Developing tools for monitoring and forecasting of onion fly *Delia antiqua* in Norway

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Abstract: The onion fly *Delia antiqua* (Diptera: Anthomyiidae) is a major pest in onion growing areas in Norway. Currently used methods for monitoring and forecasting attack seem to work un-satisfactorily, causing reduced effects of control measures. In this study, we intended to develop a selective monitoring trap by combining colour and odour sensory cues. White sticky traps and blue sticky- and water traps, with and without odour, were tested in a field experiment in Vestfold, Norway in 2016, along with fly registrations in commercial onion fields in Vestfold, Rogaland and Nord-Trøndelag in 2015-2017. Onion fly pupae were also collected from these fields in autumn 2016 to study the phenology of *D. antiqua* in laboratory emergence tests. The resulting data were used together with climate data to test SWAT for simulation of onion fly population dynamics in Norway.
Results showed that the blue sticky traps with odour were the most selective and effective. However, as the onion fly occurrence was generally very low in 2016, the results need verification from additional field experiments. High amounts of non-target catches on the sticky traps (white > blue) showed that catches on sticky traps were very time and labour-intensive compared to the water traps. In addition, several fly individuals with damaged identifying features were found on sticky traps, making a reliable morphological identification difficult. Molecular methods might be a possibility tool to achieve a more efficient identification. Emergence of one population of *D. antiqua* pupae at two temperatures indicated a theoretical base temperature of 3.9 °C for post-diapause development. From these data, the day-degree requirement for 50 % emergence would equal about 255 day-degrees (d°, Celsius). Studies of more populations at more than two temperatures are needed to obtain reliable results. Nevertheless, modelling with our Norwegian data in SWAT showed a very close relationship between forecasts and the actual first fly and first peak occurrence of *D. antiqua* in the field.
With data from more Norwegian *D. antiqua* populations and emergence data from a wider range of temperatures, we might be able to improve the model adaption in SWAT further. Additionally, after refining the monitoring system, a decision support tool for Norwegian onion producers may be established.

Keywords: onion fly, *Delia antiqua*, monitoring traps, fly phenology, simulation model, population dynamics, SWAT

Introduction

The onion production is increasing in Norway and one of its main challenges is the control of the onion fly *Delia antiqua* (Diptera: Anthomyiidae). Little is known about biology and ecology of this fly in Norway (Rygg, 1960). Today, methods for forecasting of onion fly attack or reliable monitoring for early detection are missing for Norwegian conditions. This implicate problems with decision making for applications of pest control treatments, and particularly a proper timing of the treatment. White sticky traps and white water trays are commonly used for onion fly monitoring in other countries like Canada and the Netherlands. Testing of such traps in 2013/2014 in Norway, showed that white sticky- and water traps were not efficient at Norwegian conditions. One reason might be that onion production takes place on relative small fields with short distances between different crops. This may result in high numbers of non-target flies like brassica root flies (*D. radicum* and *D. floralis*), and particularly the bean seed

flies (*D. platura* and *D. florilega)*, ending up in the traps. Identification (ID) of the key species *D. antiqua* will thereby be very time consuming, and complex taxonomic knowledge is needed. Therefore, one of the aims of our studies are to develop a trap design which is more selective for *D. antiqua*, more reliable, and a more manageable tool for onion fly monitoring in Norway. As colour and odour is important for onion fly attraction, we aim to combine both these sensory cues in the trap design. White and blue is reported to be the most attractive colours for onion flies (Judd & Whitefield, 1997). However, as non-target catches are lower in blue traps, blue might be a more selective cue than white. The onion fly is also attracted to several volatile compounds produced by onion plants, particularly by attacked plants and/or decomposing onion pulp (Ikeshoji *et al*., 1980, Ishikawa *et al*., 1987, Judd & Whitefield, 1997). In addition, enzymatic yeast hydrolysate has shown to be a feeding attractant for the onion fly (Judd & Whitefield, 1997).
Another aim of our studies are to evaluate present climate-based forecast models for onion fly under Norwegian conditions. One objective are to establish new data on the phenology of onion flies in field and laboratory, for correlation with climate data, and develop a Norwegian pilot-forecast model. From three different models for forecasts of onion fly swarming (Eckenrode *et al*., 1975, Liu *et al*., 1982, Otto & Hommes, 2000) we selected the German simulation model for population dynamics of onion fly - SWAT - (Otto & Hommes, 2000).

