Integrated control of insect pests in the Netherlands. Pudoc, Wageningen, 1980.

10.2 Epidemiology of the cereal aphid, Sitobion avenae

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In the past decennium, cereal aphids became a serious problem to wheat growing in the Netherlands. Three species are often numerous, one of them, *Sitobion avenae*, was considered the most serious pest and was studied in more detail. This species can rapidly increase in the few weeks between the onset of flowering and the milky-ripe stage. It feeds mainly on the ear. It damages not only by sucking nutrients from the plant but it also produces large amounts of honey dew that disturb the physiology of the plant and stimulate the growth of saprophytic and pathogenic fungi.

The explosive character of population growth makes forecasting difficult. Therefore growers tend to spray their fields preventively with pirimicarb or organopohsphorus compounds early in the flowering period. In view of the vast area under wheat, this means a considerable increase in the use of environmentally hazardous toxicants.

The aim of this study was to develop simulation models that can help to explain population development and that can be used for forecasting over periods of 3-5 weeks (Rabbinge et al., 1979). Possibly these models can pave the way for development of simpler rules for prognosis and of a reliable crop protection system. Moreover they may help to explain population development and guide research to the more significant relationships between aphids, their host plants and the natural enemies. The study is based on analysis of physiological and ecological phenomena at the individual level. An existing model describing the growth of wheat is simplified and coupled to the aphid population growth model to calculate the effect of the aphids on the plant making use of detailed studies on the aphid - host plant relations (Vereijken, 1979).

MODEL OUTPUT

Figure 1 shows output from the population model in comparison with field observations in 1976. The correspondence seems reasonable. The period of rapid growth as well as the peak are well described as confirmed by simulations of the epidemics of 1975 and 1977. Somewhat less correspondence exists for the collapse of the population. At that phase, mortality by predation and *Entomophthora* spp. seems important as well as emigration of alates. The action of *Entomophthora* spp. is not incorporated in the model because of lack of experimental data.

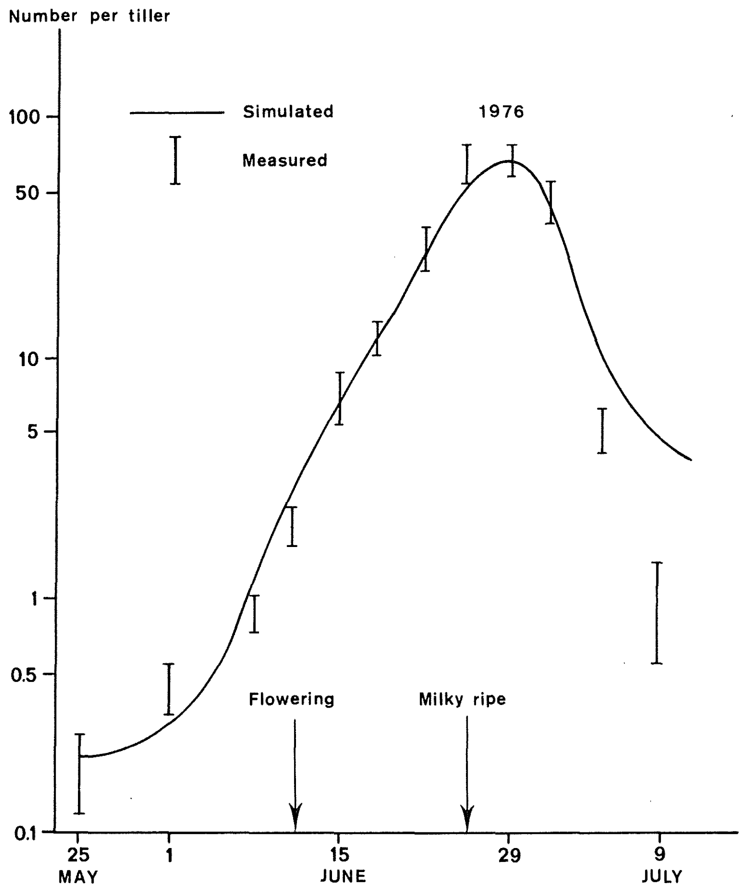

Fig. 1. Simulated and counted total number of *S. avenae* in 1976. The control numbers are given in terms of 95% confidence intervals.

AGE-DISTRIBUTION

From field observations, we may deduce that alates immigrate until around flowering of wheat. Afterwards, the number of immigrated alates on the plants no longer increases. As the offspring of these alates consists of apterae, these constitute the main driving force of population growth. Their number largely explains future growth. The offspring of apterae are mainly alates that are assumed to emigrate. Simulation with the above assumptions on immigration and emigration incorporated in the model gives a reasonable correspondence between simulated and observed age distribution as expressed by the L_4 instar (Fig. 2). The model includes parameters for development and reproduction from literature data and laboratory studies. The correspondence indicates that our laboratory data on development and reproduction suffice to understand the population growth in the field.

