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Phenology of apple sawfly activity

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Summary

Sawfly flight activity was monitored in a range of apple orchard sites in the south east and west of England, using white sticky traps to which sawflies are attracted. In five orchards the total catches exceeded 50 sawflies. Based on air and soil temperature records from electronic temperature loggers located in the orchards, accumulated heat sums were calculated in day degrees above a developmental threshold temperature, as an indicator of the rate of development of sawfly pupae within the soil. There was some indication that soil temperature in Spring was relatively higher at sites with light sandy soil. The site to site variation in the timing of first flight activity of sawfly in relation to accumulated heat sum in 1998 and 1999 was such that it is not possible to make general predictions with precision. The trapping records indicate that in order to be confident about monitoring the early flight activity, traps should be placed in orchards by the time the accumulated heat sum for that site in day degrees above 4°C (calculated from 1st March), reaches 200 day degrees for soil temperature or 180 day degrees for air temperature.

Introduction

Apple sawfly (*Hoplocampa testudinea* (Klug)) is a pest that can be very damaging in unsprayed apple orchards; it is not reliably kept in check by natural enemies. For many years BHC (gamma-HCH) was used as an effective insecticide treatment against apple sawfly, but this material is no longer registered. It is now known that some fungicides are effective against apple sawfly (Olszak & Maciesiak, 1996; Cross & Jay, 1998), and that they are most effective when applied when adult sawflies are active. An understanding of the timing of flight activity of apple sawfly would therefore be valuable because it would:-

-ensure that traps are placed in the orchard in time to monitor the earliest flight of sawfly adults

-enable soundly based decisions to be made on the need for, and timing of, pesticide applications

-optimise the effectiveness of insecticide applications, which in turn ultimately extends the useful life of new insecticides by delaying the development of resistance in the target pest.

Biology of apple sawfly

(This outline of sawfly biology was given in the 1998 report, but as it is necessary background, it is repeated here).

Apple sawfly passes through one generation per year, with the adults flying actively in apple orchards during April and May. A detailed account of the biology of apple sawfly is given by Miles (1932) and Dicker (1953). Adults mate among the blossoms on apple trees, and the females subsequently lay eggs in the receptacles of the apple flowers just below the stamens. The female has an ovipositor with serrated edges (hence the name ‘sawfly’), and with it she cuts a slit in the receptacle in which she lays her egg. A drop of liquid subsequently exudes from the slit, leaving a brown mark; egg-laying sites are thus detectable. The reported total number of eggs laid by one female ranges from thirteen (Velbinger, 1939) to 32 (Dicker, 1953). After hatching from the egg, the larva starts burrowing into the fruit, usually starting in the calyx and continuing around the developing fruitlet, just under the skin, before burrowing towards the centre of the fruit and the seeds. Some larvae die before beginning this deeper burrowing and the fruits that develop subsequently exhibit a characteristic ‘ribbon’ scar on the surface. Those larvae that successfully reach and consume the seeds then leave that fruit and attack another, eating their way directly to the seeds. This leaves a large and characteristic entry hole, around which accumulate wet, reddish brown droppings. A few larvae proceed to attack a third fruit (Steer & Thomas, 1935). Apples that have suffered damage to the seeds as a result of sawfly feeding usually fall from the tree as part of the ‘June drop’.

After feeding for around four weeks, the mature larva emerges from the fruit and drops to the ground, burrows into the soil, and spins a cocoon within which it remains in the ‘pre-pupal’ stage until the following spring. By excavating cocoons from the soil, several researchers have investigated the depth at which overwintering in this stage occurs; results indicate variously that most pupae occur between 8 and 23 cm deep (Miles, 1932), in the top 10 cm (Hey & Steer, 1934), and in the top 15 cm (Dicker, 1953). The depth to which larvae burrow probably depends on the penetrability of the soil, but it seems that most pupate within the top 15 cm. In the following spring, adult sawflies emerge from the cocoons, mate and lay eggs in the apple receptacles.

Monitoring the flight activity of apple sawfly

The white colour of apple flowers is attractive to apple sawfly adults. (This is evidently not the only means that sawflies have for locating apple flowers, since some red-flowered apples are attacked). Based on research by Owens and Prokopy (1978) who analysed the spectral reflectance of apple blossoms, white sticky traps attractive to apple sawfly adults have been designed, with large reflectance at the non-UV end of the insect visible spectrum (400-650 nm) (Wilbolz & Staub, 1984;1986). These traps are now available commercially as the ‘Rebell’ trap.

Materials and methods

‘Rebell’ white sticky traps were located at a height of 1.5m in trees in apple orchards to monitor the flight activity of apple sawflies. Those orchard sites that had yielded the lowest catches in 1998 were not monitored in 1999, with the exception of one site which was retained because temperature loggers were located in the orchard for another purpose; two new farms were added in 1999. Traps were placed in orchards at Home Farm, HRI-East Malling, Rocks Farm, East Malling, two farms elsewhere in Kent, and four farms in the West Midlands (see Table 1). Traps were examined and the numbers of sawfly recorded at intervals of seven days or less; traps were replaced with new ones when the caught insects or debris were sufficient to reduce catching efficiency.

