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Influence of Temperature on Development of *Zygogramma suturalis* - An Insect Used to Control *Ambrosia artemisiifolia*

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Abstract

In 1984 the beetle *Zygogramma suturalis* was first introduced from the U.S. to Yugoslavia for biological control of common ragweed (*Ambrosia artemisiifolia*). The biology and ecology of this insect were investigated extensively, and some results are presented here. At a range of six constant temperatures between 16 and 27°C egg development took from 3 to 18 d. The temperature threshold was 12.5°C and the thermal constant 56.8°C. At variable daily temperatures development lasted 6.04 d with a sum of effective temperatures (SET) 57.9°C. At a range of 6 constant temperatures from 19 to 27°C larval development took 7 to 34 d, the temperature threshold was demonstrated 14.8°C and the thermal constant 111.1°C. At variable daily temperatures the development took an average of 16.7 d with a mean SET of 106.8°C. Fourth instar larvae enter the soil and pass through prepupal and pupal stages, and the callow adult remains in the soil until it hardens. At a range of constant temperatures from 19 to 27°C development in the soil took 11 to 29 d; i.e. 4 to 12 for the callow adult. At variable daily temperatures development in the soil averaged 19.4 d. The development time from egg to adult at a range of six constant temperatures from 19 to 27°C took from 25 to 59 d. At variable daily temperatures development averaged 42.1 d. Considering the dependence of *Z. suturalis* to temperature, an acclimatization in Middle and South Europe is possible.

Introduction

Autochthonous insect enemies of common ragweed (*Ambrosia artemisiifolia* L.; Asteraceae) in Yugoslavia are not suitable for the biological control of this weed (Igrc *et al.* 1984, Maceljski and Igrc 1988). Therefore, *Zygogramma suturalis* F. (Coleoptera, Chrysomelidae) a host-specific leaf feeding beetle from the United States was introduced to Yugoslavia in 1984 (Igrc 1987).

In 1978 this beetle was released in the USSR (Kovalev and Medvedev 1983). Several authors (Kovalev and Cerkasin 1983, Kovalev *et al.* 1983, Kovalev and Vecernin 1985, Reznik *et al.* 1986, and Kuznjecov *et al.* 1987) reported total acclimatization, massive propagation in the field and excellent control of common ragweed.

After its introduction in Yugoslavia, *Z. suturalis* was reared under laboratory conditions, and its biology and ecology were investigated. Because temperature is a decisive factor in acclimatization and development of every insect, the influence of temperature on the development of every stage of *Z. suturalis* was investigated in depth.

Piper (1975) stated that at room temperature of 20 to 25°C egg development lasts 5 d, larval development 15 to 18 d, the prepupal stage 7 to 8 d, the pupal stage 6 to 9 d, and hardening of the adult 2 to 3 d, thus completing development in the soil in 15 to 20 d. Piper (1975) observed that 35 to 43 d are needed for complete development at room temperature.

Kovalev and Medvedev (1983) report that egg development lasts 5 to 6 d at 25°C, and 10 to 12 d under natural conditions. Kovalev and Cerkasin (1983) report that at a temperature threshold of 11.5°C eggs need 75°C to develop, larvae 190°C, the prepupal stage 70°C, pupal

stage 90°C and the whole development 410 to 450°C (avg. 425°C). According to Kovalev and Vecernin (1983), larval development lasts 28 d at 18.5°C.

Methods and Materials

The effect of temperature was tested at constant and variable temperatures. Constant temperatures were tested in the range from 15 to 27°C, with RH of 65 to 75%. The effect of variable daily temperatures was investigated in the laboratory and in an unheated glasshouse.

The results obtained at constant temperatures were calculated using Blunck's equation 1 (Blunck 1923, Bodenheimer 1927):

$$t\,(T - c) = C$$

where t = duration of development; T = temperature; c = temperature threshold; and C = the thermal constant. The sum of effective temperature (SET) needed for the development at variable temperatures was calculated using the temperature threshold established at constant temperature.

For larval development, potted young ragweed plants were used as food. The duration of the life cycle was obtained by observing the development of every individual.

Results and Discussion

Egg Development

At constant temperatures 544, eggs were used in the trials. In Blunck's equation the values obtained at 19 and 25°C were used. The temperature threshold for the development of eggs is 12.5°C, and the thermal constant 56.8°C (Fig. 1).

In trials at variable daily temperatures, 907 eggs of the first generation and 1132 eggs of the second generation were used. Average duration of egg development was 6.04 d (range 3 to 13 d). The average SET needed for development for both generations was 57.9°C (Fig. 2).

