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Carob moth in almonds

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Introduction

Carob moth *Apomyelois (=Ectomyelois) ceratoniae* is a pest of numerous tree crops around the world, including almonds. In recent years carob moth has caused increasing concern for the Australian almond industry. The larval stage (caterpillar) of carob moth feeds on almond kernels, making them unsuitable for sale as whole kernels for human consumption, and possibly increasing the risk of fungal infection. The presence of insect-damaged kernels can also reduce the quality grading of whole batches of kernels, resulting in significant economic loss.

Carob moth is considered to have originated in the Mediterranean area but it is now widely distributed across many countries. In California, carob moth became the only serious insect pest of dates after its appearance in the Coachella Valley date-growing region in 1982. It has not yet become a noticeable pest in California's commercial almond crops in the Central Valley to the north, possibly due to the geographical separation of the two regions and to the stringent management controls already in place for its relative, the navel orange worm.

An old pest of new importance

Carob moth has been recorded in almonds in Australia since the 1960s but appears to have been considered a real problem only sporadically. During the unusually wet summer of 2010/11, some growers noted high levels of kernel damage from carob moth leading up to harvest, indicating that under the right conditions this moth can become a serious economic pest.

A large part of the carob moth's life cycle occurs inside almond mummies - nuts that remain on trees after harvest, and it seems likely that its increased populations and damage to almonds seen in recent years began with increases in the numbers of mummies in orchards. Mummies often develop as a result of hull rot, a fungal disease that develops on almonds once the hulls have split and is favoured by warm, wet conditions. Such conditions occurred across our major almond growing districts soon after hull split in 2007 and 2011. At the same time, the number of bearing trees in the industry was growing rapidly, doubling between 2004 and 2007 and more than doubling again to 2011. The exponential growth in nut production combined with favourable conditions for hull rot is likely to have resulted in very large increases in mummy numbers across the industry.

Figure 1: A Carob moth larva and damaged kernel.

Identification of carob moth

Table 1 contains a summary of the different life stages of carob moth. See the fact sheet '***Carob moth: Monitoring guidelines***' for more complete descriptions.

Biology & behaviour

Carob moth is in the moth family *Pyralidae*, members of which are commonly referred to as 'snout moths' because of the snout-like appearance of their mouthparts. Pyralid moths include Indian meal moth *Plodia interpunctella*, a widespread major pest of stored foods, and navel orange worm (NOW) *Amyelois transitella*, the main pest of almonds in USA.

Like most insects, the development and behaviour of carob moth is dictated by temperature. Eggs will not develop below about 16°C, larvae require temperatures above 9.5-12.5°C depending on diet, and about 12.5°C is also the minimum for pupal development. Moth flight is unlikely at temperatures below 15°C.

The moths tend to stay still during the day and fly, mate and lay eggs between dusk and dawn. Each female can lay up to 200 eggs, with most being laid within the first six days after the moth's emergence from its pupal case. The moths survive typically for about one week, but up to two weeks under ideal conditions.

Plants that carob moth infests and that are likely to be found in almond districts in Australia include pistachio, Chinese fan palm, date, carob, honey locust, black locust, chestnut, walnut, fig, guava, olive, pomegranate, quince, loquat, apple, apricot, citrus and grape (dried fruit remaining on vines).

Egg

0.7mm long.

White when laid, pink when mature.

New larva

1mm long.

Typically pink. Actively feeding.

Mature larva

Up to 15mm long.

Typically pink. Actively feeding.

Pre pupa

Up to 15mm long.

Typically pink. Stops feeding & spins a silk cocoon for pupation.

Pupa

About 12mm long.

Dark ridge and double row of 'teeth' on back.

Adult

8-12mm long.

Grey with 13-20mm wingspan and wavy pattern.

Table 1: Life stages of carob moth.

Carob moth has been found to prefer laying eggs on mouldy fruits and nuts. This includes almond mummies and immature almonds that are infected with anthracnose, otherwise it only lays onto current-season almonds once the hull has split.

In many instances, carob moth infests almonds only between the hull and shell, with no kernel damage occurring. In Sunraysia, as little as 2% and up to 30% of infested nuts have been found to have damaged kernels.

Life cycle in almonds

The typical life-cycle of carob moth in almonds in Australia is described in Table 2. Data from moth trapping and modelling indicate that usually three full generations of carob moth develop each season. The spring generation takes about eleven weeks to develop from eggs to adults, while warmer temperatures help the summer generation develop in eight weeks. In some orchards and seasons, sporadic flights can be detected as late as early June, probably in response to a series of warm days. These flights may suggest the start of a fourth generation of moth emergence which is then cut short by a return to low temperatures.

