Forecasting carrot fly activity in carrots in Denmark with MORPH model

Purpose:

- to measure and collect temperature data for the carrot fly forecast model in MORPH and
- to investigate the possibilities to use MORPH in Denmark to forecast optimal timing of carrot fly control. Control in this context could be by spraying or harvesting before visible attack on roots.

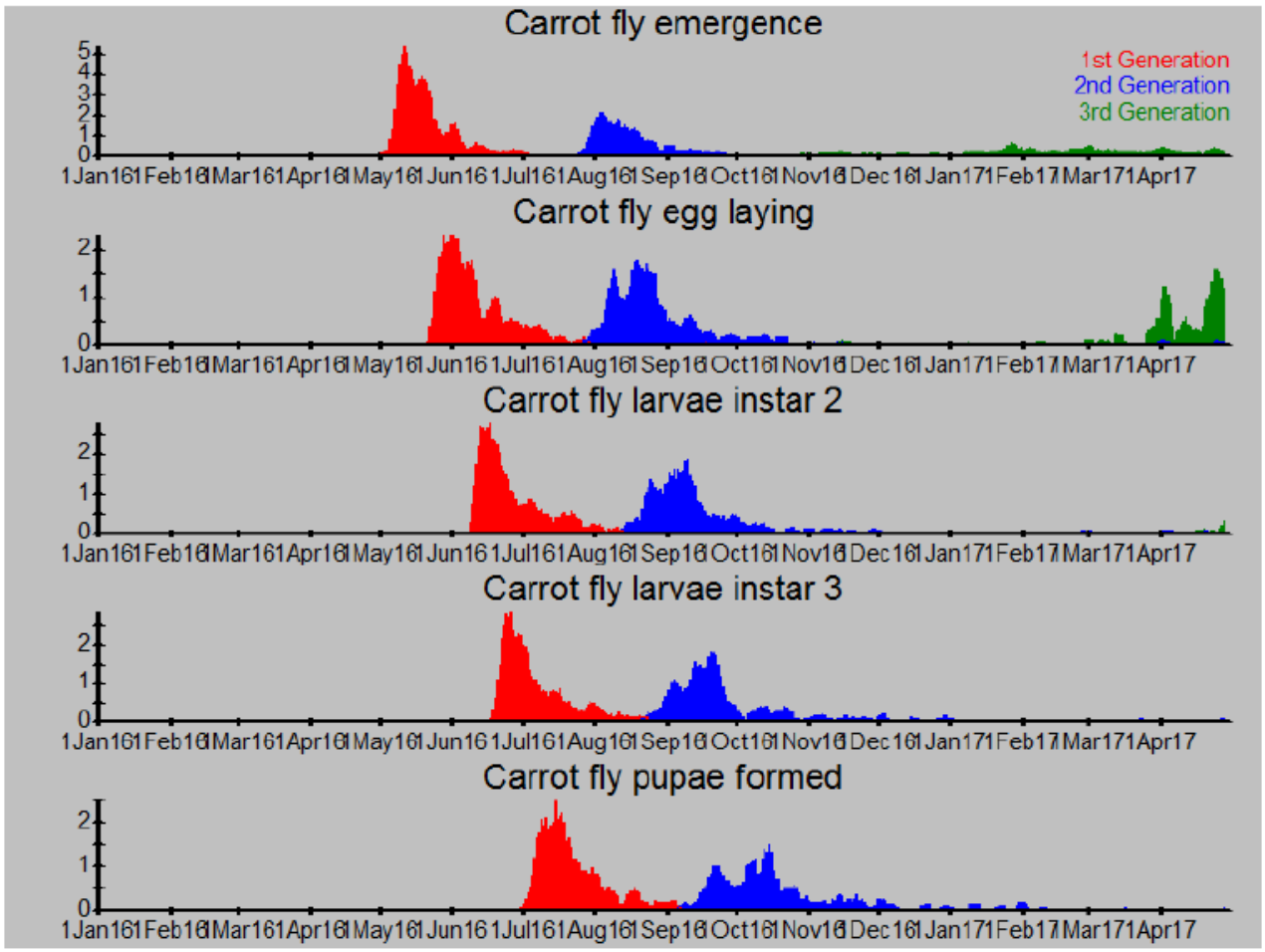
Background:

Carrot flies are perceived as an increasing challenge in carrots in some parts of Denmark. Mainly because the possibilities to control carrot flies with insecticides has been severely limited. There is only one approved insecticide (25 g/kg lambda-cyhalothrin) and the application is limited to maximum two seasonal sprays including control of other insects such as cutworms and aphids. The area of organic carrots is increasing and here Spruzit Neu is approved with maximum two seasonal sprays and only for control of aphids and cutworm.

