ACCURACY OF MODELS FOR PREDICTING PHENOLOGY OF BLACKHEADED FIREWORM AND IMPLICATIONS FOR IMPROVED PEST MANAGEMENT

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Blackheaded fireworm is one of the most destructive pests of cranberries in Wisconsin. When control of the pest is necessary, growers need to apply insecticides or alternative measures while susceptible life stages are present. Tools such as pheromone traps and sweep net samples can inform growers of the proper times for application, but these tools are limited. For example, sweep net samples can not indicate when eggs begin to hatch or what proportion of eggs have hatched. Events such as egg hatch, however, can be predicted with temperatures in phenology models. Models can also show how insects respond to their environment, and can indicate weaknesses we can exploit in management programs. This report is a summary of research on the phenology of blackheaded fireworm. We will discuss models for predicting phenology, the expected accuracy of the models, and how they can be used in pest management.

Life Cycle of Blackheaded Fireworm

Before the Cranberry Insect Phenology Project, we knew only the most general information about the life cycle of blackheaded fireworm. All the known information could be represented in a single diagram (Fig. 1) and summarized in a paragraph. The insect overwinters as an egg and hatches in May. Larvae are present from May until mid-June. Adults (moths or “millers”) are present about the same time the plant is flowering. Eggs laid by these insects hatch, grow into larvae and adults, and complete development by August. Usually, there are just two generations per year. Adults in August and September lay eggs that hibernate and hatch the following spring.

The development of blackheaded fireworm at different temperatures has been studied in the laboratory (see report by Kachadoorian and Mahr for the 1991 Wisconsin Cranberry School). This information has been incorporated into models that use temperature to simulate when life stages. are present in cranberry marshes. Specifically, the models predict when eggs hatch, when larvae become third instars, and when the insects become pupae. These models have been tested with field data gathered from 1989 to 1992. Only two, one for oviposition and one for hatch of summer eggs, are simple enough to calculate by hand (see report by Cockfield and Mahr for the 1991 Wisconsin Cranberry School). All others require hourly temperatures and are calculated on a computer. The details of the calculations are beyond the scope of this report.

Hatch of Eggs in the Spring

We evaluated a model that predicts hatch of eggs in the spring with data from four marshes in 1990 and one marsh in 1991 and 1992. In general, predictions were close to observed hatch in cranberry marshes (e. g. Fig. 2). After testing the predictions, we can expect the percentage hatch to occur within 6 days of the predictions 68% of the time (see standard deviations in Table 1).

Larvae of the Overwintered Generation

Newly-hatched blackheaded fireworm larvae prefer to eat new leaves, and will refuse to eat old leaves, even to the point of starvation. For example, the majority of larvae began feeding on the newest leaves of growing cuttings within 6 hours after hatching, whereas the majority of larvae on dormant cuttings failed to feed and died within a few days (Fig. 3). Of the larvae that do feed on old leaves, their growth will be retarded, perhaps by poor nutrition. Therefore, we expected the condition of cranberry leaves to affect significantly the phenology of feeding larvae.

Larvae were sampled in an unsprayed cranberry bed in Warrens. The percentage of large larvae (third, fourth, and fifth instars) was calculated. The model simulated slower growth and greater mortality of blackheaded fireworm when the plants were dormant compared to when the plants were growing. In 1990, this type of model simulated larval development better than a version without diet components (Fig. 4). Simulations by both models were similar in 1992, probably because egg hatch did not occur until mid-May, just before the plants started to grow. If egg predictions are accurate, then the larval model predictions would be expected to fall within five days of the actual events 68% of the time (Table 1). The model depended on accurate hatch predictions. Changing the dates of hatch earlier or later than observed changed the predictions by about the same amount.

The model simulated few large larvae present before bud break. After bud break began on 15 May, a rapid increase in later instars was predicted. By the first week in June in 1990, insects were predicted to enter the pupal stage (Fig 5).

The synchrony of bud break and egg hatch affected the number of larvae predicted to survive from a group of overwintered eggs. As new growth was simulated to occur earlier, such as would occur in a bed of an early variety, a greater number of larvae were predicted to survive (Fig. 6).

Pheromone Traps and Oviposition

Pheromone traps were monitored in an unsprayed bed in Warrens. During the first flight, newly-laid eggs were counted on 500 cranberry cuttings replaced every three days.

Data from pheromone traps and oviposition sampling were consistent from year to year. One example is shown in Figure 7. On the unsprayed bed, days from first catch was a good predictor of both pheromone trap catches and percentage of eggs laid. Pheromone trap catches on sprayed marshes, however, did not follow a clear pattern (Fig. 8). Likewise, oviposition in sprayed marshes may be just as variable as pheromone trap catches. Nevertheless, the data generated from the unsprayed marsh can give us some approximations. We can expect no eggs to be laid the first week, 36 % of eggs to be laid the second week, 37 % the third week, 22% the fourth week, and 4 % the fifth week after the first moth is trapped. For those marshes not treated with insecticides, the estimates will be more reliable. The oviposition calculations need to be coupled with models of hatch and larval development to be used as an aid in timing control treatments.

Hatch of Summer Generation Eggs

During three summers, moths were confined on cranberry cuttings and newly-laid eggs were collected. Hatch of the eggs was monitored and compared to model predictions. Summer generation eggs began to hatch between 2-7 days and ended within 6-15 days after oviposition (e. g. Fig. 9). The degree-day model for hatch of summer generation eggs may be as accurate as the daily temperature calculations will allow. Events in egg hatch can be expected to occur within 1.4 days of the predictions 68% of the time (Table 1).

Development of Larvae from a Cohort of Eggs

In 1989, moths were caged over cranberry plants on marshes in three different counties. Most eggs were laid within the first 24 h. The larvae hatched from the eggs were sampled and the percent third, fourth, and fifth instars were calculated. Model predictions were compared to larval samples at each marsh.

