Nemapogon granellus (L.) pest on corks of wine bottles stored for aging

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Abstract

The European grain moth, *Nemapogon granellus* (L.) (Lepidoptera, Tineidae), is reported as a pest in wine cellars where larvae feed on, and tunnel into, the corks of wine bottles. When tunnels ultimately connect both ends of the cork, the wine itself is affected and bottles rejected due to alteration in the organoleptic properties of the wine. Activity of larvae causes also aesthetic damage to the corks, which must be replaced before delivery to consumers. During 2011 and 2012 heavy infestations of European grain moth was observed in two Italian wine cellars, causing serious damage on exposed wine-bottle corks. The infestation occurred on high quality red wine bottles (approximately 13,000) stored for aging for over twenty years. In the control of *N. granellus* Integrated Pest Management (IPM) strategy was adopted: monitoring an trapping of adults with pheromone traps, accompanied by careful cleaning of the rooms, shelves and machinery, alternated with localized treatments using fogs with pyrethrum, and by the replacement of the infested corks. In addition, adoption of cellar sanitation procedures reduced the sources of pests as well as the possibility of insect reproduction.

Keywords: European grain moth, infestation, wine cellars, red wine aging, Italy, IPM

1. Introduction

We observed heavy damage occurring on corks of red wine bottles in two Italian wine cellars. The infestation was due to *Nemapogon granellus* (L.) (Lepidoptera, Tineidae). *N. granellus* is a widespread and partially synanthropic species, cited as the European grain moth, Corn moth, Cork moth, and Wolf moth. It is nearly cosmopolitan in temperate regions of the world and includes indoor and outdoor populations. It is most common in temperate regions. *N. granellus* is a moderately cold hardy species that can develop at a temperature as low as 6.4°C. In Canada and Russia, its occurrence is generally restricted to the warmest parts of the grain-growing areas of these countries. Currently it has a cosmopolitan distribution, no doubt through transport of stored products by man (Robinson and Nielsen, 1993).

N. granellus belongs to the fungus moth family (Figure 1). Tineid larvae have also traditionally been categorized as detritophagous, lichenivorous or fungivorous. Detritophagy involves tineids in a wide range of niches, in a wide range of biological systems, with habits ranging from the mundane to the bizarre, from feeding on fallen leaves to feeding on guano in bat-caves, on mammal corpses, on insect remains, in or below spider's webs, and on feathers in bird's nests.

N. granellus is found in granaries, warehouses, elevators, mills, museums, and wine cellars. It feeds mostly on cereals that have a high moisture content (up than 14%). Larvae can cause serious damage to stored rye, wheat, barley, oats, corn, soybeans, rice, dried fruits, garlic, mushrooms, almonds, hazelnuts, walnuts, peanuts, chestnuts, bran, grass seeds, clovers, flax, ergot, chocolate, mushrooms, seeds of ornamental plants, prunes, tobacco, decayed wood,

lichens and pharmaceutical products (Crop Protection Compendium, 2004). Their presence often leads to secondary infestation by mites. They have also been found in mouldy cheeses (Frilli, 1960; Ottogalli et al., 1979) and can feed on animal fibres, hair and feathers, dried meat, wine corks and, according to Zagulajev (1964), confectionary and book bindings. It is reported attacking the corks of wine bottles, especially those that have mould growing and upon them.

Figure 1 *Nemapogon granellus*, adult (left), larva (middle), pupa (right).

Feytaud (1910), Bender (1941), Cangardel (1971), Delbecque (1990), Sarto I Montys (2002), and Trematerra et al. (2013), reported the importance of *N. granellus* as a pest in wine cellars where larvae feed on, and tunnel into, the corks of wine bottles. This causes aesthetic damage to the corks, which must then be replaced before delivery to consumers. When tunnels ultimately connect both ends of the cork, the wine itself is affected and bottles should be rejected due to alteration in the organoleptic properties of the wine.

2. Life cycle of *Nemapogon granellus*

According to Bender (1941), *N. granellus* larval development takes 200-400 days at a constant temperature of 18°C and a relative humidity of 80-90%. But temperatures in wine cellars are often below 18°C, which accounts for the extremely long larval development, and hence a very slow appearance of signs of infestation. The physical limits of complete development and multiplication are 7-27°C at 65-95% relative humidity. The optimum conditions for development are about 25°C and 90% relative humidity.