Yellow sticky traps are very common in Danish carrot production to monitor the activity of carrot flies in the carrot fields and used for timing of spraying or in the organic carrot production to identify potential attack and timing of harvest. The use of yellow traps is very sensitive to how they are placed in the field, angulation, wind direction, height, type of fence along the field and field size. But traps only tell us something about the activity of the carrot flies during the week before, and can't forecast the activity of carrots flies. In some European countries models to forecasting the carrot fly activity has been implemented, like in UK with the MORPH carrot fly forecast from University of Warwick. Here they have found that yellow traps as a tool for timing of spraying can be optimized, if they are supported by the MORPH forecasting tool based on the air and soil temperature. The MORPH model needs hourly air temperatures and soil temperatures (6 cm) from 1 February until end of activity. Based on those data MORPH calculates and predicts when the overwintering carrots files will emerge, lay eggs and develop into larvae for the first and subsequent generations of carrot flies.

Examples of output from MORPH model 2016:

Model run at 16 May 2016 at 21:08



Summary Information

Event	Date
First damage (Swedish)	26 Jun 2016
10% emergence 1st generation	10 May 2016
50% emergence 1st generation	19 May 2016
90% emergence 1st generation	12 Jun 2016
First damage (Swedish)	8 Sep 2016
10% emergence 2nd generation	2 Aug 2016
50% emergence 2nd generation	14 Aug 2016
90% emergence 2nd generation	14 Sep 2016
First damage (Swedish)	1 May 2017
10% emergence 3rd generation	18 Nov 2016
50% emergence 3rd generation	16 Feb 2017
90% emergence 3rd generation	13 Apr 2017
First damage (Swedish)	9 Jul 2016
10% egg laying 1st generation	27 May 2016
50% egg laying 1st generation	8 Jun 2016
90% egg laying 1st generation	6 Jul 2016
First damage (Swedish)	15 Sep 2016
10% egg laying 2nd generation	8 Aug 2016
50% egg laying 2nd generation	24 Aug 2016

90% egg laying 2nd generation 3 Oct 2016
First damage (Swedish) 1 May 2017
10% egg laying 3rd generation 12 Mar 2017
50% egg laying 3rd generation 14 Apr 2017
90% egg laying 3rd generation 28 Apr 2017
10% entering 2nd instar 1st generation 13 Jun 2016
50% entering 2nd instar 1st generation 22 Jun 2016
90% entering 2nd instar 1st generation 22 Jul 2016
10% entering 2nd instar 2nd generation 25 Aug 2016
50% entering 2nd instar 2nd generation 9 Sep 2016
90% entering 2nd instar 2nd generation 25 Oct 2016
10% entering 2nd instar 3rd generation 14 Jan 2017
50% entering 2nd instar 3rd generation 29 Apr 2017
90% entering 2nd instar 3rd generation 1 May 2017
10% entering 3rd instar 1st generation 23 Jun 2016
50% entering 3rd instar 1st generation 2 Jul 2016
90% entering 3rd instar 1st generation 1 Aug 2016
10% entering 3rd instar 2nd generation 4 Sep 2016
50% entering 3rd instar 2nd generation 21 Sep 2016
90% entering 3rd instar 2nd generation 10 Nov 2016
10% pupae formed 1st generation 9 Jul 2016
50% pupae formed 1st generation 20 Jul 2016
90% pupae formed 1st generation 18 Aug 2016
10% pupae formed 2nd generation 22 Sep 2016
50% pupae formed 2nd generation 15 Oct 2016
90% pupae formed 2nd generation 22 Dec 2016

Test description:

In 2016 9 weather stations from Metos and Decagon have been set up on 1st of February near carrot fields in different areas in Jutland representing different fields in each area. In each field and nearby fields, carrot fly activity has been monitored on yellow sticky traps with 5 traps per field. The first generation carrot fly activity was followed in 10 different fields for early carrot production. The second generation carrot fly activity was followed in 15 different fields for late carrot production near the weather stations.
6 weather stations in North Jutland and 3 weather stations in central Jutland following 12 different fields in North Jutland and 14 fields in central Jutland in total.
The temperature was a bit over normal in spring and summer 2016 but often cloudy. August was with normal temperatures and September was with temperature much higher than normal followed by sunshine.
Temperature data from the weather stations has been collected weekly during the season and transformed through an Excel spreadsheet into a text format that MORPH can read. This data transformation is challenging. First of all because MORPH operates with English dot decimal separation, where Danish computers operate with a comma separation and second because the weather stations do not deliver data in a format that fits MORPH directly.
The MORPH model from University of Warwick has kindly been made available for testing in Denmark in 2014, 2015 and 2016.