The models predicted egg hatch, then development to the third instar starting from the day eggs were laid. Models indicated the correct week when insects became third instars (e. g. Fig. 10). Actual events would be expected to occur 1.5 days from the day predicted 68% of the time (Table 1).

Larvae of the Summer Generation

Larvae were sampled in an unsprayed cranberry bed in Warrens and the percent larvae third, fourth, and fifth instar were compared to model predictions. The model predicted the correct week when larvae were molting to third instars (e. g. Fig. 11). However, accurate predictions depended on accurate dates of oviposition. Moving the oviposition dates forward or backward in time moved the predictions by about the same amount.

The models indicated a narrow window for effective insecticide applications to control blackheaded fireworm in summer (Fig. 12). Large larvae were abundant just as the plants ended flowering, or when pesticide treatments hazardous to pollinators could be applied. However, insects begin to drop into the soil and pupate around the same time, thereby potentially escaping an insecticide application. Therefore, the models confirm the need to apply insecticides just after flowering, and the need for control methods compatible with pollinators, such as biological controls.

Conclusions

Models that predict blackheaded fireworm phenology have been shown to predict egg hatch and development of larvae with little bias. We know how accurate-they have been for the past three years. We also know what information is needed for the most accurate timing of insecticide, biological, or cultural control measures. Above all, the hatch of eggs in spring determines the phenology of larvae later on. The day when plants start to grow and insects feed on new leaves determines when large larvae will be present. Finally, accurate estimates of oviposition are needed to predict the development of larvae in the summer.

Acknowledgment

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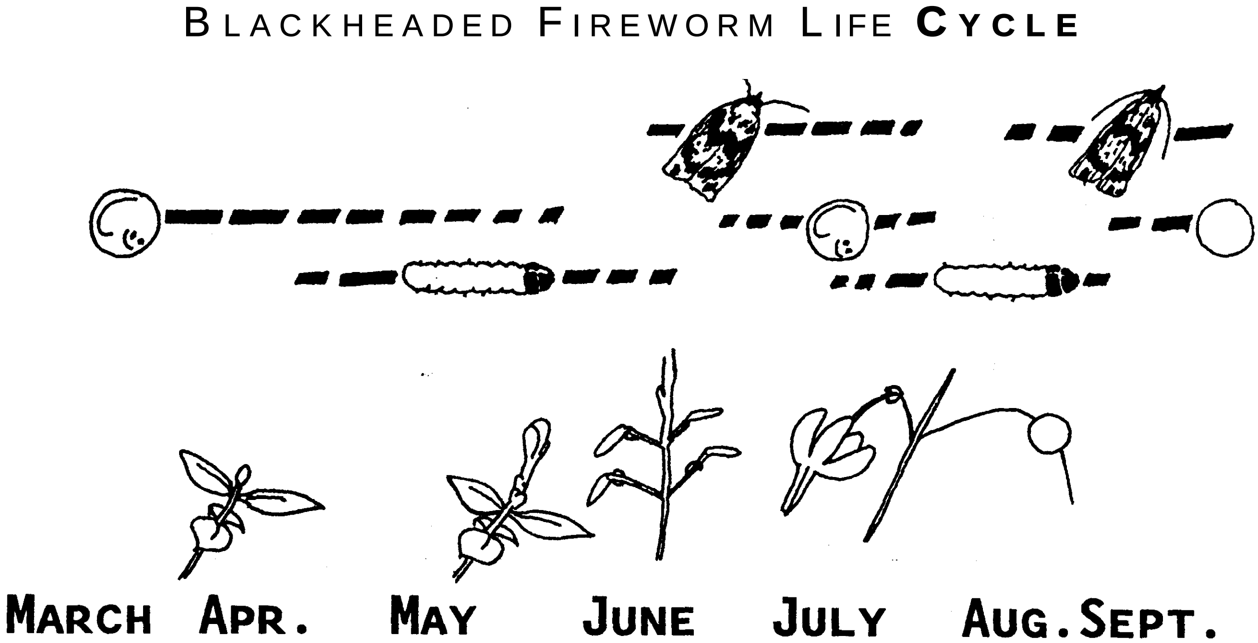

Fig. 1. Life stages of blackheaded fireworm and when they occur in a cranberry marsh. The lower drawings represent corresponding growth stages of cranberry plants, from dormancy, early shoot growth, hook stage, flowering, and formation of fruit.

