DEVELOPMENT OF AN ENVIRONMENTALLY FRIENDLY
METHOD TO CONTROL THE MEALYBUG PHENACOCUS
EMANSOR IN IRIS BULB STORES THE NETHERLANDS

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Summary
Mealybugs form a recurrent problem in storage rooms of flower bulbs in the Netherlands, despite preventative chemical treatment. The causes of this problem, and the biology, ecology and dispersal opportunities of the mealybugs were investigated. Alternative control methods (both curative and preventative) were tested. Combined physical and biological control methods offer good prospects to solve the mealybug problem in an environmentally friendly manner.

INTRODUCTION

Since 1966, the mealybugs Phenacoccus emansor Williams & Kozarzhevskaya and P.avenae Borchsenius have recurrently been found as a pest of flower bulbs in storage rooms in the Netherlands, and in bulbs exported from the Netherlands (Williams & Miller, 1985; Williams & Kozarzhevskaya, 1988).

Mealybugs (Homoptera; Pseudococcidae) are insects that feed on the phloem of their host plants. Some species inject toxins which distort the growth of plants, others may simply weaken or kill plants by feeding on them in large numbers. In addition they may transmit viruses.

Flower bulbs are stored in crates within controled temperature rooms. P. emansor and P.avenae occur under the dry skins that cover the bulbs, where they feed on the living tissue, causing damage and ultimately killing the bulb. The hidden life style of the pest and the dark storage of bulbs for periods often exceeding several generations of mealybugs, make it difficult to discover their presence before considerable losses have already occurred.

P. emansor and P.avenae are not native to the Netherlands. It is logical to suppose that the mealybugs have originally reached the country via the import of contaminated bulbs of some sort. The area of origin of P. emansor and P.avenae is thought to be Asia minor and/or the Mediterraneane. Many bulbs are imported from Turkey, and this country has repeatedly been associated with the mealybug problem in the Netherlands. P. emansor and P.avenae are polyphagous: they can use a variety of bulbs and Gramineae as host (Williams & Miller, 1985; Williams & Kozarzhevskaya, 1988).

Generally, pest outbreaks occur only in those bulb species which have a warm (around 30 °C) storage phase, for example iris and freesia. Mealybug numbers do not reach pest levels in other bulb species, which are stored at much lower temperatures, less suitable for
mealybug population growth. Iris bulbs can become infested when different bulbs are stored together, or through the use of crates in which mealybugs have remained behind. The majority of the iris bulbs which are stored in the Netherlands are also grown in this country. A small part is grown in France, and few are imported from Israel.

To prevent potential damage by mealybugs, storage rooms for iris and freesia are regularly treated with the gasiform pesticide pirimiphos-methyl (Actellic 50). However, this method has some disadvantages: the treatment is not 100% effective, the mealybugs may develop resistance, and the application is dangerous to humans and environment.

Here we report on investigations into the biology, ecology, origin and dispersal of the mealybug *P. emansor*. Pest outbreaks of *P. avenae* have not been reported recently, and because the species is nowhere in culture, we investigated only *P. emansor*. The biology of *P. avenae* is probably very similar to that of *P. emansor*. The investigations are aimed at the development of alternative ways to prevent and control mealybug infections. These alternatives should be environmentally friendly and more effective than the current method.

There are three non-exclusive possibilities how mealybugs can continue to cause problems in the Netherlands. First, mealybugs may repeatedly be imported. Second, the mealybugs could have permanently established themselves in the storage rooms after they were imported at some point in the past. And third, mealybugs may have established themselves in the field in the Netherlands, and from there repeatedly enter the storage rooms together with harvested material. In the remainder of the paper, investigations are presented that shed light on the probability of each of these three infection routes, and on the effect of several alternative control methods.

**BIOLOGY OF *P. EMANSOR* AND REARING CONDITIONS**

*P. emansor*: The mealybug has 4 developmental stages and moulds 3 times. Sizes range between 0.4 and 3 mm. Reproduction is obligately sexual; about 30% of the offspring are male. Females mate when they are in the fourth instar. At 30 °C, the developmental time of *P. emansor* is shorter and its fecundity is higher than at 20, 25 and 35 °C. At 30 °C, minimum developmental time was 21 days and fecundity was about 400.

Rearing. The mealybug *P. emansor* was cultured at 27-30 °C and ambient humidity on peeled iris bulbs or, occasionally, on freesia corms. Iris bulbs were all variety Blue Magic. The mealybug strain originated from a pest outbreak in iris and was obtained from the Bulb Research Centre.