In countries with temperate climate, the first flight of the moth is observed early in spring (about April) after which overwintered larvae population are observed either during autumn or spring. The latest flight takes place during late summer (about August) from the generation of moths emerged in the previous spring. The well-developed larvae of the second generation overwinter under a sheltered web or in their cocoons. Adults emerge in mid-summer and mating occurs a few hours after emergence, whereas egg laying begins 2 days later and lasts for 3-13 days. *N. granellus* moths usually occur in one or two generations per year; indoors, where temperatures are milder, there may even be a continual succession of generations (Pelham-Clinton, 1985). The cool conditions of wine cellars however, likely cause considerable a slow-down of the generation cycles. In Germany, *N. granellus* adults have been found in cellars only during summer (Bender, 1941); in the Bordeaux region of France, they were observed over two periods in mid-June-late July and on early September-late October (Cangardel, 1971). Sarto I Monteys (2002) found adults in cellars in Ghazir (Lebanon) in July; he also reported *N. granellus* as cellar pest in Spain, from infestations in Penellers (Leida, 1994), Castellet I Gornal (Barcelona, 1997), Haro (La Rioja, 1998), and Espiells (Barcelona, 1999). In Britain the moth probably has two generations a year, overwintering as mature larva (Carter, 1984). According to Zagulajev (1964), in heated food

stores it can produce two or three generations a year. In Italy *N. granellus* shows from 1 to 4 generations per year (1st generation in April-June; 2nd generation from mid-June to mid-August; and 3rd generation from August to October) with adults observed from April till November and overwintering as mature larva (Trematerra *et al*., 2013). In Canada and United States the life cycle is completed in about 10 weeks, and there are about two generations per year. In Swedish granaries, there is usually one generation and a second, partial one per year, and the winter is spent in the larval stage. In spring, the overwintering larvae come out and pupate in cocoons in wall cracks, floors, and wooden material; adults emerge 2-3 weeks later.

3. *Nemapogon granellus* in wine cellars and damage to wine-bottle corks

In 2011, in the mentioned Tuscan wine cellars (Italy), an infestation of *N. granellus* was highlighted by the presence of debris on the cork external surface (Figures 2-3), due to the larval feeding and the presence of a dust layer including tiny pieces of cork and feces, all tied together by larval silk. Larvae of *N. granellus* produce silk webbing and frass as they feed and pupate. Irregular holes may be present in infested cork (Figure 4). Many pupal exuviae were found, mixed to, and partially immersed in, the dust layer. The infestation occurred on high quality red wine bottles (approximately 13,000) stored for aging for over twenty years. We estimated that the infestation has been in place continuously for at least the last five years. The aging stores where the bottles were placed had a constant temperature of 15°C and a high relative humidity (about 80%), and were kept in semidarkness. Females of *N. granellus* had been laying eggs in cracks on the surface of unprotected damp corks. Existing literature (Sarto I Monteys, 2002) reports that damp corks are preferred over dry or completely wet corks. In our case all the infested corks were damp and no possibility of comparison with dry cork infestation was possible. According to some authors, the oviposition behaviour of *N. granellus* is influenced by the bottle content: bottles containing red wine are preferred, even though oviposition can take place also on white wine bottle-corks. In our case the infestation only affected bottles containing red wine.

The need to study in detail the structure of the infested corks forced us to remove them without the use of a corkscrew, to avoid hiding or changing the shape of larval tunnels. Some debris has been also observed on the aluminium cap covering the cork of several bottles (Figures 3-4). Corks of these bottles, as in the previous cases, showed irregular tunnels and cavities along the upper two-thirds of their entire length, but the quality of the wine in the bottle was not negatively influenced and a decrease in the level of the liquid content was not observed. Most likely the cork infestation occurred in these bottles before the positioning of the aluminium cap, which was not an obstacle to the larval development into the corks.

From our observations we can assume that in unprotected corks, internal larval tunnels and cavities generally do not reach the cork bottom, but are restricted to its upper two-thirds. Nevertheless, a marked decrease in the level of the liquid content was observed in these bottles and we assume that, due to the severity of the infestation, the wine quality might have been negatively affected.

Irregular galleries are produced by the larvae, both horizontally and vertically, in the most internal part of the cork and along the cork walls, in contact with the inner walls of the bottle neck and vertically, in the most internal part of the corks (Figures 3-4). During feeding, *N. granellus* larva pushes up the debris gradually produced that accumulates on the outer cork surface.

Larval tunnels are often colonized by fungi. The presence of fungi on the cork external surface represents a suitable laying substrate for females and its occurrence into the galleries can facilitate cork digestibility by larvae. However, it was uncertain whether *N. granellus* larvae feed on the cork, on the fungi or on both.

Figure 2 Damage produced by *Nemapogon granellus* in a wine cellar.

Figure 3 Corks damaged by larvae of *Nemapogon granellus*.

Figure 4 Damages and irregular galleries produced by larvae of *Nemapogon granellus*.

4. Integrated Pest Management in wine cellars

In our case Integrated Pest Management (IPM) program included education, appropriate waste management, structural repair, maintenance, biological and physical control techniques, and pesticide applications in areas where special problems existed (Trematerra, 2013). The main activities taken into account were the following.

Application of fine mesh nets to windows and installation of double-doors to prevent the entry of *N. granellus* adult specimens from the outside.