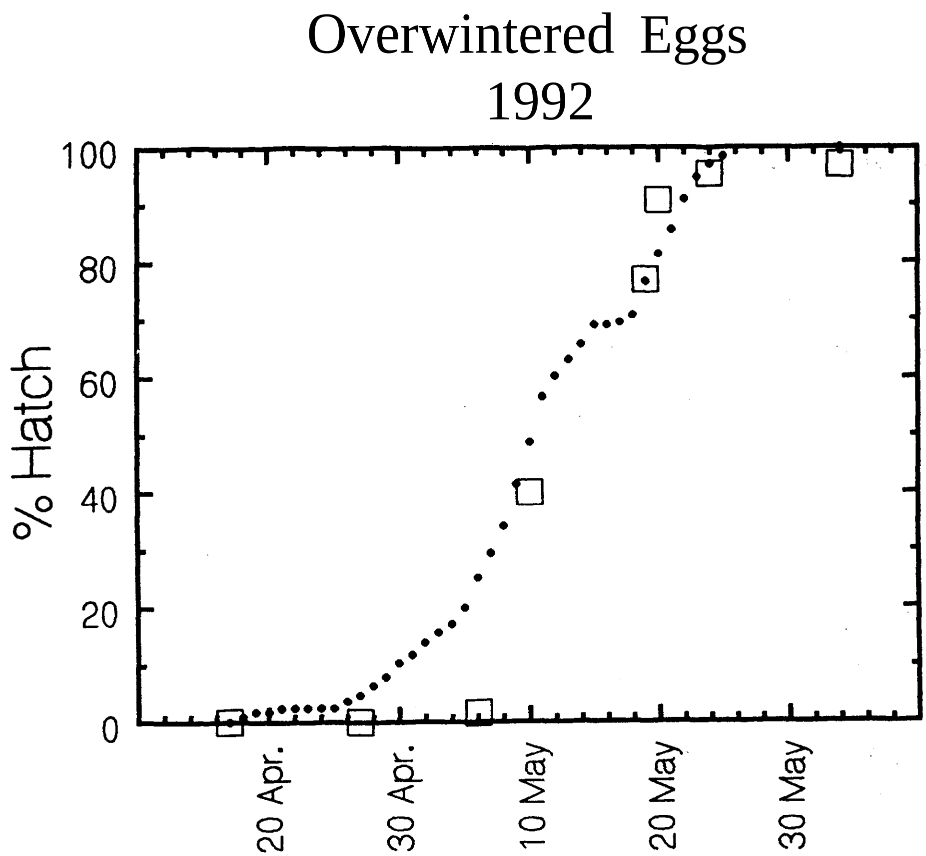

Fig. 2. Percent of viable overwintering blackheaded fireworm eggs hatched in a commercial cranberry marsh, 1992. Hatch was observed (•   ) and predicted by a computer model (•).

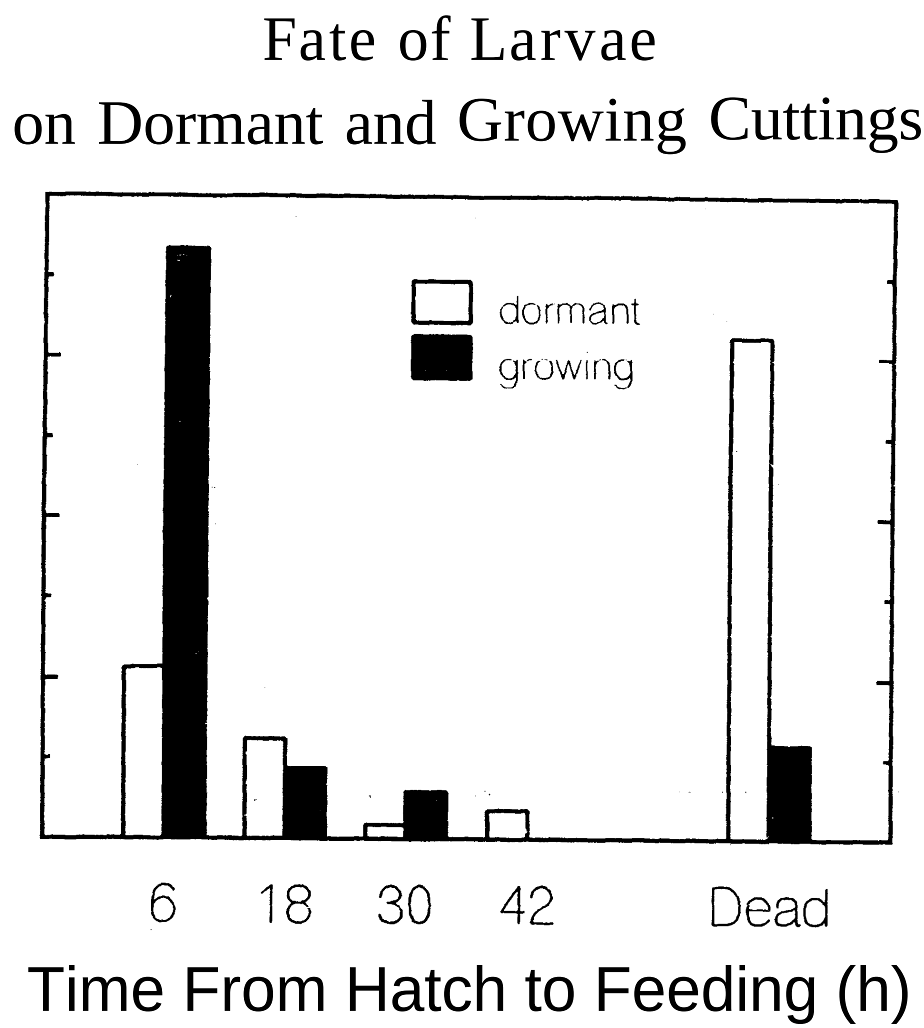

Fig. 3. The fate of newly-hatched blackheaded fireworm larvae (successful feeding or death) when confined on either dormant or growing cranberry cuttings at a cool temperature.