**THE ORIGIN OF INFECTIONS IN DUTCH IRIS BULB STORAGE**

1. **Imports**

Field work was carried out in Turkey in May and June 1996. Both highland areas where bulbs are native, and lowland areas where bulbs are processed and stored were examined. Above 1000 m, wild and cultivated bulbaceous plants and Gramineae were checked for the presence of mealybugs. These were all free of *Phenacoccus* mealybugs. In the lowland areas, Gramineae and very scarcely occurring wild bulbaceous plants were checked in ruderal areas, as well as around several bulb stores. In both places,
P. graminicola Leonardi was found. This species is closely related to P. avenae but does not proliferate on bulbs. According to the owners of bulb stores, however, mealybug problems do occur sometimes in stored bulbs in Turkey.

Import sampling. From 1 June 1997, samples have been taken from all bulb imports of six companies in the Netherlands. All bulb species and all countries from which bulbs were imported were covered. Samples were stored during three months at 30 °C (the most suitable temperature for mealybug population growth). This allows mealybugs to grow into colonies, making them easier to detect. In addition, clean iris bulbs or freesia corms were provided in every sample as alternative food for any P. emansor or P. avenae that might be present.

Forty-five bulb species (12 iris varieties were counted as one species) were incubated, from the following 11 countries (in alphabetical order): England, France, Germany, Israel, Japan, Korea, Romania, South-Africa, Syria, Turkey and the USA. So far, 62% of the iris samples and 76% of the other samples have been scored. No mealybugs have been found yet.

2. Infection sources in the Netherlands

2a. Is the iris culture a source of infections? Iris bulbs are normally planted outdoors in November or early December. We investigated what happens with mealybugs when infested bulbs are planted. In addition, the role of ants in the spread of P. emansor was investigated.

- Winter planting. Heavily infested iris bulbs were planted in November or December in an experimental field at the Bulb Research Centre, Lisse, in the winters 1995-96 and 1996-97. Clean bulbs were planted in between the infested ones. At regular intervals, samples of originally clean and originally infested bulbs were dug up. In both years, the number of living mealybugs on the sampled bulbs declined steadily during winter and had become zero in spring. The remaining bulbs were dug up in August, stored at 30°C and examined a few months later. This also revealed not a single living mealybug.

- Spring planting. It was also investigated what happens to mealybugs during summer, in case some mealybugs might survive milder winters than the ones during which we were able to carry out field work. Heavily infested iris bulbs were planted in spring and early summer of 1996. After sprouting of the bulb, the majority of the mealybugs moved to the above-ground plant parts. Their numbers declined but remained slightly larger than zero. A few insects reproduced on the plants. At harvest, the presence of live and dead mealybugs on the bulbs was scored. Compared to the situation at planting, the number of living mealybugs on the bulbs was reduced more than 30 times, and the number of infested bulbs was about ten per cent of the original number.

- The role of ants. Iris is not out in the field year round, so P. emansor would need other host plants in order to establish itself outdoors. In general, ants are known to attend homopterans. In the case of P. emansor, ants might provide transport between different host plants, especially towards the bulbs. However, field experiments showed that Lasius niger, the only ant species occurring in bulb fields, had no interest in P. emansor, neither as honeydew source nor as food.
2b. **Storage rooms and crates as infection sources.** Nine bulb companies were interviewed about their logistics (the way storage rooms and crates are used and cleaned). Crates were not systematically disinfected and different companies may use the same individual crate.

Longevity data of *P. emansor* without food were then collected, to determine whether empty crates in which mealybugs have remained behind can form a source of infection. Mealybugs were stored without food at seven different temperatures, ranging between -5 and +52 °C. The longevity of *P. emansor* was found to range from less than two days at 52 °C to over seven months at 4 °C. Even at -5 °C, longevity was up to 2½ months. Thus, the incidentally applied procedure of cleaning infected crates by "letting the mealybugs freeze to death outside", is ineffective as their longevity is high at low temperatures.

The combined data on logistics and survival show that infested crates can form a source of mealybug contamination, both within and between companies.

### ENVIRONMENTALLY FRIENDLY CONTROL METHODS

Both preventative and curative methods for the control of *P. emansor* are to be developed. The effect of several physical methods and the possibilities of biological control were investigated. The three items which may need disinfection are iris bulbs, crates and storage rooms.

1. **Physical methods**

   The following treatments were investigated for their effect on the survival of *P. emansor* on iris bulbs.