Results:

The tables below show predicted dates by which 10% and 50% of the carrot flies will emerge/lay eggs at the nine locations with weather stations.

The days predicted were very stable all spring until the end of 1st generation carrot fly activity on all locations. The forecast gave 29th of May as the day for 10% egg-laying. The activity on the yellow traps peeked in the first week of June.

Based on temperature data from 9 weather stations the MORPH model gave very different forecast days for the second generation carrot fly activity varying from 13th of August to 4th of September on different fields. The egg-laying activity of the second generation carrot flies monitored on yellow sticky traps did also vary from 1st of August to 5th of September.

MORPH forecast based on temperature data from local weather stations:

16th Feb forecast, 1st generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	23 Apr	29 May	9 June
Site 2	25 Apr	31 May	10 June
Site 3	24 Apr	30 May	10 June
Site 5	25 Apr	30 May	9 June
Site 6	26 Apr	29 May	8 June

29th Feb forecast, 1st generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	28 Apr	29 May	7 June
Site 2	29 Apr	29 May	10 June
Site 3	30 Apr	29 May	9 June
Site 5	1 May	30 May	8 June
Site 6	1 May	29 May	11 June

15th March forecast, 1st generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	2 May	30 May	12 June
Site 2	5 May	29 May	9 June
Site 3	5 Apr	30 May	12 June
Site 5	4 May	28 May	7 June
Site 6	5 May	29 May	9 June
Site 7	3 maj	29 maj	9 June
Site 8	10 maj	29 maj	8 June

4th Apr forecast, 1st generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	3 May	29 May	10 June
Site 2	5 May	29 May	9 June
Site 3	6 Apr	30 May	11 June
Site 5	5 May	29 May	8 June
Site 6	6 May	29 May	9 June
Site 7	4 May	29 May	7 June
Site 8	3 May	29 May	8 June

18th Apr forecast, 1st generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	4 May	29 May	7 June
Site 2	5 May	30 May	10 June
Site 3	6 Apr	28 May	7 June
Site 4	6 May	29 May	9 June
Site 5	6 May	30 May	7 June
Site 6	6 May	29 May	9 June
Site 7	4 May	28 May	8 June
Site 8	3 May	29 May	10 June

2nd May forecast, 1st generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	6 May	31 May	9 June
Site 2	8 May	28 May	8 June
Site 3	9 Apr	29 May	8 June
Site 4	8 May	31 May	9 June
Site 5	9 May	30 May	9 June
Site 6	9 May	29 May	9 June

16th May forecast, 1st generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	10 May	28 May	8 June
Site 2	13 May	28 May	7 June
Site 3	13 Apr	29 May	8 June
Site 4	10 May	27 May	8 June
Site 5	15 May	29 May	6 June
Site 6	12 May	29 May	7 June
Site 7	6 May	30 May	11 June
Site 8	7 May	29 May	9 June

05th June forecast, 1st generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	9 May	27 May	4 June
Site 2	13 May	30 May	9 June
Site 3	12 Apr	30 May	4 June
Site 4	10 May	28 May	5 June
Site 5	14 May	31 May	10 June
Site 6	12 May	29 May	5 June
Site 7	6 May	28 May	6 June
Site 8	6 May	27 May	6 June

12th June forecast, 2nd generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	31 July	7 Aug	22 Aug
Site 2	6 Aug	13 Aug	29 Aug
Site 3	3 Aug	9 Aug	25 Aug
Site 4	4 Aug	10 Aug	25 Aug
Site 5	8 Aug	17 Aug	28 Aug
Site 6	2 Aug	8 Aug	24 Aug
Site 7	31 July	6 Aug	20 Aug
Site 8	1 Aug	8 Aug	21 Aug
Site 9	31 July	8 Aug	25 Aug

