

## The influence of temperature on multiplication of the potato-cyst nematode (*Globodera rostochiensis*)

*Temperaturens indflydelse på opformeringen af kartoffelcystenematoden (Globodera rostochiensis)*

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### Summary

Field and laboratory experiments showed that multiplication of the potato-cyst nematode can be controlled if the potatoes are lifted before the accumulated degree-days have passed 440°C (with 6°C as a basis), corresponding to 85–90 days after early planting.

**Key words:** Potato-cyst nematode, soil-temperature, multiplication, degree-days, phenological control.

### Resumé

Kartoffelcystenematoden *Globodera rostochiensis* er en alvorlig skadegører i nogle kartoffelmarker. Adskillige forfattere fra hele Europa har beskrevet fænologisk bekæmpelse af denne nematode, og det fremgår, at under tempererede klimatiske forhold er temperaturen den vigtigste faktor for udviklingshastigheden.

På baggrund af disse oplysninger blev der i 1982 foretaget undersøgelser for at belyse, om fænologisk bekæmpelse kan opnås under danske markforhold. I 24 parceller blev kartofler af sorten »Primula« lagt. Kartoflerne blev senere taget op på 6 forskellige tidspunkter med en uges mellemrum. Et lignende forsøg blev foretaget med sorten »Bintje« i småparceller (betonrør). Før kartoflerne blev lagt og efter optagning blev udtaget jordprøver til bestemmelse af antallet af kartoffelcystenematoder. Lufttemperaturen registreredes fra den nærmeste meteorologiske station.

For at teste hypotesen om fænologisk bekæmpelse, som fremkom af disse undersøgelser, blev der i 1983 foretaget laboratorieundersøgelser, hvor 3 forskellige temperaturforløb simuleredes.

Laboratorieforsøgene blev foretaget i væksthuse, hvor sorterne »Alma« og »Bintje« blev lagt i 250 ml gennemsigtige plasticpotter, som nedgravedes i sand. Sandets temperatur kunne kontrolleres på 3 forskellige niveauer.

Resultaterne fra mark- og småparcelforsøgene viser, at nematoderne afslutter deres udvikling fra 79–86 dage efter kartoflernes lægning. Dette svarer til 334–385 graddage med 6°C som udviklingsnulpunkt. Laboratorieundersøgelserne viser, at antallet af graddage her ligger mellem 259–542.

Antallet af graddage, udregnet som middelværdien af det interval, hvor nematoderne afslutter deres udvikling, logaritmetransformeres og sættes i relation til den begyndelsestemperatur, kartoflerne blev lagt ved. En lineær regressionsanalyse viser, at antallet af graddage er uafhængigt af begyndelsestemperaturen. Dette betyder i praksis, at kartoffelcystenematodens udviklingshastighed kun er afhængig af, om foråret bliver varmt eller koldt. Nematoderne afslutter deres udvikling efter ca. 440 graddage (middelværdien af udviklingstiden for mark-, småparcel- og laboratorieforsøg), hvilket under danske forhold svarer til 85–90 dage efter tidlig lægning.

**Nøgleord:** Kartoffelcystenematode, jordtemperatur, opformering, graddage, fænologisk bekæmpelse.

## Introduction

The potato-cyst nematode *Globodera rostochiensis* is a serious plant parasite in potato fields. Several authors have reported on phenological control of this nematode. One of the first to approach the problem in this way was Grainger (2) from Scotland. Later Brande and D'Herde (1) reported from Belgium that the formation of new cysts containing viable eggs is reduced by planting early varieties (Eersteling) and by early harvesting (before 20 June). Weebly and Jones (9) also confirmed that, in South Wales, populations of *G. rostochiensis* were reduced by early harvesting. When potatoes were planted on 11 March and harvested after 83 days, population densities declined.

According to Jones (6) temperature is the major factor determining the rate of development under conditions where climatic extremes are not experienced.

On the basis of these reports, similar investigations were made in Denmark in 1982 to see if phenological control could be achieved under Danish field conditions.

To test hypotheses developed with experiments in 1982 laboratory experiments were carried out in 1983, in which 3 different temperature regimes were simulated.

## Materials and methods

### Field experiment, 1982

Potatoes were planted on Samsø on 30 March in 24 plots, each 2 × 4 m. The potato cultivar used was »Primula«, and the tubers were pregerminated.

Before the potatoes were planted, soil samples to estimate the density of potato-cyst nematodes (Pi) were taken at random from each plot. After the last lifting date, soil samples were again taken from each plot to estimate the population density (Pf).

Potatoes were lifted from 4 plots chosen at random at weekly intervals from 17 June to 15 July.

Air temperature was recorded at a height of 2 m at Røsnæs, the closest meteorological station, 25 km away from the experiment.