Materials and methods

Developing a monitoring trap

We tested blue water traps (RONDO®-Yellowtrap, Temmen GmbH, Hattersheim, Germany; coloured with blue spray colour, light blue RAL 5012, colour code: #2191BD) and blue sticky traps (15 x 8 cm, one element of Rebell® blu, Andermatt Biocontrol, Grossdietwil, Switzerland), with and without odour, respectively. As a control we included white sticky traps (15 x 20 cm, one element of Rebell® bianco, Andermatt Biocontrol). Based on literature research, odour collections and volatile analyses on onion plants carried out in our laboratory (Thöming et. al., 2014), we selected a blend of the following volatile compounds as odour attractant; 2-phenylethanol (CAS 60-12-8), n-valeric acid (CAS 190-52-4), dipropyl-disulphide (CAS 629-19-6), ethyl acetate (CAS 141-78-6), tetramethylpyrazine (CAS 1124-11-4), n-heptanal (CAS 111-71-7), 1-octen-3-ol (CAS 3391-86-4) and enzymatic yeast hydrolysate. The seven synthetic compounds were present at a 1:1 ratio and the total load of active ingredients in each dispenser was 10.5 mg. The blend was diluted in mineral oil and pipetted on dispensers consisting of 1 cm Parotisroll, size 5 cotton wicks (Roeko, Langenau, Germany) inserted into 1.5 mL Easy-Fit polypropylene microtubes (Treff, Degersheim, Switzerland). The enzymatic yeast hydrolysate were applied in an extra dispenser (0.2 g / dispenser). A pair of dispensers was mounted on the blue water and blue sticky traps, respectively.
In 2016, the traps were tested in an onion field in Slagentangen near Tolvsrød, Vestfold, Norway. Three groups of five traps (white sticky trap, blue sticky trap, blue sticky trap + odour, blue water trap, blue water trap + odour) were set up in randomized order in the part of the field where fly attack was expected, i.e. close to the onion field of the previous year. The traps were placed 2 m from the field border and with 5 m between the traps. From 10th of May 2016, trap catches were registered once a week until the first flight peak had passed (mid-July). Morphological ID of trap catches was carried out in the laboratory under a binocular microscope. Specimens chosen by size and appearance were removed from the sticky traps using Glurex forte® (Andermatt Biocontrol) or heptane, and the work was performed under a fume hood (Murphy, 1985). Specimens from water traps were identified directly without

preparation. The most recent work on morphological identification of *Delia* pest species has been used as reference when performing the morphological identification (Savage *et al*., 2016).

Evaluation of SWAT, a climate-based forecast model for the onion fly

All years (2015-2017), traps were arranged to register onion fly occurrence in three different onion production regions in Norway; Vestfold (Tønsberg), Rogaland (Jæren) og Nord-Trøndelag (Frosta). Three pairs of traps (white sticky trap, blue water trap) were set up in randomized order in the part of the field where fly attack was expected. The traps were placed 2 m from the field border and with 5 m interspace. Flight registration and morphological ID of trap catches were performed as described above.

In autumn 2016, onion fly pupae were collected in Rogaland, Vestfold and Nord-Trøndelag to study the phenology of *D. antiqua* from different regions in Norway. The pupae were kept in lightly moist vermiculite and sand at 2 °C until spring, for completion of diapause development. Then, emergence tests aimed at establishing the lower temperature threshold and the day-degree requirement for post-diapause development were conducted. Due to limited numbers of pupae, emergence tests were carried out at only two temperatures (9 and 15 °C) for one of the populations, and at one temperature (15°C) for other samples. A two-point linear regression method was used to find the theoretical base temperature for development (Bodenheimer, 1924, Collier & Finch, 1985).

The collected data from the *D. antiqua* flight registration were correlated with weather data from the particular nearby weather station. These field data were related to the laboratory data from overwintering pupae and emergence time. The simulation model for population dynamics of onion fly SWAT has been used for evaluation.