Spring Larvae

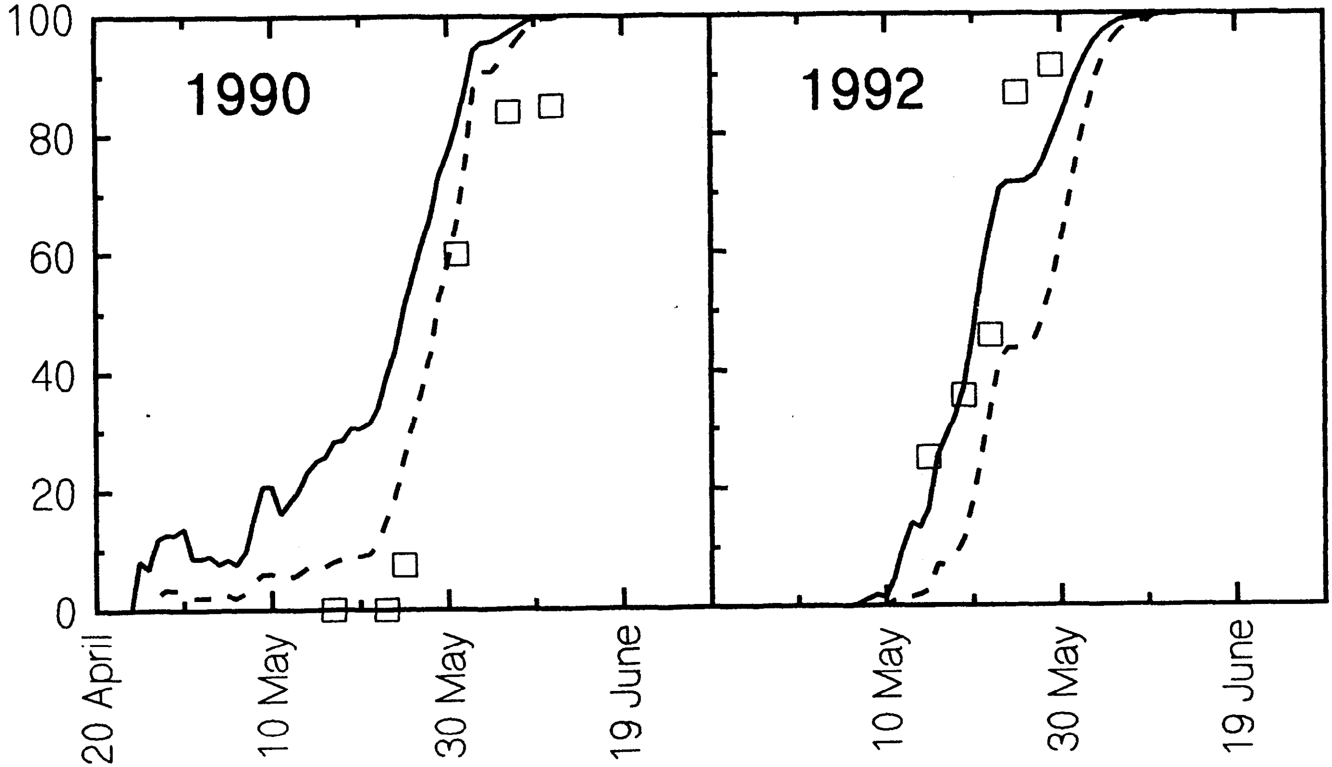

Fig. 4. Percentage of blackheaded fireworm larvae third instar or older in foliage samples from an commercial cranberry marsh, Warrens, WI. Solid lines, predictions by development model without plant phenology components. Dashed lines, predictions by model with plant phenology components. Squares are observations.

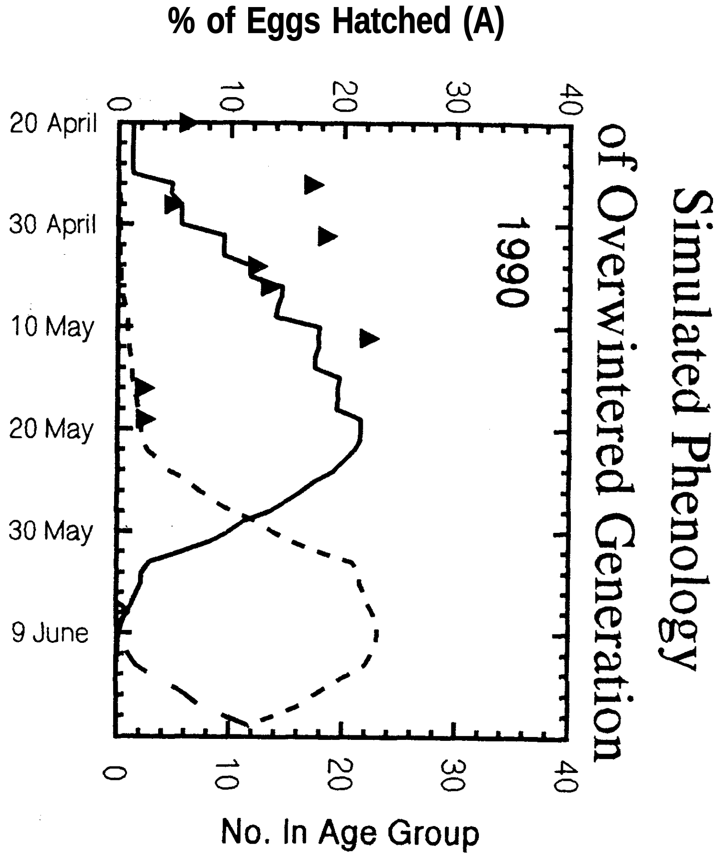

Fig. 5. (▲) Percentage of total monitored eggs hatched in a commercial cranberry marsh. (solid line) Simulation of the number of first and second instars, (small dash) third, fourth and fifth instars, and (large dash) pupae and adults developed from monitored eggs.