   1a. **High temperature treatment.** Iris bulbs die when they are kept for more than 3 days at 40 °C (Kamerbeek, 1962). Even a temperature treatment which is lethal to iris bulbs, namely 5 days at 45 °C, was not sufficient to kill all mealybugs.

   1b. **Submerging bulbs in warm water.** Two treatments were tested: the standard method used against nematode infections in iris (2 h at 45 °C or 2½ h at 43.5 °C), and 20 min at 57 °C (Vigodsky, 1970). After 2 hours at 45 °C or 2½ h at 43.5 °C, mortality of *P. emansor* on iris was of no significance. Submerging bulbs for 20 min in water of 57 °C, however, lead to 100% mortality among the mealybugs. It should be noted, however, that it was not yet tested whether mealybugs which are situated in between the fleshy parts are killed by this method as well. Such deep infections may occur in iris bulbs after long storage.

2. **Biological control**

   The parasitoid *Metanotalia maderensis* (Walker) was reared from *P. graminicola* collected in Izmir and surroundings (Turkey), during the above mentioned field survey, in May 1996. It was subsequently cultured on *P. emansor* on iris or freesia bulbs at 30 °C and ambient humidity.
Life span, developmental time and daily and total fecundity of the parasitoid *M. maderensis* were measured on excess *P. emansor* at 30 °C and ambient humidity. *M. maderensis* had a high average fecundity (above 200) and its developmental time was two days shorter than that of *P. emansor* at 30 °C. The parasitoid was synovigenic and produced about 20 offspring per day at maximum. The latter implies that *M. maderensis* only slowly overtakes its host in numbers.

A simulation model was constructed to investigate whether this parasitoid is capable of eliminating local outbreaks of *P. emansor*. The model predicted that, depending on the initial densities of host and parasitoid, conditions exist under which *M. maderensis* drives *P. emansor* to local extinction. The next step in our investigations will be to study the wasps' long distance detection of host colonies.

The life span without food of *M. maderensis* was low. For preventative biological control (preventative release of *M. maderensis* to serve as a biological guard in bulb storing cells) our next investigations will concern whether its life span can be increased by offering food or alternative hosts in the storage rooms.

**DISCUSSION**

The relative importance of the three possible infection routes of iris storage rooms in the Netherlands: repeated importation, establishment in the Dutch field, and establishment in the storage rooms, is as follows.

First, repeated import of *P. emansor* is a possible infection source, but since we have not found any mealybugs in the import samples scored so far, our data suggest that the incidence of import is low at most.

Second, the Dutch field is not a continuous source of mealybug infections, because the population growth of *P. emansor* is negative during winter as well as during summer. In winter, there was 100% mortality of *P. emansor*. This is true both in the harsh winters described here and in the mild winter of 1989-90 (Hofker et al., 1991). The longevity data of *P. emansor* at different temperatures show that the low winter survival is not caused by the low temperature. We suppose that the winter mortality is caused by a combination of factors among which soil moisture is one. In summer, mealybug numbers and the fraction of infested bulbs were strongly reduced. This leads to the important conclusion that a new pest cannot arise from the field, as long as mealybugs are effectively controlled inside the bulb stores.

Third, the combined data of the companies' logistics and mealybug survival without food, show that *P. emansor* can easily be dispersed via infested crates. The problem with these mealybugs is that their presence usually goes unnoticed for a relatively long time, so infested crates may be reused before the mealybugs' presence in the company is detected.

A fourth possible source of infections was detected in the course of the project. Recently, several freesia cultivating and storing companies reported pest outbreaks of *P. emansor* and the problem currently appears to be even larger in freesia than in iris. Freesia is not imported but grown in the Netherlands, and contrary to iris, freesia is seldom planted outdoors. It is generally cultivated under glass. Because of the differences, the freesia culture might permit population growth of *P. emansor*, and so form a source of infections.

The following possibilities to control *P. emansor* in an environmentally friendly way were found promising. High temperature treatment is suited to disinfect crates and
storage rooms: a treatment of 52 °C killed all mealybug stages, including eggs, within two days. Infested bulbs can be treated by submerging them in water of 57 °C. The latter method is also applicable to infested crates. Biological control using the parasitoid M.maderensis looks promising. Future work will largely comprise of further investigations into biological control and into the application of the physical and biological control methods mentioned here on a practical scale.

In conclusion, our data show that by using integrated pest management, the mealybug problem in iris stores can be solved in an environmentally friendly manner.

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