### Microplot experiment, 1982

A microplot experiment was carried out in 30 concrete pipes ( $\varnothing = 60$  cm) at the Centre for Plant Protection (CCP). A 20-cm layer of nematode infested soil had been placed in the pipes beforehand. The cultivar »Bintje« was used. The potatoes were lifted from 5 pipes at weekly intervals between 14 June and 27 July. Soil samples were taken before and after the experiment. In this experiment the air temperature was recorded at a height of 2 m at Værløse, the closest meteorological station, 15 km away from the experiment.

### Laboratory experiment with 3 different temperature regimes, 1983

The experiment was carried out in a glasshouse in containers where the soil temperature could be controlled at 3 levels. The temperature regimes are shown in Fig. 1.

The 2 potato cultivars 'Bintje' and 'Alma' were grown in 250 ml pots made of transparent plastic.

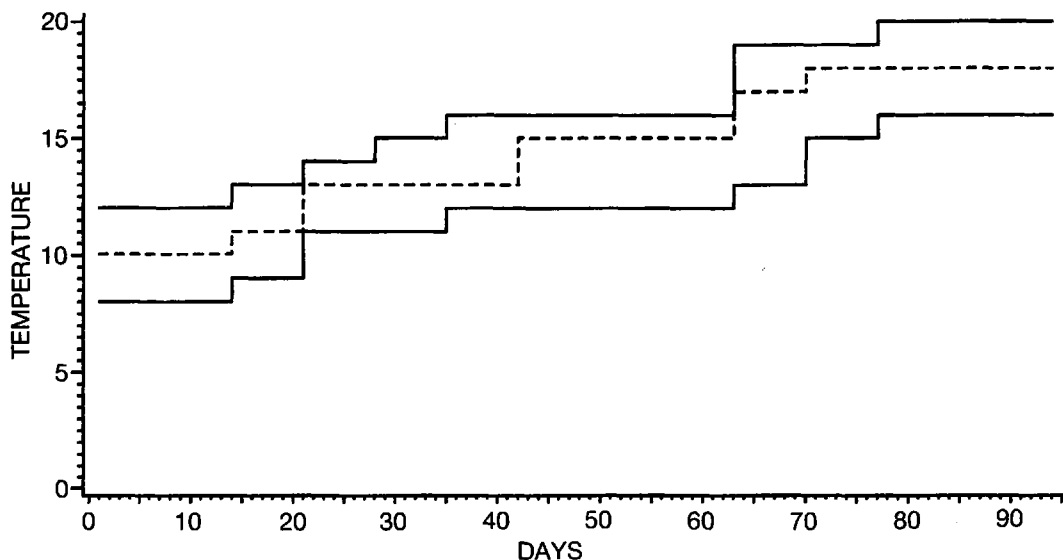


Fig. 1. Temperature regimes in the laboratory experiment. The 3 temperature limits: (1) 8–16°C, (2) 10–18°C, (3) 12–18°C.

*Temperaturforløbet i laboratorieforsøget. De 3 temperaturgrænser.*

The plastic containers were embedded in sand. 8 replicates were used for each treatment.

The roots of the plants were checked twice a week for female nematodes from 45 to 93 days after the start.

#### *The nematodes*

In all experiments a pure population of *G. rostochiensis* patotype Ro-1 was used.

#### *Statistical analysis*

For the statistical analysis a one-way ANOVA test and a linear regression analysis were used (3).

#### **Results**

##### *Field and microplot experiments*

The figures in Table 1 show that new nematodes finish their development between 79 and 86 days after planting, corresponding to 334–385 degree-

**Table 1.** Nematode density from a field experiment at Samsø before planting (Pi) and after lifting (Pf). N = 4. SE in brackets. \* =  $p < 0.05$ .

*Forekomst af nematoder fra markforsøg på Samsø før lægning (Pi) og efter optagning (Pf).*

Lifting date week no. Optagnings- tidspunkt uge nr.	Days after planting Dage fra lægning	Pi (eggs/g soil) (æg/g jord)	Pf (eggs/g soil) (æg/g jord)	Pf/Pi
24	79	54 (7)	16 (3)	0.3 (0.1)*
25	86	59 (14)	57 (12)	1.1 (0.2)
26	93	48 (9)	44 (8)	1.1 (0.4)
27	100	50 (10)	49 (6)	1.1 (0.2)
28	107	35 (5)	54 (6)	1.7 (0.3)
29	114	64 (13)	44 (9)	0.7 (0.1)*

**Table 2.** Nematode density from a microplot experiment at Centre for Plant Protection before planting (Pi) and after lifting (Pf). N = 5. SE in brackets. + = significant different ( $p < 0.05$ ) from \$. ns = not significant.  
Forekomst af nematoder fra markforsøg på Planteværnscentret før lægning (Pi) og efter optagning (Pf).