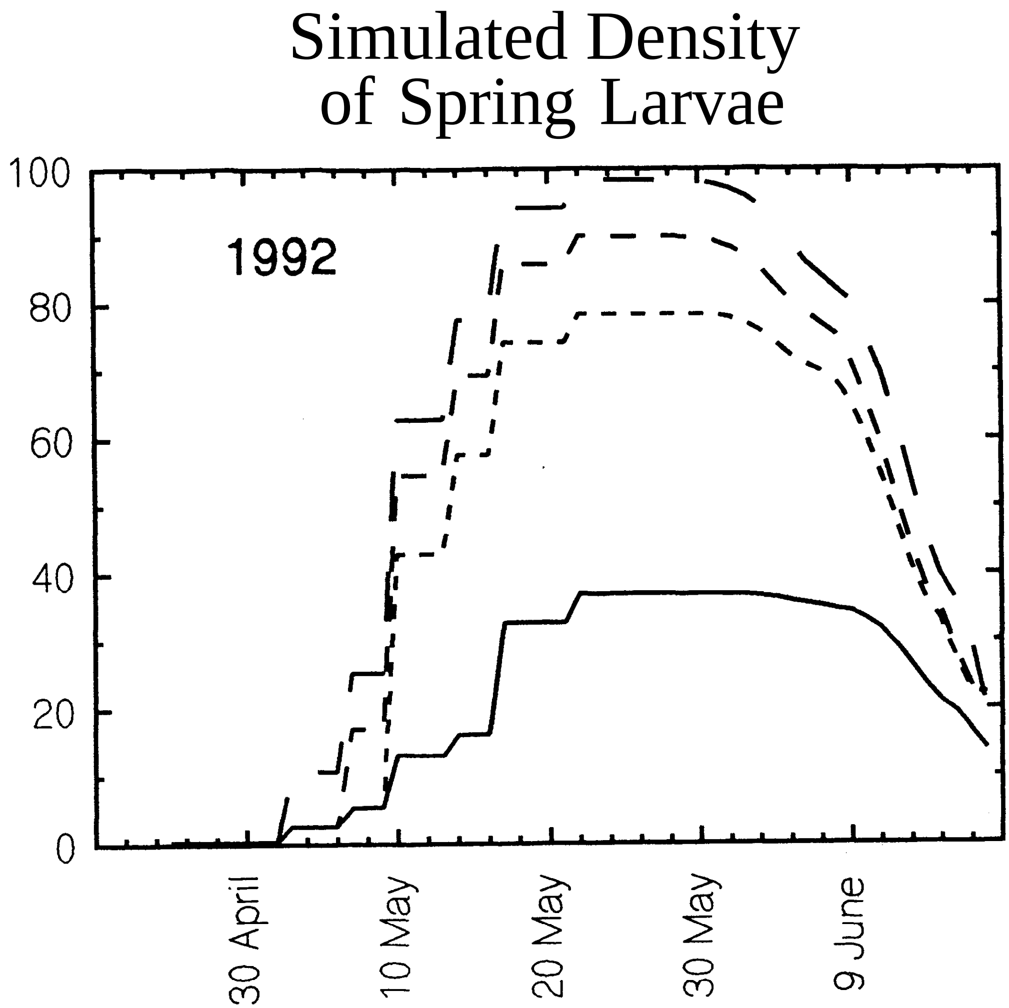

Fig. 6. Number of larvae simulated to survive from 100 hatched eggs. Simulations were based on egg hatch monitored on a marsh in 1990. (solid line) Number of larvae surviving if bud break occurred 15 May, (small dash) 10 May, (medium dash) 5 May, or (large dash) 30 April.

Pheromone Trap Catches and Oviposition

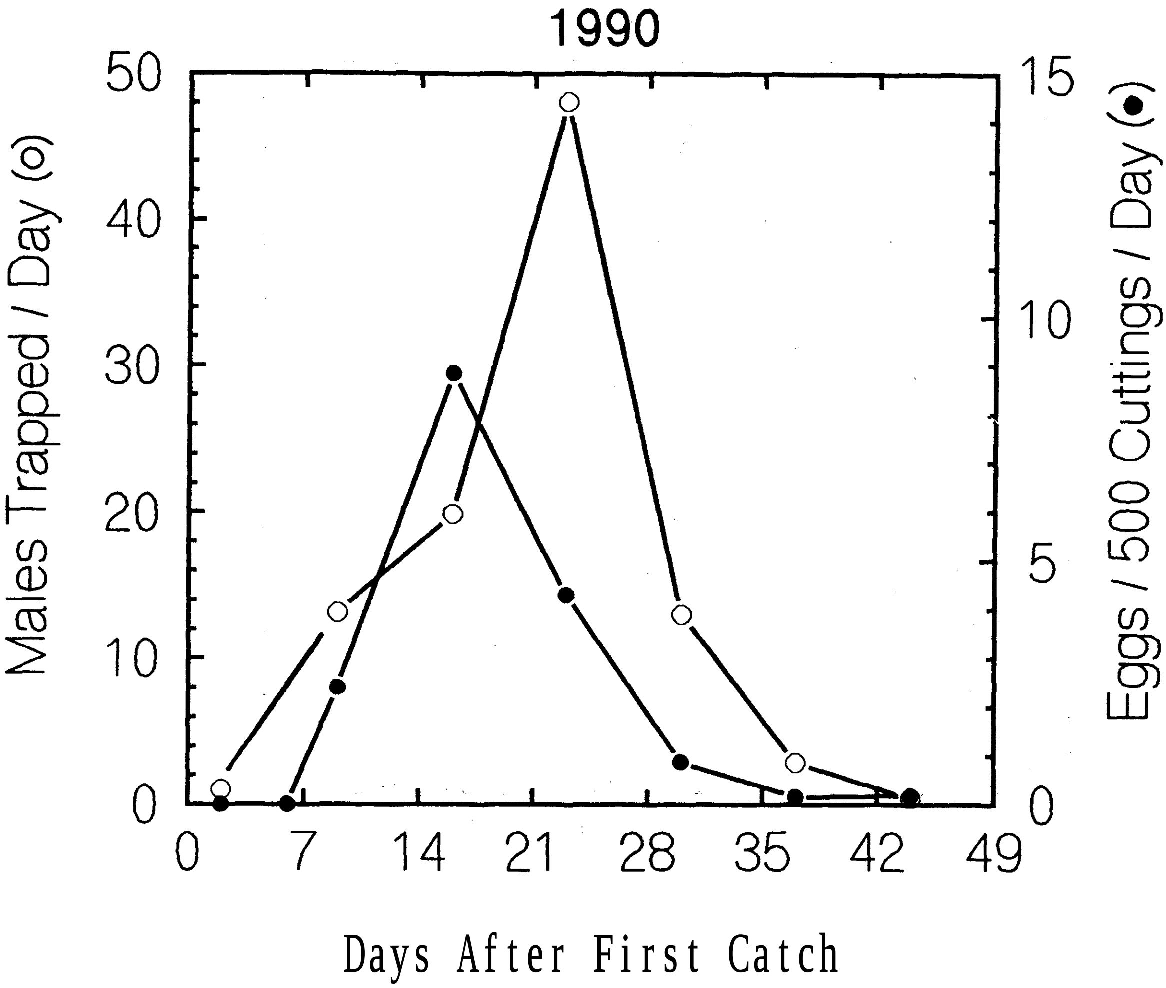

Fig. 7. Comparison of blackheaded fireworm caught in pheromone traps (o), and eggs laid on cuttings (•) in an unsprayed cranberry bed in Warrens.