26th June forecast, 2nd generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	2 Aug	8 Aug	24 Aug
Site 2	9 Aug	17 Aug	30 Aug
Site 3	4 Aug	11 Aug	27 Aug
Site 4	4 Aug	11 Aug	26 Aug
Site 5	11 Aug	20 Aug	3 Sep
Site 6	3 Aug	9 Aug	26 Aug
Site 7	30 July	6 Aug	22 Aug
Site 8	1 Aug	8 Aug	22 Aug
Site 9	1 Aug	7 Aug	22 Aug

10th July forecast, 2nd generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying

Site 1	3 Aug	9 Aug	25 Aug
Site 2	11 Aug	21 Aug	4 Sep
Site 3	5 Aug	12 Aug	28 Aug
Site 4	6 Aug	14 Aug	28 Aug
Site 5	15 Aug	23 Aug	8 Sep
Site 6	3 Aug	9 Aug	25 Aug
Site 7	31 July	7 Aug	24 Aug
Site 8	2 Aug	8 Aug	25 Aug
Site 9	3 Aug	9 Aug	24 Aug

01st August forecast, 2nd generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	5 Aug	11 Aug	28 Aug
Site 2	16 Aug	24 Aug	7 Sep
Site 3	6 Aug	13 Aug	26 Aug
Site 4	10 Aug	17 Aug	01 Sep
Site 5	20 Aug	27 Aug	11 Sep
Site 6	5 Aug	12 Aug	25 Aug
Site 7	4 Aug	9 Aug	26 Aug
Site 8	4 Aug	11 Aug	25 Aug
Site 9	4 Aug	10 Aug	27 Aug

14th August forecast, 2nd generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1	5 Aug	16 Aug	29 Aug
Site 2	18 Aug	28 Aug	12 Sep
Site 3	8 Aug	18 Aug	30 Aug
Site 4	12 Aug	22 Aug	4 Sep
Site 5	21 Aug	30 Aug	17 Sep
Site 6	5 Aug	16 Aug	27 Aug
Site 7	4 Aug	15 Aug	26 Aug
Site 8	5 Aug	14 Aug	26 Aug
Site 9	4 Aug	14 Aug	28 Aug

29th August forecast, 2nd generation carrot fly activity

Region	Forecast 10% emergence	Forecast 10% egg-laying	Forecast 50% egg-laying
Site 1 (29 Aug)	5 Aug	13 Aug	26 Aug
Site 2	18 Aug	30 Aug	14 Sep
Site 3	8 Aug	17 Aug	29 Aug
Site 4 (1 Aug)	12 Aug	21 Aug	6 Sep

Site 5	21 Aug	4 Sep	22 Sep
Site 6	5 Aug	14 Aug	26 Aug
Site 7	5 Aug	16 Aug	28 Aug
Site 8	5 Aug	15 Aug	27 Aug
Site 9	4 Aug	14 Aug	29 Aug

The tables below shows the number of carrot flies on the yellow sticky traps per day per trap.
The threshold is 0.2 flies per day per traps.
The first two tables representing fields in North and Mid Jutland respectively for the first generation carrot flies.
The next two tables representing fields in North and Mid Jutland respectively for the second generation carrot flies.
The three figures below show the average number of carrot files in the fields on the yellow sticky traps.

Carrot fly activity on yellow sticky traps 1. generation

	23-maj	30-maj	06-jun	13-jun	19-jun	26-jun
Field 1	0	0	0	0		
Field 2	0	0,03	0,09	0,06	0	
Field 3	0	0,43	0,26	0,26	0,06	
Field 4	0	0,03	0	0	0	0
Field 5	0	0,03	0	0,03	0,07	0
Field 6	0	0	0	0	0,06	

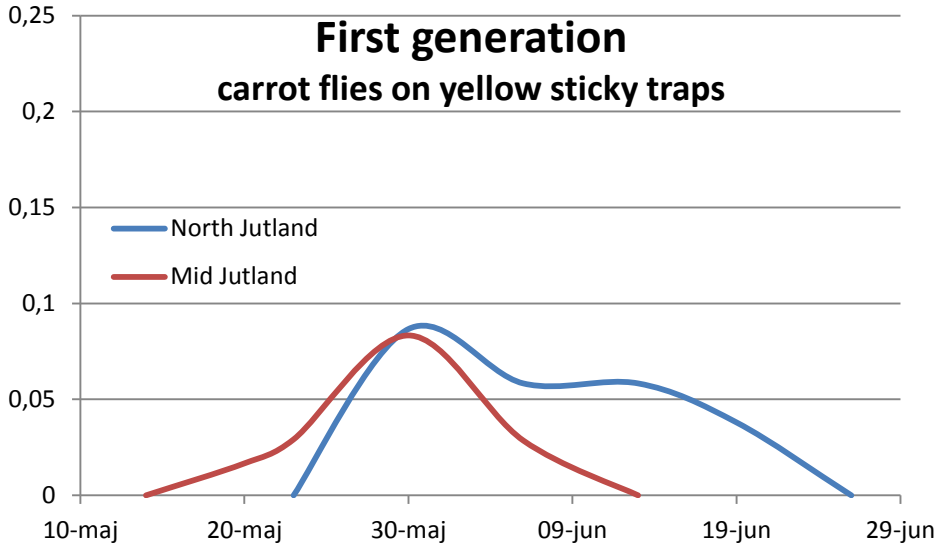
	14-maj	20-maj	26-maj	01-jun	08-jun	14-jun
Field 7	0	0,07	0,07	0,27	0,06	0
Field 8	0	0,00	0,00	0,03	0,06	0
Field 9	0	0,00	0,05	0,00	0,00	0
Field 10	0	0,00	0,00	0,03	0,00	0