Lifting date week no. Optagnings- tidspunkt uge nr.	Days after planting Dage fra lægning	Pi (eggs/g soil) (æg/g jord)	Pf (eggs/g soil) (æg/g jord)	Pf/Pi
25	76	34 (6)	12 (4)	0.5 (0.2) +
26	83	46 (6)	7 (3)	0.2 (0.1) +
27	90	30 (4)	27 (5)	1.0 (0.3) ns
28	97	37 (3)	83 (38)	2.3 (1.1) \$
29	104	36 (4)	44 (10)	1.3 (0.4) ns
30	111	34 (6)	49 (22)	1.2 (0.4) ns

days with 6° as a basis (Table 3). This basal temperature is chosen because it is the development zero for *Globodera rostochiensis* (4,7). The low Pf/Pi ratio 114 days after planting is caused by a very high number of nematodes in one plot (>100 eggs/g soil). This overcrowding results in a quotient less than 1.

At the microplot experiment at CCP the new

nematodes finish their development between 83 and 90 days after planting (Table 2), corresponding to 434–497 degree-days (Table 3). The large variation gives a low level of significans. The decrease in the Pf/Pi ratio 104 days after planting, may be due to a very warm period and consequently misgrowing potato plants.

**Table 3.** Temperature conditions during the test period. Røsnæs can be compared to Samsø and Værløse to Centre for Plant Protection. The temperature is 24 hours/week mean. The sum is degree-days with 6° as basis temperature measured from the day of planting.

Temperaturforhold i forsøgsperioden. Røsnæs kan sammenlignes med Samsø og Værløse med Planteværnscentret. Temperaturerne er 24 timers ugentlige gennemsnitstemperaturer. Summen er graddage med 6°C som basis temperatur udregnet fra lægningstidspunktet.

Week Uge	Røsnæs (°C)	Sum (degree-days) Sum (graddage)	Værløse (°C)	Sum (degree-days) Sum (graddage)
13	5.0	–	5.9	–
14	5.8	–	5.9	–
15	7.5	–	7.5	–
16	7.2	–	7.4	–
17	7.2	–	6.9	–
18	10.1	–	10.5	–
19	12.2	–	12.2	–
20	13.4	–	14.7	–
21	18.5	–	20.5	–
22	13.7	–	13.4	–
23	12.8	–	11.5	–
24	13.4	334 (1st lift)	13.6	–
25	15.1	385 (2nd lift)	15.1	385 (1st lift)
26	16.5	446 (3rd lift)	16.1	434 (2nd lift)
27	19.0	512 (4th lift)	19.9	497 (3rd lift)
28	17.9	601 (5th lift)	18.4	581 (4th lift)
29	19.0	685 (6th lift)	19.6	673 (5th lift)
30	22.5	–	22.6	760 (6th lift)

**Table 4.** Cyst development and sum of temperatures (6°C as a basis) of 'Bintje' (A) and 'Alma' (B). White cysts (w), yellow cysts (y), and brown cysts (b). N = 8. + = cysts present. · = no registrations, the potatoes were rotten. *Cystevudvikling og temperatursummer. Hvide (w), gule (y) og brune (b) cyster.*

Days after planting <i>Dage efter lægning</i>	Initial temperature											
	8°C			10°C						12°C		
	w	y	b	Sum degree-days	w	y	b	Sum degree-days	w	y	b	Sum degree-days
<b>A.</b>												
45	-	-	-	173	+	-	-	243	+	-	-	312
53	-	-	-	221	+	-	-	315	+	+	-	394
57	+	-	-	231	+	+	-	351	+	+	-	434
59	+	-	-	243	+	+	-	369	+	+	+	454
64	+	-	-	259	+	+	-	414	+	+	+	504
67	+	+	-	281	+	+	-	447	+	+	+	542
71	+	+	-	311	+	+	+	493	·	·	·	594
75	+	+	-	344	+	+	+	540	·	·	·	646
79	+	+	-	383	-	+	+	588	·	·	·	698
85	+	+	+	443	-	+	+	660	·	·	·	777
89	-	+	+	467	-	+	+	700	·	·	·	833
93	-	+	+	491	-	+	+	740	·	·	·	888
<b>B.</b>												
45	-	-	-	173	-	-	-	243	+	-	-	312
53	-	-	-	221	+	-	-	315	+	+	-	394
57	+	-	-	231	+	+	-	351	+	+	-	434
59	+	-	-	243	+	+	-	369	+	+	-	454
64	+	-	-	259	+	+	-	414	+	+	-	504
67	+	+	-	281	+	+	+	447	+	+	+	542
71	+	+	-	311	+	+	+	593	+	+	+	594
75	+	+	-	344	+	+	+	540	+	+	+	646
79	-	+	-	383	-	+	+	588	-	+	+	698
85	-	+	+	443	-	+	+	660	-	+	+	777
89	-	+	+	467	-	+	+	700	-	-	+	833
93	-	+	+	491	-	+	+	740	-	-	+	888

#### Laboratory experiment

Table 4a shows for the variety 'Bintje' the new cysts finish their development after 259-281, 447-493 and 434-454 degree-days with 8°C, 10°C, and 12°C as initial temperature, respectively. For the variety 'Alma' the figures are 383-443, 414-447 and 504-542 respectively (Table 4b).