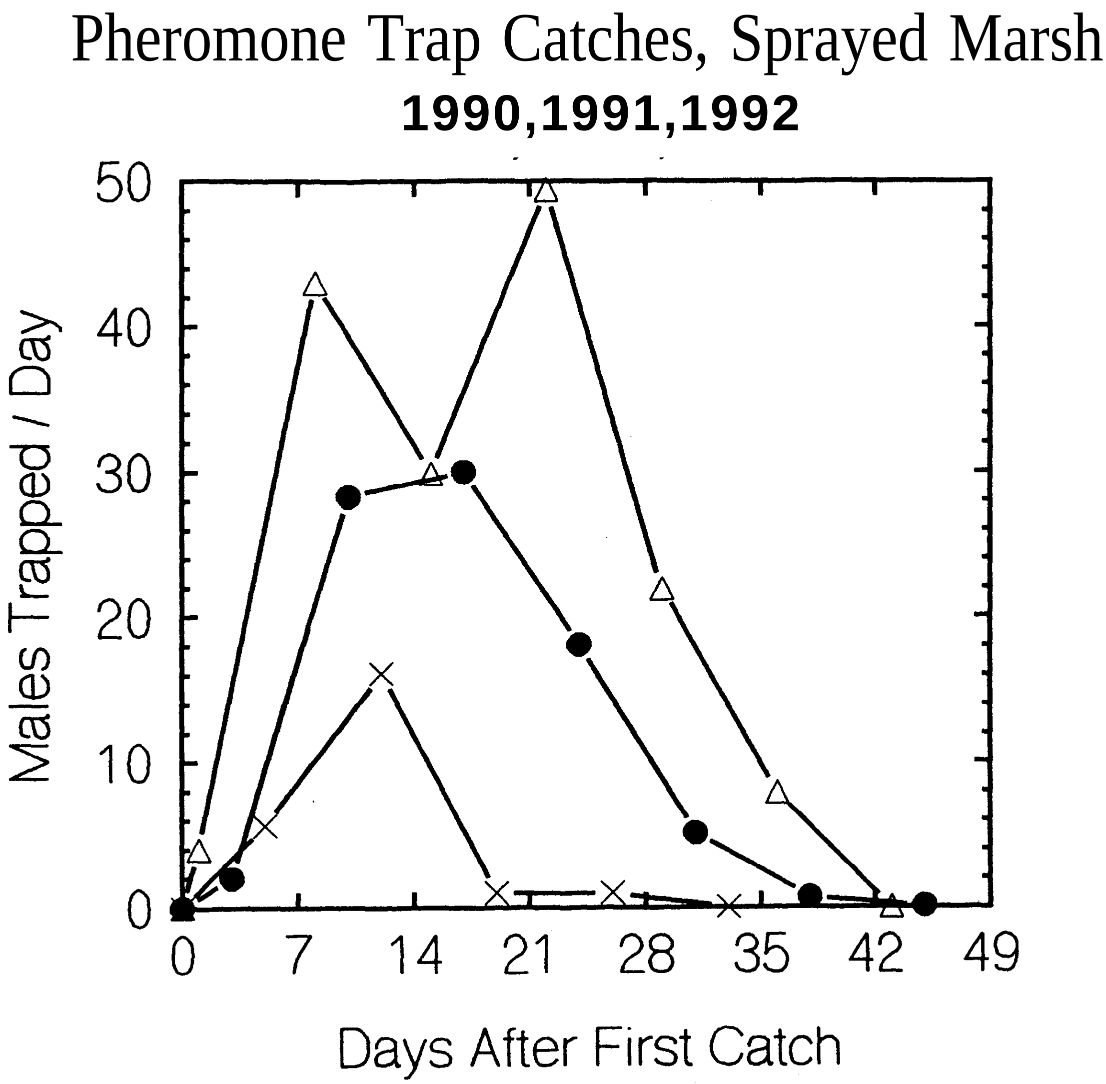

Fig. 8. Blackheaded fireworm in caught pheromone traps on cranberry bed treated with insecticides in Wisconsin Rapids, 1990 (x), 1991 (•), and 1992 (▲).