Management options

Orchard hygiene

The importance of mummy nuts to carob moth development in almond orchards cannot be overstated. Neither can the potential value of mummy management, both as a control strategy for this pest and a risk-reduction exercise against carpophilus beetle, diseases such as hull-rot, and contamination of the current-season crop at harvest. In California, the almond industry uses mummy reduction as a key aspect of its NOW management program and the same approach is likely to benefit the Australian industry. The Californian industry recommends that mummy numbers be reduced to a maximum of two per tree to obtain significant benefits in the way of reduced kernel damage from NOW. Indications are that a similar threshold will apply for carob moth.

Effective mummy management involves not just removal of mummies from trees, but also destruction of those nuts, by flail mowing for example, to destroy any carob moth they contain.

Harvest management

Infestation and damage levels within the current-season crop increase significantly, the longer that crop is exposed to egg-laying by carob moths. This means that kernel damage can be minimised by harvesting the new crop as soon as possible once it is mature, and fumigating or processing it without delay.

Insecticide

At the time of writing this fact sheet two insecticide options were available for carob moth management in almonds through permits from the Australian Pesticides and Veterinary Medicines Authority (APVMA), arranged by the Almond Board of Australia (ABA).

An emergency use permit allows the application of Altacor® (DuPont™; 350 g/kg chlorantraniliprole) at hull-split and a minor use permit allows Prodigy™ (Dow AgroSciences; 240 g/L Methoxyfenozide) to be used between egg hatch in the first generation of carob moth (September) and hull-split.

Both insecticides target the eggs and larvae of moth pests including carob moth and are reported to have minimal disruptive impact on beneficial species such as predators and parasites.

For more details on the APVMA permits, contact the ABA, and before using any pesticide, read and follow the label instructions.

Biological control

Globally, 38 species of parasitic wasps have been recorded to attack carob moth, along with several parasitic flies and predatory beetles and bugs. The European earwig *Forficula auricularia* is also a predator of carob moth and is present in large numbers in many almond orchards. Several species of parasitic wasps have been observed on carob moth in almonds in Australia, including *Trichogramma carverae*, one of the species reared commercially for management of moth pests in other crops (Figure 2 & 3). Biological control may make a useful contribution to the management of carob moth in Australian almonds but it is yet to be fully explored.

Current research

Pheromone-based mating disruption was developed to manage carob moth in dates in USA and has been the subject of recent research in almonds in Australia. Mating disruption aims to restrict the development of damaging populations of pests by interfering with the ability of males and females to locate each other, thereby reducing the prevalence of mating and production of viable eggs. While this approach has shown some promise in almonds, further work is required to achieve the necessary results in improved kernel quality and to determine its economic viability.

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	Larvae begin to pupate inside mummy nuts on the trees.
	As temperatures rise, larvae and pupae complete their development and start to emerge as moths. The moths fly and mate at night and females start laying eggs on mummy nuts. All eggs of this generation will be laid on mummy nuts. Emergence and egg-laying by this generation of moths continues to the end of spring.
	Eggs laid in early spring have developed into moths which now begin to emerge and mate. The emergence and egg-laying by this summer generation continues until late summer. Eggs are laid only on mummy nuts until the new crop reaches hull split.
	From hull split onward eggs are laid on mummies and split new season nuts. Larvae begin damaging the new crop of kernels. After harvest, eggs continue to be laid on new season nuts on trees, as well as on old mummy nuts. Eggs laid in early summer develop into moths which begin to emerge and mate in late summer. Emergence and egg-laying by this late summer generation continues into autumn.
	Moth emergence and egg laying onto new and old mummies continues through March but typically drops away by late April due to low temperatures. Some limited moth activity is sometimes seen in late May/early June. This may be the trace of an autumn generation.
	Larvae continue to develop slowly inside new and old mummy nuts on the trees.

Table 2: Typical lifecycle of carob moth in almonds.

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Figure 2: Dark, parasitised carob moth egg.

Figure 3: *Trichogramma* parasitoid from carob moth egg

Further Reading

Gothilf S. (1984) Biology of Spectrobates ceratoniae [synonym for Ectomyelois ceratoniae] on almonds in Israel. Phytoparasitica, 12(2): 77-87.

Contacts

Bugs for Bugs Pty Ltd. Commercial producers of *Trichogramma carverae* and other biological control agents for a range of crop pests.

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