No significant differences between the development of eggs of the first and second generations were observed. Also, the results of our trials at variable temperatures were not significantly different from the results obtained at constant temperatures.

Larval Development

The development of 375 larvae was observed at several constant temperatures. The data obtained at 20 and 25°C were used in Blunck's equation (Fig. 3). The temperature threshold for larval development was 14.8°C, and the thermal constant 111.1°C. Therefore, the thermal threshold for larval development is much (2.3°C) higher than that for eggs.

To check the calculated threshold, freshly-eclosed larvae were held at 15°C. They were able to develop only to the second instar. From 20 larvae already in the fourth instar only nine were able to enter the soil at 15°C and they did not transform into adults.

In trials at variable daily temperatures in the laboratory, development of the first generation (724 larvae) lasted an average of 15.1 d with a mean SET of 115.9°C (range 7 to 57 d and 43.9 to 454.4°C SETs; Fig. 4). In the glasshouse, larval development of the first generation (75 larvae) lasted an average of 24.4 d with a mean SET of 68.8°C (range 11 to 55 d and 23.7 to 220.9°C SETs). Development of the second generation (938 larvae) averaged 17.6 d with a mean SET of 99.3°C (range 8 to 51 d and 23.9 to 273.1°C SETs).

Mean development time of 1,737 larvae was 16.7 d with a mean SET of 106.8°C. The range of temperature in the laboratory during the development of the first generation was smaller,

therefore the SET correspond better to the thermal constant. The differences between the SET at variable temperature and the thermal constant would have been smaller if the SET had been calculated in degree/hours and not in degree/days.

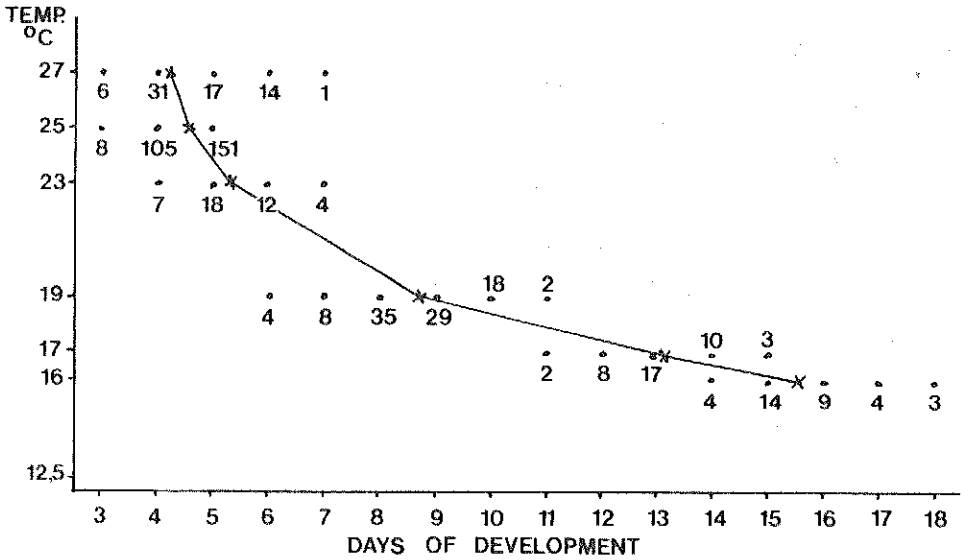

Figure 1. The influence of constant temperature on duration of development of eggs of *Zygogramma suturalis* F.

Development in the Soil

Larvae enter the soil to pupate, first building a pupal chamber in which they pass a prepupal stage. After the pupal stage, the callow adult remains in the soil until it hardens. Since the effect of air temperature is indirect and is influencing differently each of these three processes, Blunck's equation was not used. The SETs were calculated only as an orientation, using the larval threshold of 14.8°C as a hypothetical temperature threshold for development occurring in the soil. Results of constant temperature trials with 159 individuals are shown in Table 1.

Table 1. Duration of the processes in the soil and needed SET at constant temperature

Temp.	Duration (d) of stages			Total days		SET °C [1]	
(°C)	Prepupal	Pupal	Adult	Range	Average	Pupal stage	Total stay in the soil
19	8-12	11-16	2-4	21-29	24.5 ± 0.75	46.2-67.2	102.9
20	7-12	10-14	2-3	18-26	21.3 ± 0.77	52.0-72.8	110.8
20.5	7-12	8-10	2-3	17-22	19.5 ± 0.53	45.6-62.0	111.1
23	6- 7	6- 8	2	14-17	16.5 ± 0.77	49.2-59.6	135.3
25	5- 8	5- 9	1-2	11-19	15.4 ± 0.55	51.8-91.8	157.1
27	4- 6	5- 6	1-2	11-13	12.5 ± 0.57	61.0-73.2	152.5

[1] Hypothetical temperature threshold 14.8°C.