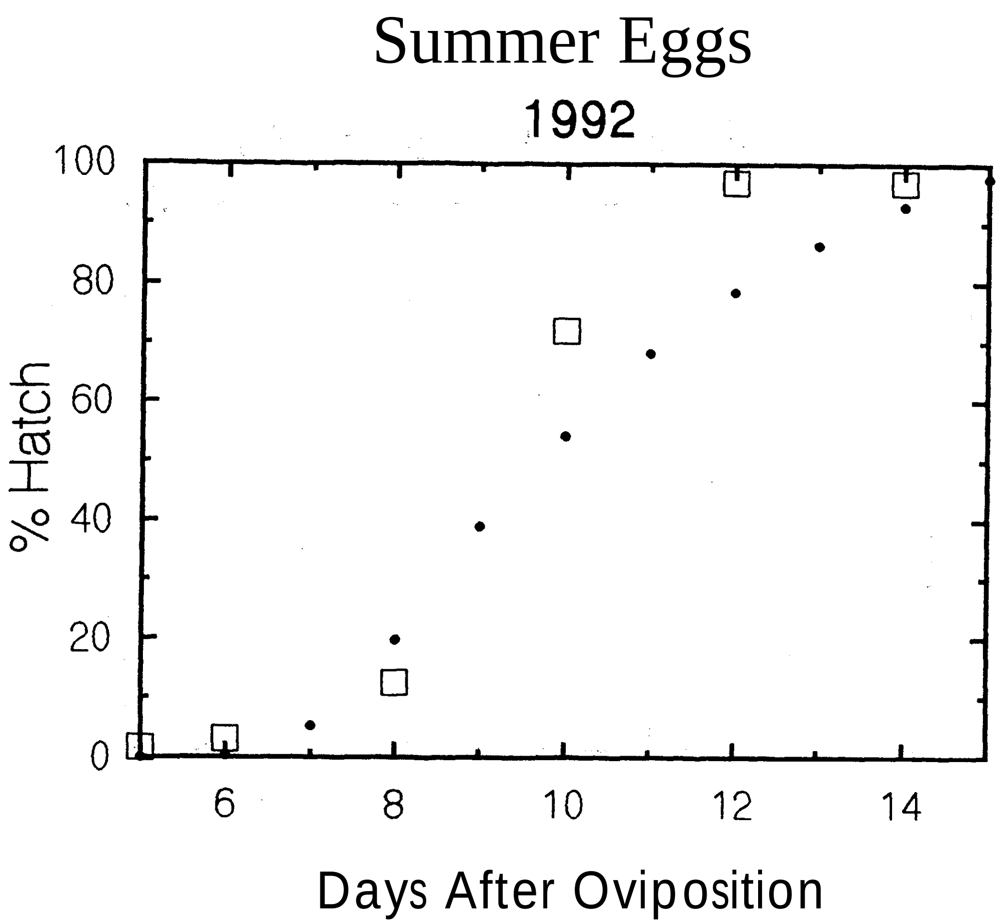

Fig. 9. Percent of viable summer generation blackheaded fireworm eggs hatched in a cranberry bed in Warrens. Hatch was observed (•) and predicted by a degree-day model (•). Data are from eggs laid 14 June 1992.

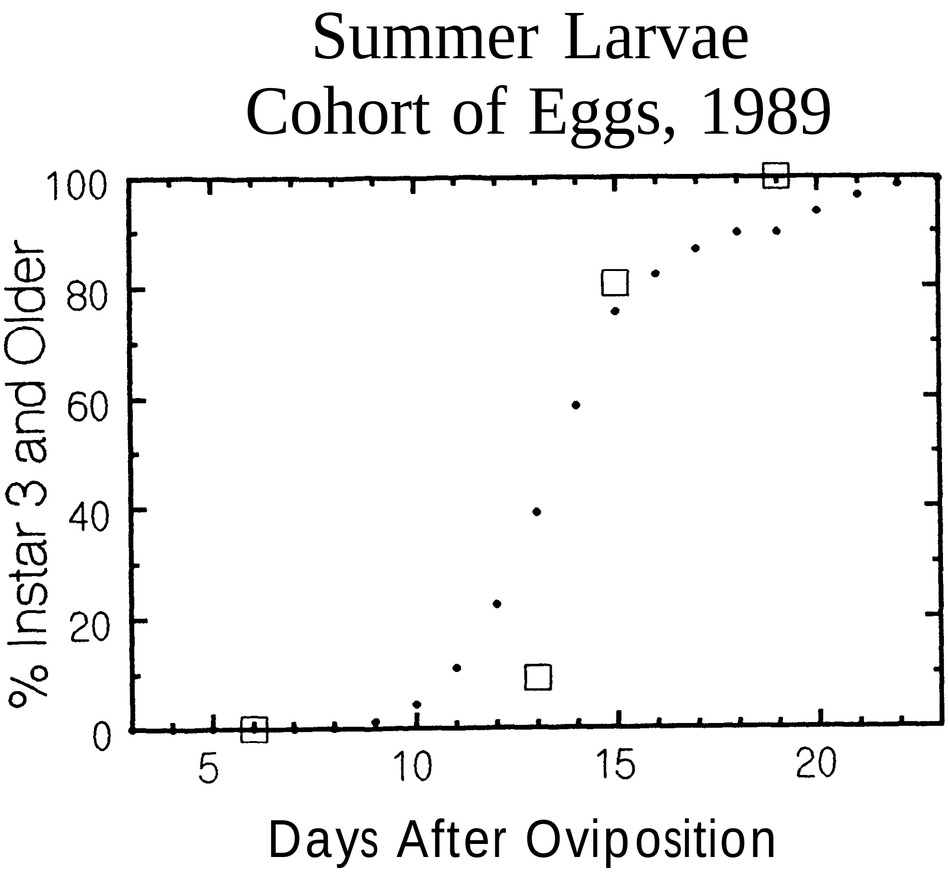

Fig. 10. Predicted (•) and observed (•) percentage of blackheaded fireworm larvae third instar or older in foliage samples. Larvae were from eggs estimated laid 6 July 1989, Wisconsin Rapids, WI.