#### Discussion

To compare the results from the field and microplot experiments with the laboratory experiments it is necessary to record the temperature in the

same way. As the air temperature is correlated with the soil temperature this was used to calculate the accumulated temperature. Table 5 shows this correlation for temperatures recorded at Copenhagen. Therefore approximate comparisons between the field and microplot experiments and the laboratory experiments can be made.

A linear regression analysis has been made on log (degree-days) in relation to the initial temperature (Fig. 2). The number of degree-days are calculated from the mean of the interval, where the nematodes finish their development.

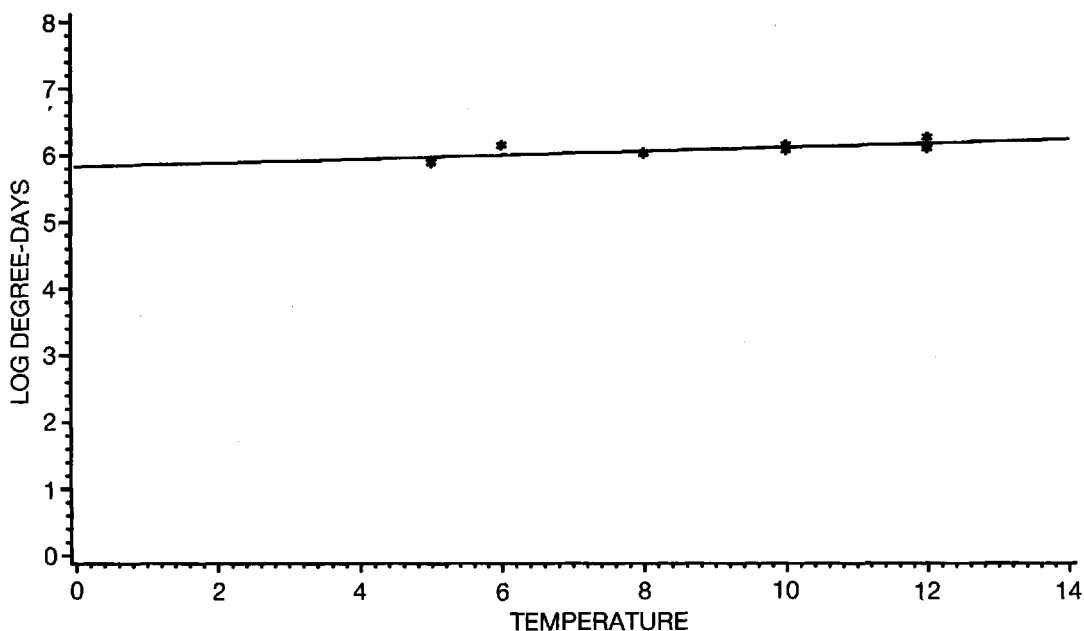


Fig. 2. Linear regression analysis on log (degree-days) in relation to initial temperature. Degree-days and temperature in °C. The regression coefficient ( $b=0.03$ ) is not significant different from zero.

*Lineær regressionsanalyse på log (graddage) i relation til begyndelsestemperatur. Graddage og temperatur i °C. Regressionskoefficienten er ikke signifikant forskellig fra 0.*

The regression coefficient ( $b=0.03$ ) is not significantly different from zero, which means it is probable that the regression line is parallel to the x-axis. Consequently the nematodes finish their development after about 440 degree-days (mean of field, microplots and laboratory experiment) corresponding to 85–90 days after early planting.

Calculations based on experiments on the life history of several species of cyst-nematodes, from various parts of the world, indicate that one gen-

eration requires about 690 degree-days, measured above 5°C (8). The present results show less degree-days (approximately 530 converted into 5°C as a basis) than were found by *Siggeirsson* and *Quigley* (8). However present results indicate the beginning of the generation time, which is less than the time needed for the whole life-cycle.

Consequently phenological control can be used if potatoes are lifted before 85–90 days after early planting.

**Table 5.** Mean temperatures (°C) recorded at Copenhagen (1974–83) at a level of 2 m above ground and a soil depth of 25 cm (5).

*Middeltemperaturer (°C) målt ved København (1974–1983) i 2 m højde og 25 cm dybde.*

	March	April	May	June	July
2.00 m above 2.00 m højde	1.9	5.1	10.6	14.6	15.8
0.25 m below 0.25 m dybde	2.2	5.5	10.0	14.3	15.8

## Literature

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