Results and Discussion

Onion fly monitoring

The onion fly occurrence was very low in the region (Vestfold) where the field experiment testing different monitoring traps were performed in 2016 (Fig. 1). The highest numbers of onion flies were trapped with white sticky traps, but also the blue sticky traps with odour were efficient (Fig. 1). A reliable conclusion on the sex ratio of the trapped onion flies is not possible based on the overall low number of trap catches. The non-target catches, particularly other *Delia* spp. (*D. radicum, D. floralis, D. platura, D. florilega)* which are very difficult to distinguish morphologically from *D. antiqua,* were much lower in the blue sticky traps compared to the white sticky traps. Thus, the blue sticky traps, particularly the ones with odour, were by far the most selective for *D. antiqua* (Fig. 1). In the blue water traps (with and without odour) no flies were trapped in Vestfold in 2016. However, in the other regions onion flies were recorded in blue water traps in 2016 and 2017. As the fly ID and data evaluation for 2017 is still in progress, the results are not included here. Nevertheless, additional field experiments are needed to verify these preliminary but promising results.

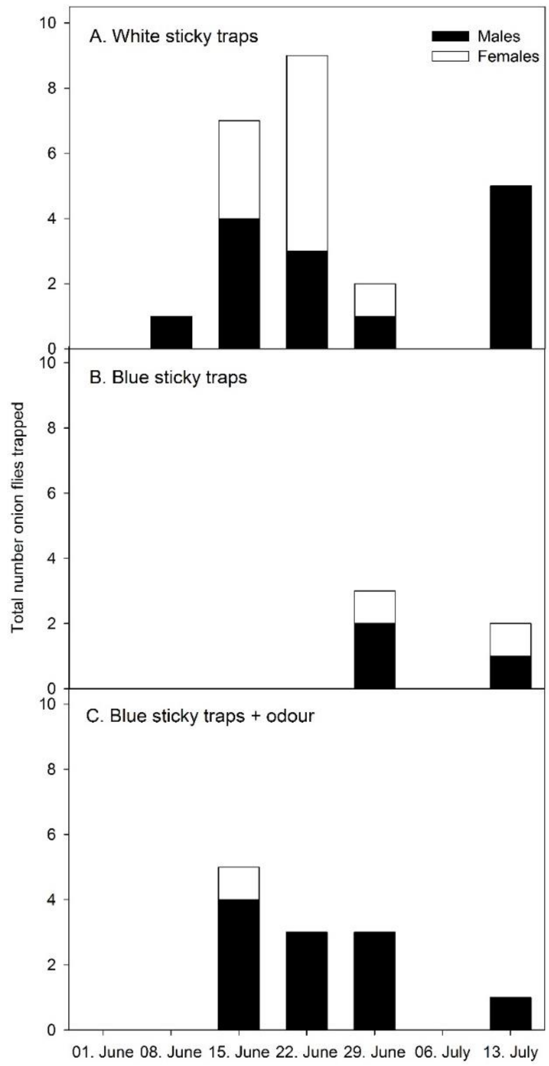

Figure 1. Trap catches as total number onion flies in the period 10th of May until 13rd of July testing white sticky traps (A), blue sticky traps (B), blue sticky traps + odour (C), blue water traps, blue water traps + odour. Water traps did not catch onion flies in this experiment and results are not presented here.

Morphological ID of specific fly catches from the different trap types have shown that managing sticky traps were very time and labour-intensive. Especially the white traps seemed to attract very high numbers of non-target flies. Furthermore, the use of sticky traps often implicated several fly individuals with flawed identifying features, which made a reliable ID impossible. The water traps were much easier and faster to handle and ID results seemed more reliable. Aiming for a trap design that is selective for *D. antiqua*, and at the same time a reliable and easy manageable tool for onion fly monitoring, an efficient and steady fly ID method should be included in the overall trap development. Molecular ID might be a possibility to achieve more efficient fly ID than the morphological ID we have used here.

Targets for future research are; (1) to verify the catch efficiency of the developed trap designs tested in this study in different regions in Norway and over several years, (2) in doing so, refine the best trap design and, (3) develop a reliable and efficient method for fly ID.