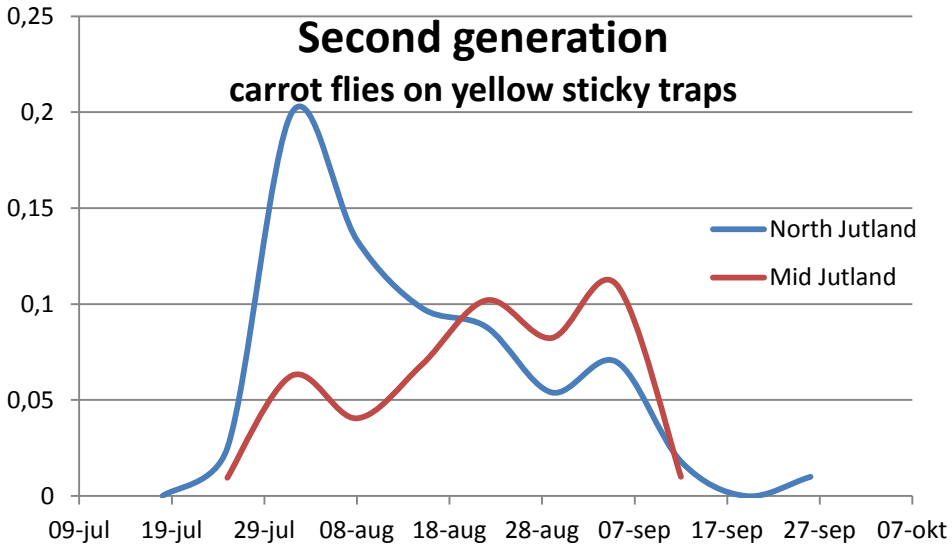
Carrot fly activity on yellow sticky traps 2. generation

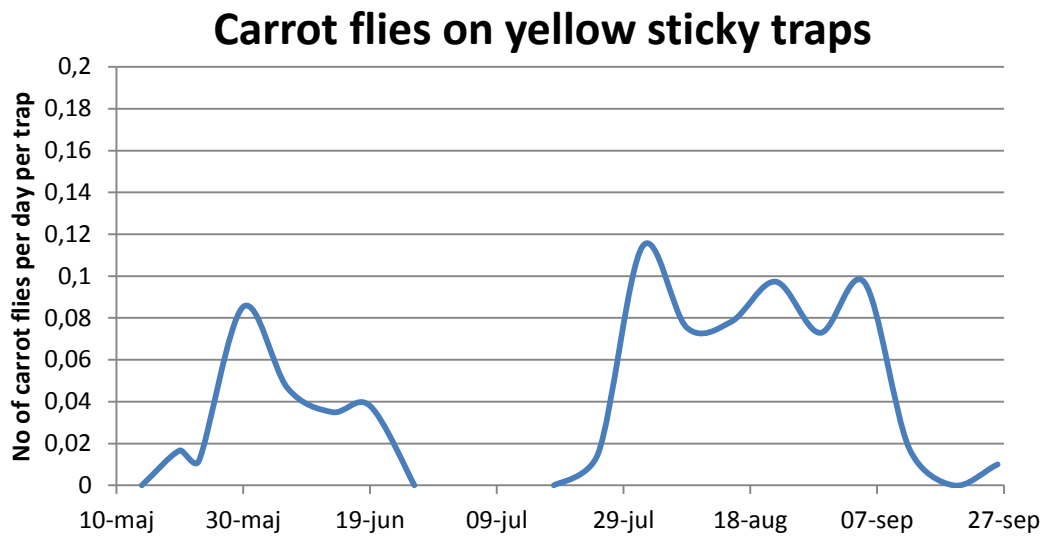
	18-jul	25-jul	01-aug	08-aug	15-aug	22-aug	29-aug	05-sep	12-sep	19-sep	26-sep
Field 11	0	0	0,23	0,23							
Field 12	0	0,06	0,14	0,11	0,29	0,29	0,06	0,09	0	0	0,03
Field 13	0	0	0,03	0,03	0	0,06	0,03	0,06	0,03	0	0
Field 14	0	0	0	0	0	0	0,03	0,06	0	0	0
Field 15	0	0	0,03	0,03	0	0	0,06	0,03	0	0	
Field 16	0	0,09	0,77	0,4	0,2	0,09	0,09	0,11	0,06		