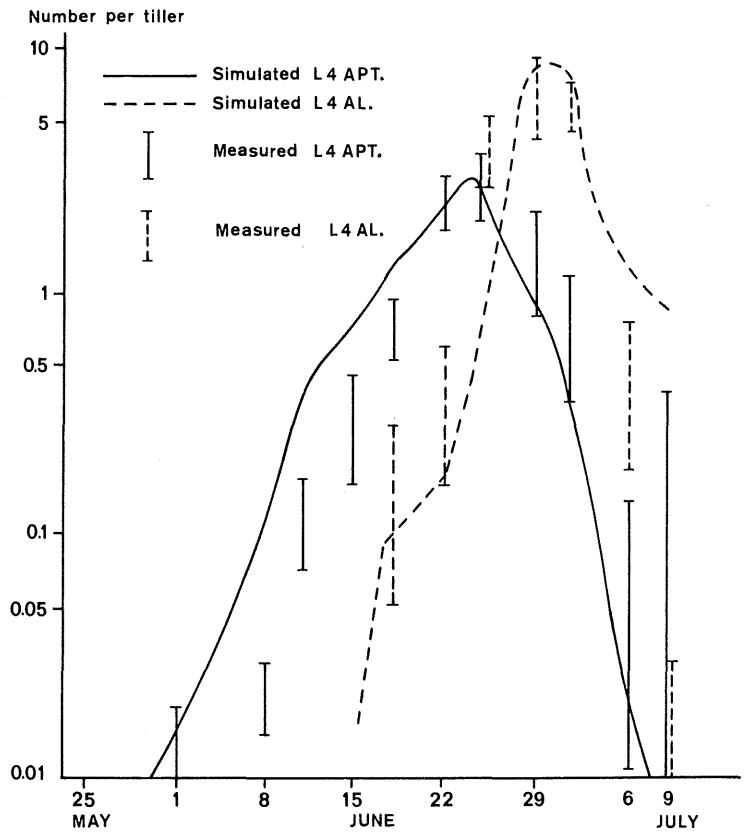

Fig. 2. Simulated and counted number of alate and apterous L_4. The counted numbers are given in terms of 95% confidence intervals (Figure from Neth. J. Pl. Path.).

SENSITIVITY ANALYSIS

The modelling effort may help to pin-point black spots in our knowledge and to evaluate the relative significance for the population dynamics of different phenomena. To determine the contribution of different processes, sensitivity was analysed. The computer model was run with some of the relations changed or with subprocesses omitted and replaced by simple algorithms. This sensitivity analysis gives the following results.

Immigration

Ignoring immigration in the simulation after the end of May had little effect on ultimate growth in 1976 but a distinct one in 1975 and 1977. In 1976 immigration before the end of May determined later population level.

Emigration

The offspring of alates are generally apterous like those of non-crowded apterae but the latter situation rarely occurs in the epidemic. Crowding L_1 causes immediate wing development in some specimens. Crowding of L_4 and apterous adults results in many alate offspring. The fate of these alates is vital for understanding the epidemic. Do they emigrate or do they stay in the field and reproduce? Field observations indicate that most of them emigrate but some may reproduce. No correlation was found between the number of alates swarming above the field after the middle of June and the number in the field on the plants. No increase in the number of L_1 was found in that period. Moreover the number of apterae decreased in contradiction to an important role of alates remaining in the field and reproducing, as these alates should have mainly apterous offspring.

In the model, we assumed that in this phase no immigration occurred and that alates were lost from the system. As the curves of simulation and field observations reasonably coincide, this supports our hypothesis on alate behaviour.

Predation

With emigration alone, the population collapse was not completely predicted. The calculations showed the necessity of an important mortality factor. Besides *Entomophthora* spp., predators like Syrphids were important. In the final phase of the epidemic, such factors that eliminate apterous adults are vital to the collapse. Predation on larvae is less important then, as most of these develop into emigrating alates. The role of parasites too has to be considered with this aspect in mind. When they prefer to attack only younger stages, they are unlikely to contribute much to population collapse.

The model calculations revealed that the place of the breaking point in the functional response curve for predator's predation rate on prey density was essential in describing its effect.

ABIOTIC FACTORS

In the simulation model, a decrease of temperature delayed population growth but the population finally reached a higher level, perhaps because of differences in response to temperature of growth rates of plant an aphid.

Not incorporated in the model were the parasites and diseases. The aphidiid parasites *Aphidius uzbekistanicus* resembling *A. ervi*, *A. picipes* and *Praon volucre* were found regularly.

Each year, another species predominated. Only in 1977, a clear effect of parasites was found when they were probably responsible for a 60% decrease in the number of apterae during the growth phase of the epidemic. In the final phase most aphidiids are attacked by hyperparasites. In 1977, a very high percentage of aphids was attacked by *Entomophthora* spp. It was not incorporated in the model as little was known of the biology.

POPULATION COUNTS

In field work, all larval stages, apterae, alates, mummified aphids, predators and aphids attacked by *Entomophthora* spp. were counted. We tried to obtain an accuracy level of $S(\bar{x})/\bar{x} < 0.1$ for the total number of living aphids. So sample size was constantly changing. As a rule, the number of samples decreases when the number of aphids increases. With a doubling time of about three days, the population grows by some 25% per day. So in order to keep the variance low, all counts have to be completed within a day.

Weather strongly affects variance. When the weather is bad, aphids become more evenly distributed over the plants. It is yet unclear how this factor will affect the future growth rate of the population. In the notably bad summer of 1978, this more even distribution was clearly observed.

PROSPECTS

Knowledge about the processes in the system is lacking. As more experimental data become available for use in the model, our confidence can increase. Of much importance is the help of the model in integration of fragmentary knowledge and guidance in experiments.

The development of a forecasting model forms just one part of the warning system. More knowledge is needed of the effect of the aphids on their host plant and of host on aphid to reach a reliable management system. The results of a combined population model and plant model are encouraging (Rabbinge & Vereijken, 1979) but still much more research is needed to make these models applicable in practice.

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