Air and soil temperatures were recorded using small electronic temperature loggers ('Gemini Tinytag'). The loggers were enclosed within solar radiation screens ('mini Stevenson screens'), and the remote probes of the soil temperature loggers were buried at a depth of 10 cm. Loggers were downloaded periodically, and readings were integrated to derive daily mean temperatures. Experiments by Graf *et al*. (1996a) have shown 4°C to be the threshold temperature below which the sawfly pupa does not develop. The amount by which each daily mean temperature exceeded 4°C was added to an accumulating day degree heat sum.

Results and Discussion

Sticky trap catch records are given in Table 1. Total catch per orchard ranged from 363 to zero but, in five orchards on five farms, the total catches exceeded 50. The dates of first catch and maximum catch are given in Table 2 for these orchards. Accumulated day degree heat sums above the 4°C threshold are given in Tables 3 and 4. Table 3 gives the heat sums derived from starting the temperature accumulations on 1st January and Table 4 from 1st March.

Sawflies overwinter in the pre-pupal stage within a cocoon in the soil. They are thus at the same temperature as the surrounding soil. The rate at which they develop in spring is governed by temperature; thus the accumulated heat sum, based on soil temperatures above the development threshold temperature, should give a measure of the rate of development, and the timing of the completion of pupal development, i.e. adult emergence. First catches in 1999 were in the range 353-518 day degrees from 1st January (Table 3). These heat sums are within the range of those of 1998.

Overwintering sawfly pupae are in a state of diapause during the winter, during which time they do not develop even if their temperature rises above the development threshold temperature. Research on populations of apple sawfly in Switzerland and The Netherlands has shown that pre-pupae remain in diapause until early March (Graf *et al*., 1996b; Zijp & Blommers, 1997), so temperatures during January and February are not likely to influence their development. One might expect therefore that a start date of the beginning of March for accumulating heat sums would give a more realistic indicator of development and adult emergence. Heat sums calculated in this way for the date of first emergence are in the range 268-385 day degrees, which again is within the range of the 1998 figures.

As it is not always convenient to monitor soil temperature, it is appropriate to question whether air temperature records would give an adequate indication of soil temperature, and thus of sawfly development. Heat sums based on air temperatures are also given in Tables 2 and 3. In general, soil temperature (at 10 cm depth) follows air temperature quite closely, but the peaks are not as high, and the troughs not as low; the soil buffers the air temperature fluctuations. Another feature of the soil mass is that it heats up gradually during the year, so that in January daily mean soil temperatures are generally lower than air means, but by late spring soil means are higher than air means. Both of these features are apparent in Figures 1-3, which give a plot of daily mean soil and air temperature recorded at East Malling, Ightham and Dormington. The important questions for sawfly development are:-

-how close is the relationship between accumulated heat sums based on soil and air temperatures?

-is the relationship the same regardless of location and soil type?

These questions can be addressed by examining monthly totals of accumulated heat sums based on soil and air temperature at different sites, for the months March-May (Table 5) (the relevant period for sawfly pupal development). For the month of January the heat sum based on air temperature was generally around 1.3x that based on soil temperature. By March the factor was below 1.0 at two sites, and by May the factors were in the range 0.83-0.92 (Table 5). The general trend of the soil warming in comparison to air temperatures is apparent, but it is also evident that the relationship between soil and air temperature varies with location. There is a possible relationship with soil type here; the site at Ightham is on a light sandy soil, East Malling a fine sandy loam and the others a loam with a greater clay content, particularly Sandford. At East Malling and Ightham, where the soils are lighter and likely to drain better than at the other locations, soil temperatures are generally higher in relation to air temperatures.

However, it is clear that underlying these considerations is the fact that the timing of flight activity, in relation to soil or air temperature heat sums, varies from site to site.

In particular, sawfly activity was very early, in relation to heat sum, in the orchard at Ightham, in 1998 (see report for 1998) and 1999 (Table 3 & 4). In both years the heat sum (soil temperature, from 1st March) at first catch was about 100 day degrees (or more) less than at the other sites. At that time of year, 100 day degrees represents approximately 10 days. The total catch at Ightham was higher than at any of the other sites in both years, but this earlier first catch is not merely an effect of population size, because the decline in catches after the peak was also earliest at Ightham. There is no obvious reason to account for this early activity observed at Ightham, but it does raise the possibility that local populations may not all respond to temperature in exactly the same way. Given this situation, the approximation that arises from using air temperatures rather than soil temperatures as an indicator of the timing of flight is not an important source of error.

It is evident that, given the apparent site to site variation in the timing of sawfly flight activity in relation to temperature, it is not possible to make general predictions with precision. In order to be confident about monitoring the early flight activity of apple sawfly, white sticky traps should be placed in orchards by the time that the locally relevant accumulated heat sum in day degrees above 4°C (calculated from the 1st March) reaches 200 day degrees for soil temperature, or 180 day degrees for air temperature.

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