	25-jul	01-aug	08-aug	18-aug	25-aug	01-sep	07-sep

Field 17	0,00	0,02	0,02	0,20	0,12	0,17	0,31
Field 18	0,00	0,07	0,07	0,03	0,05	0,05	0,03
Field 19	0,00	0,02	0,00	0,05	0,07	0,10	0,14
Field 20	0,02	0,00	0,00	0,02	0,10	0,05	0,00
Field 21	0,00	0,02	0,02	0,08	0,12	0,26	0,50
Field 22	0,00	0,00	0,02	0,02	0,00	0,00	0,00
Field 23	0,01	0,00	0,00	0,00	0,01	0,01	0,04
Field 7	0,07	0,38	0,10	0,12	0,14	0,07	0,03
Field 24	0,00	0,10	0,07	0,10	0,21	0,05	0,02
Field 25	0,00	0,00	0,10	0,06	0,21	0,07	0,04







Average no of carrot flies on yellow sticky traps on all traps in all fields

In this test it has been very difficult to compare the forecast from MORPH with the activity on the yellow sticky traps.

1. First, because the fields has been sprayed in the season with insecticides based on the forecast.
2. Second, because the number of carrot flies on the yellow sticky traps in general was very low in 2016 and only on very few occasions up around the threshold - maybe because of spraying.

If we look on the average number of carrot flies on the yellow sticky traps and compare it with the spread on the days predicted by MORPH it looks like there in general is no conflict between the forecast and the activity in the fields. But it's not possible to compare the individual fields with the corresponding weather station.

In 2014 early spring gave early carrot fly activity and in 2015 rainy cold weather gave late carrot fly activity. Both events were predicted by the Morph forecast. I 2016 the first generation peak was well predicted were as the activity of the second generation was spread out over a long period. The Morph model does also supply the user with a graph of the egg-laying activity period. Looking at the graphs from the fields, it looks like the egg-laying period is spread out over a longer period in 2016 the in 2015 and 2014.

In 2015 the forecast said 17 days from emergence to 50% egg-laying as an average of all fields, where as in 2016 it was around 23 days period with a lower peak.

The results in 2016 shows that it is important to look at both the peak and spread of the carrot fly activity.

Conclusions:

- Converting data from the Metos weather stations into MORPH is a challenge. This needs programming if it's going to run automatically in large scale in future.
- It looks like MORPH can be used to forecast the first generation of carrot fly activity for a larger region because the differences between locations are small. To forecast the second generation activity the weather data needs to be more local.

- The tests in 2014 and 2015 indicate that there might be a correlation between the model forecast, and the actual activity displayed on the yellow traps in the fields. In 2016 the activity was spread out over a longer period in autumn for the second generation. Maybe because of the weather or maybe because of insecticide spraying in the fields. For 2016 insect spraying in the test fields makes it difficult to confirm a correlation between Morph forecast and the carrot fly activity on the yellow sticky traps.
- When the decision to spray is based only on yellow traps, spraying will often be too late. When fly activity peaks on the yellow traps, most of the eggs will all ready have been laid. The yellow traps are on the other hand a very good complement to the MORPH forecast, verifying the accuracy of the model.
- The MORPH model might predict when the carrot flies are laying eggs but can't predict if the threshold is going to be exceeded. That's where the yellow traps become useful.

Weather station with rain gauge and temperature sensor in air and soil.

Yellow traps for carrot flies 10 meter from fence and 10 meters apart.

Carrot fly attack on root.

LRM, 2016

Projektet er støttet af Produktionsafgiftsfonden for frugt og gartneriprodukter under GAU