Climate-based forecast model for onion fly

A sufficient number of *D. antiqua* pupae for emergence at two temperatures was obtained only from Rogaland (South-Western Norway). Results based on accumulated emergence curves showed that 50 % of emergence occurred within 23 and 50 days at 15 and 9 °C, respectively (Fig. 2).

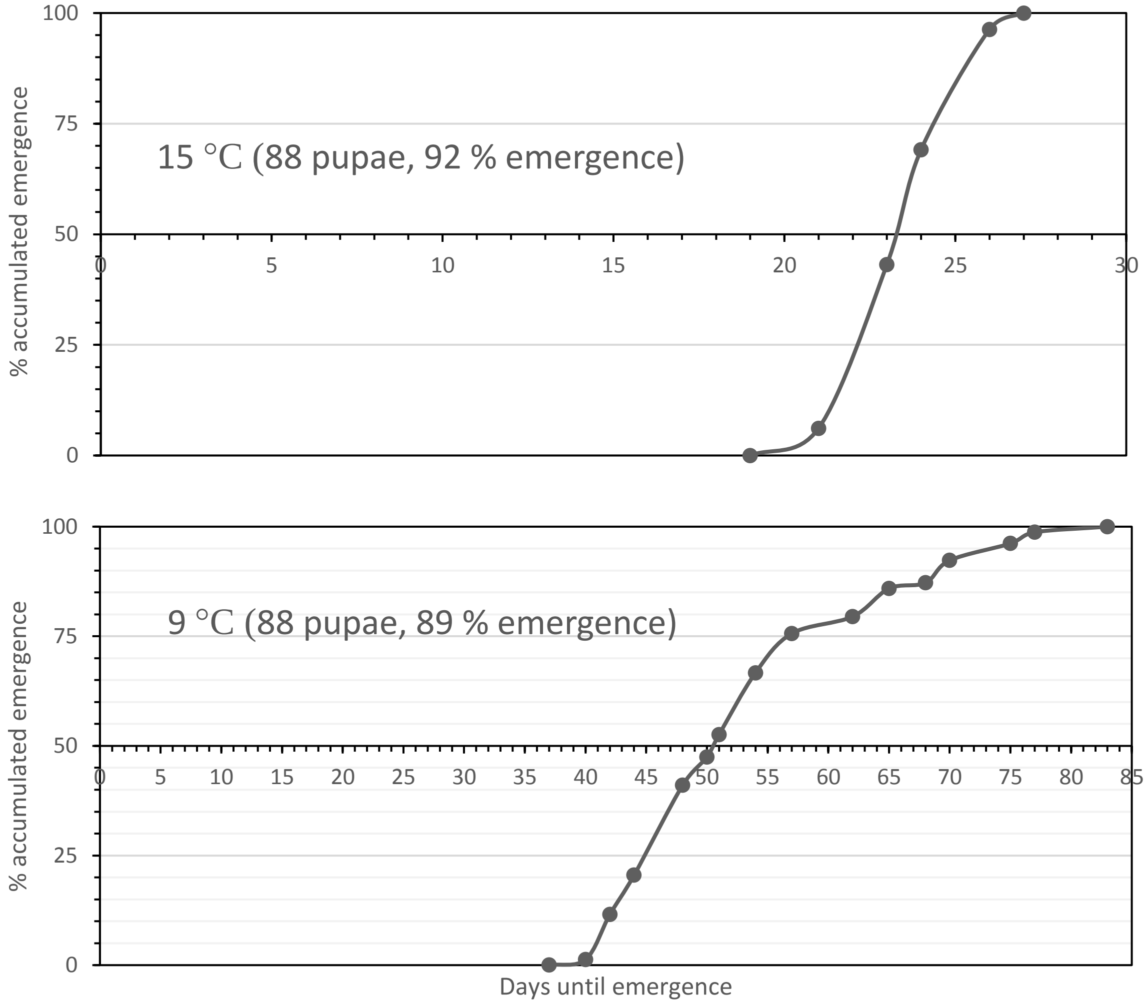

Figure 2. Emergence pattern of a Norwegian onion fly (*D. antiqua*) population (Rogaland) at 15 and 9 °C.