Control of *N. granellus* adults, and of other stages, free in the cellars through treatment of the environment with fog (using pyrethrum); in this case the insecticide, produced as a cloud, progressively covers all surfaces inside the cellars. The first fog treatment was carried out in October 2011 (against *N. granellus* new annual generation), the second treatment was done one month later, the third in March 2012 and the fourth in July 2012 (as a preventative against possible new generations).

Application of polyethylene capsules on the bottles before placing them in storage. Usually wine producers do not top their bottles with protective capsules, while the wine is maturing in the cellars, but rather at the end of the process, just before distribution to consumers. Even though we observed presence of *N. granellus* in corks protected by aluminium capsules, we believe that the use of polyethylene capsules from the beginning of storage can be crucial in preventing infestation.

Taking into account the importance of moulds in the diet of *N. granellus* larvae, fungicides were applied to the corks before stoppering the bottles, so as to prevent or hinder mould development on the corks in cellars. This might make larval development less probable.

Monitoring and trapping of adult moths in cellar with pheromone traps (delta type) baited with (3Z,13Z)-3,13-octadecadienyl acetate, the main component of *N. granellus* sex pheromone [light traps (infrared or ultraviolet) or traps baited with red wine (or some of its components) and water traps are less effective of pheromone traps in the trapping of adults].

The IPM strategy was accompanied by careful cleaning of the rooms, shelves and machinery. Application of cellar sanitation procedures reduced sources of pests as well as the possibility of insect reproduction, particularly in areas where corks were present.

5. Moths potentially able to damage corks in wine cellars

In Mediterranean countries, up to seven microlepidopteran species have been cited as potentially able to damage wine cellar by affecting bottle corks: *Nemapogon granellus*, *N. cloacellus* Haworth, *Oinophila v-flava* (Haworth) and *Dryadaula pactolia* (Meyrick) (Family Tineidae); *Hoffmannophila pseudospretella* (Stainton) and *Endrosis sarcitrella* (Linnaeus) (Family Oecophoridae), *Aglossa caprealis* (Hübner) (Family Pyralidae).

None of these species seems to be specific to wine cellars; in fact they can also be found outdoors, feeding on other substrates.

Their access to cellars might occur secondarily. Though it is known that these species may be harmful in wine cellars in the Mediterranean countries, their incidence and relative importance still remain unclear (Sarto i Monteys, 2001; Trematerra et al., 2013). The adult of *N. granellus* looks quite similar to another wine-cellar pest, *N. cloacellus* Haworth. The head of the latter has a tuft of brownish-yellow scales, and a well-defined postmedian white spot can be seen in the disc of the forewing (not present in *N. granellus*) (Figure 5 A-D). There are also few clear differences in the genitalia of the two species (Figure 5 C-D). The following species also resemble *N. granellus*: *Tinea ruricolella* Stainton, *T. infimella* Herrich-Shäffer

and *T. salella* Zacher, but each can be distinguished by keys based on genitalia of each sex (Zagulajev, 1960 and 1964).

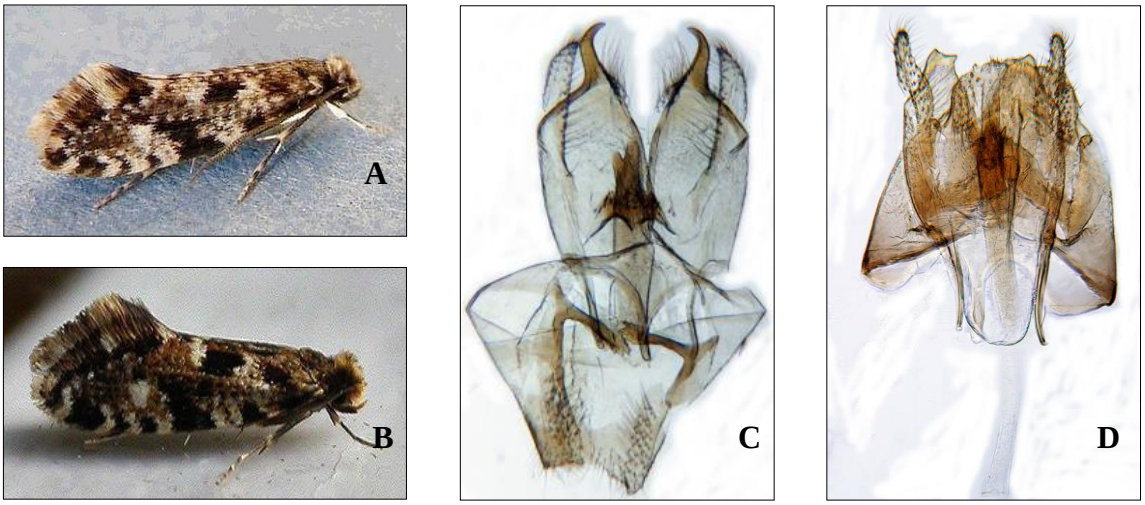

Figure 5 *Nemapogon granellus*: adult (A) and male genitalia (D); *Nemapogon cloacellus*: adult (B) and male genitalia (C).

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