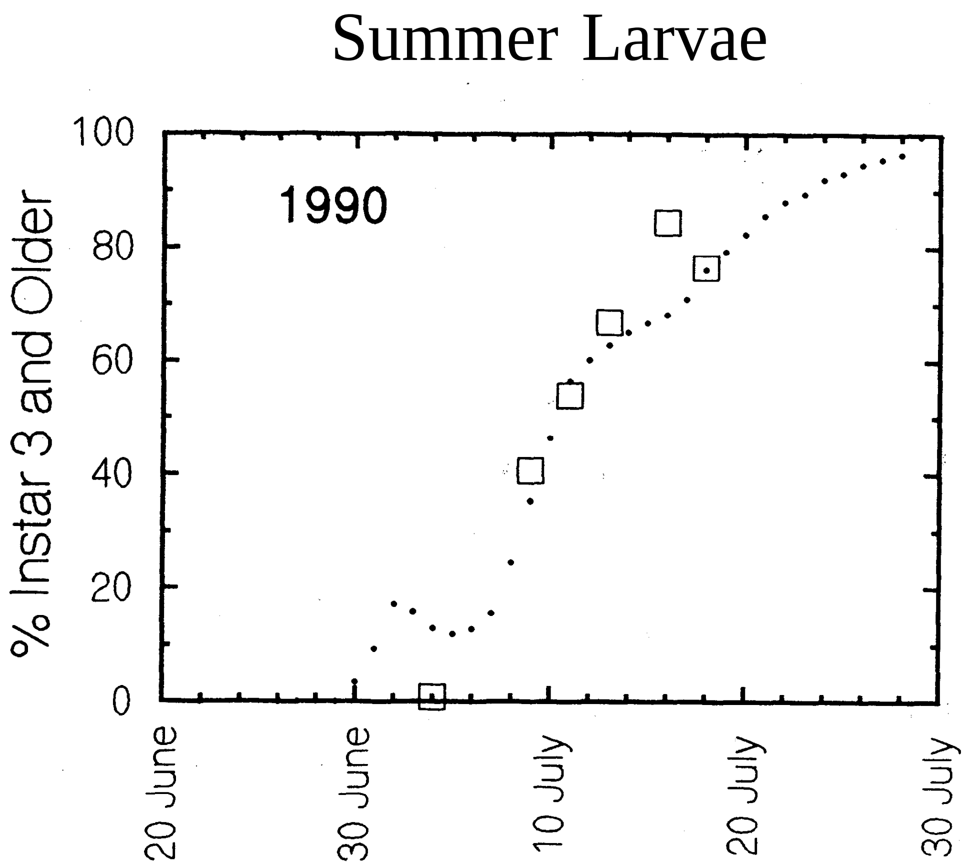

Fig. 11. Predicted (•) and observed (•) percentage of blackheaded fireworm larvae third instar or older in foliage samples from an unsprayed cranberry bed in Warrens.

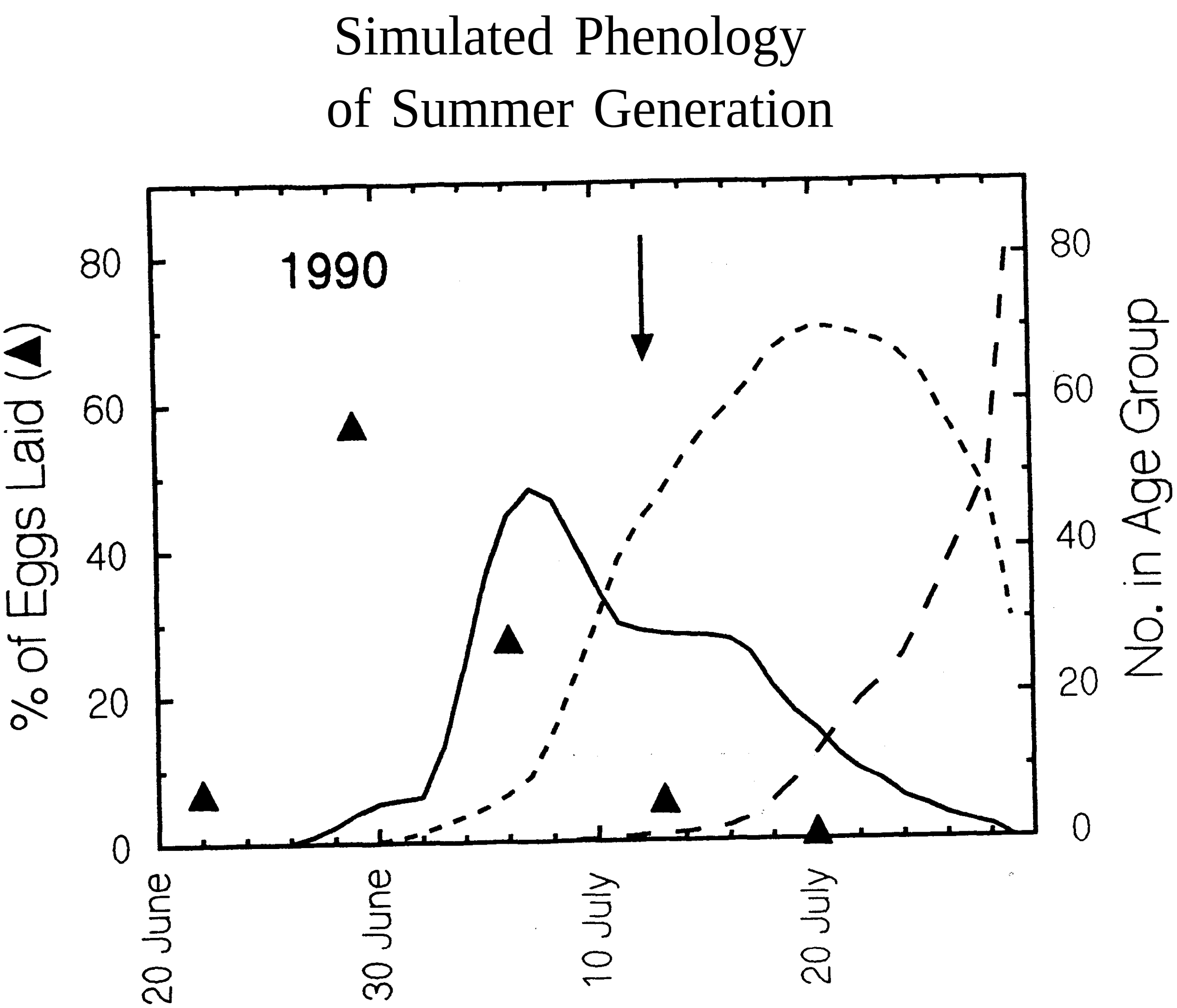

Fig. 12. Percentage of total eggs laid on sampled cuttings in an unsprayed cranberry bed in Warrens (▲). The number of first and second instars (solid line), third, fourth and fifth instars (small dash), and pupae and adults (large dash) hatched from 100 eggs were simulated from the egg hatch data.

Table 1. Accuracy of phenology models for predicting hatch of eggs and development of larvae of blackheaded fireworm

	Difference between predictions and observations (days)		
Event predicted	No. of trials	Mean	Standard Deviation
Spring egg hatch	6	+0.8	5.5
Summer egg hatch	6	-0.7	1.4
Cohort of eggs to 3rd instar	3	+0.3	1.5
Spring larvae to 3rd instar	2	+2.5	4.9
Summer larvae to 3rd instar	3	+1.0	3.6