The theoretical base temperature for post-diapause development seemed to be close to 4 °C (3.9 °C), as indicated by extrapolation of the line between the two points of developmental rate against temperature (Fig. 3). From these data, the day-degree requirement for 50 % emergence would equal about 255 day-degrees Celsius (d° C) above 4 °C. Similar calculations for two other samples of pupae (Rogaland, July collection and Vestfold) indicated a requirement of 233 and 200 d° C, respectively, for emergence at 15 °C.

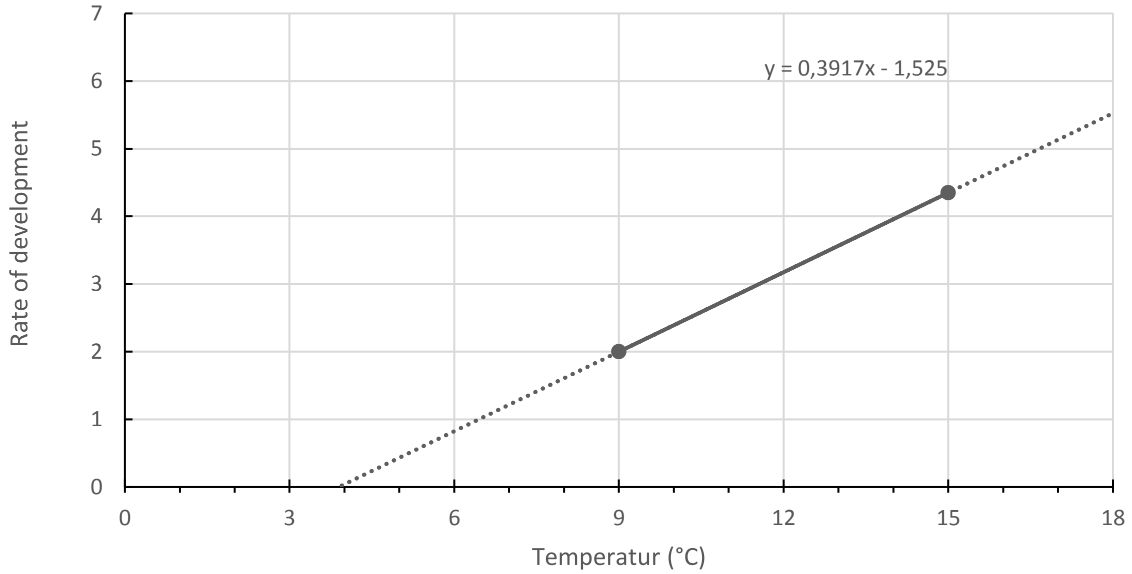

Figure 3. Developmental rates of emergence of a Rogaland population at 9 and 15 °C. Extrapolation of the linear regression line between the two points to the x-axis indicate the theoretical base temperature for post-diapause development.

These varying results demonstrate the limitation of the biological data used in the calculations. Usually, emergence tests are performed within a wide range of temperatures when previous results are scarce. This makes it possible to exclude data from outside the relatively narrow temperature area with linear relation between developmental rate and temperature (Collier & Finch, 1985). Therefore, studies of more populations and emergence at more than two temperatures are needed to obtain results with more accuracy.

The available data from the *D. antiqua* monitoring (2015-2017 in Vestfold, Rogaland and Nord-Trøndelag), together with climate data from the corresponding regions, were used to test SWAT as simulation model for population dynamics under Norwegian conditions. With SWAT, a forecast such as the first onion fly in the field, or the peak flight activity, is possible only with data from fly monitoring. The better the monitoring, the better the forecast will be. SWAT gives qualitative, but no quantitative explanations. This means that the onion producer will get to know when onion flies will attack the field, but not if the attack will be serious or minor. Thereby, SWAT may help the onion grower with correct timing of pesticide application or best time to install insect nets. The data from the *D. antiqua* emergence tests were used to perform a preliminary adaption of the model, keeping in mind that more emergence data are needed to gain a proper adaption (see paragraph above).

This preliminary modelling with our Norwegian data in SWAT showed that the program is able to forecast the occurrence of the first fly in the field and the first flight peak of *D. antiqua* very well. More biological data will help to improve the model adaption. Together with an efficient refined onion fly monitoring system it seems realistic to establish a decision support tool for Norwegian onion producers in the near future.

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