infestations in coarse-ground cornmeal, Grieshop (2006) evaluated the feasibility of using combinations of the egg parasitoid *Trichogramma Deion* Riley (Hymenoptera: Trichogrammatidae) and the larval parasitoid *Habrobracon hebetor* (Say) (Hymenoptera: Braconidae) as well as the impact of packaging on parasitoid effectiveness. Was seen in most circumstances, a combination release of *T. deion* and *H. hebetor* had the most impact [24].

Hymenopteran parasites and predatory insects have both been tested in laboratory and field conditions [25]. With the use of Habrabracon (Bracon) and hebetor (Say), *P. interpunctella* and other pyralid moths have been effectively controlled in the field [26-28]. Additionally, *Trichogramma* wasps, which are egg parasites of various lepidopteran pests, have been studied for the management of *P. interpunctella* [25, 29]. In and near storage facilities, *P. interpunctella* parasites and predators have been discovered in several investigations [30]. Adarkwah (2012) also evaluated the effect of parasitoids *V. canescens* and *H. hebetor* release, and the combination of both parasitoids on Indian meal moth populations in bulk-stored wheat and suggested that the combination could be at least as effective as the release of *H. hebetor* alone [31].

Chemical control

Although several insecticides have been employed to control Indian meal moth populations, however, their efficacy has been constrained. The Food Quality Protection Act (FQPA) has already taken a few carbamate and organophosphate pesticides off the market for post-harvest use. Moreover, certain strains of *P. interpunctella* have evolved resistance to the organophosphate Malathion and several other organophosphates [32-38].

Biochemical control

Corzo (2020) demonstrated that the essential oil from *Lippia turbinata*, known as "poleo," has been shown to have an insecticidal effect on *P. interpunctella* larvae [39]. In addition, they thoroughly characterized the neuroendocrine system of *P. interpunctella* in contrast to other lepidopteran species. Han (2017) tested the influence of organic extracts from 13 plant species on P. interpunctella. Most of these extracts were either attractants or had no effect [40]. Nikolaou (2021) tested the essential oil of *Clausena anisata*, and observed that it was highly toxic to the larval stages, and prevented the emergence of adults. When *Mentha piperita* and *Salvia officinalis* were added to a polylactic acid solution, *P. interpunctella* experienced considerable contact toxicity, with *M. piperita* exhibiting more toxicity than *S. officinalis* [41].

CONCLUSION

The Indian meal moth, Plodia interpunctella (Lepidoptera: Pyralidae), is a prominent and widespread pest of stored goods across the globe. A wide variety of items, including raw and processed grain products, animal feeds, dried fruit, nuts, and garlic, are susceptible to infestation [42]. This insect infests finished goods in warehouses and retail establishments, which may cause complaints from customers. The application of insecticidal fogs, fumigants, and sprays has traditionally been the crux of P. interpunctella management in warehouses and retail establishments [20].

Insect-resistant packaging and routine cleanliness are other critical management strategies. However, these sources of insect infestation continue since spills and broken packaging are frequent. Because completed storage items lack the ability for regrowth or recovery, unlike crops, managing pests on them present a special difficulty. Additionally, even a single bug infestation in a product might result in the loss of that product due to consumer complaints, lost future sales, and even legal action. As a result, the economic threshold for goods in warehouses and retail establishments is quite low.

The majority of research on the growth of the Indian meal moth has been conducted on preserved grains, dried fruits, or their derivative products. The type of diet that an Indian meal moth consumes while being in the larval stage has a significant impact on its mean developmental time and adult progeny output [43, 44]. A swift transition from an insecticide-based system to a more integrated approach has

been taking place in the management of P. interpunctella and other pests of stored products.

Cereals, bread, pastas, rice, couscous, flour, spices, dried fruits, and nuts are just a few of the dry foods manufactured from vegetables that are susceptible to Indian meal moth larval infestation. Crushed red pepper, chocolate, cocoa beans, coffee substitute, cookies, dried mangelwurzel, and even the toxic seeds of jimsonweed (Datura stramonium) are among the strangest foods that Plodia larvae have been recorded feeding. Additionally, it has been demonstrated that they may infest commercial pet food, particularly cracked corn that is fed to birds. Food that has been infected with them has been typically coated with the webs they leave behind.

The present study thus concludes that all food sources that are not in extremely securely sealed containers need to be discarded if larvae or moths have been discovered. Even unopened items may get infested because moth larvae may gnaw through plastic bags and weak cardboard. In addition to being famously difficult to get rid of, they may spin cocoons in rooms other than the one where they hatched and climbed on ceilings. Before they pupate, larvae in their last instar can travel across long distances. The search must thus extend beyond the local region where pupae are found if the source of an infestation is to be found. It is crucial to check any potential garment sources since pantry moths may pupate and proliferate while hiding inside clothing.

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