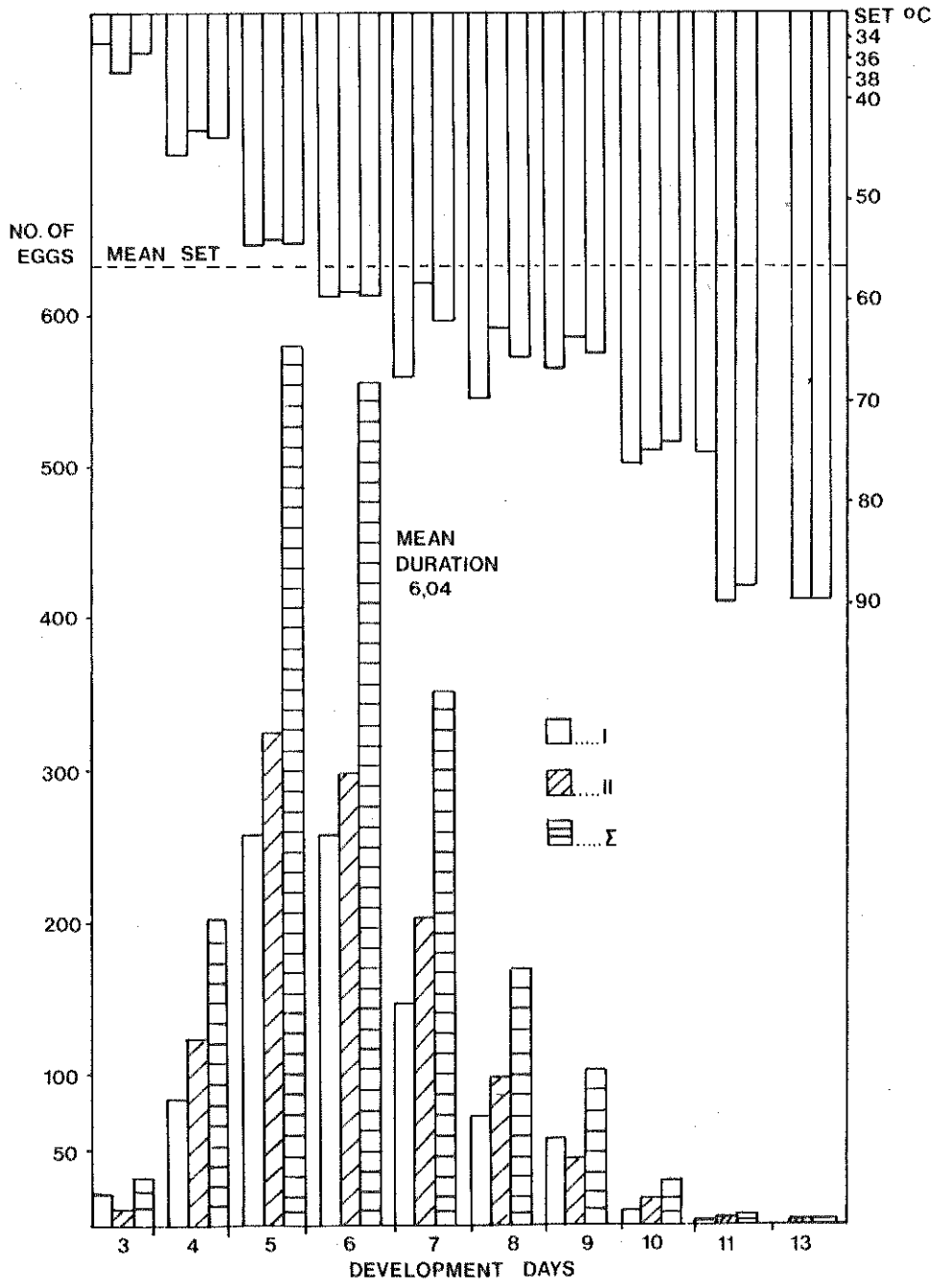

Figure 2. Duration of the development of eggs at variable temperature with corresponding sums of effective temperatures (SET) (I and II gen. and Σ).

In trials at variable temperatures in the laboratory, development in the soil of the first generation (152 individuals) lasted an average of 17.3 d at a mean SET of 129.5°C (range 11

to 31 d and 50.6 to 267.2°C SETs). In the glasshouse the development of 47 individuals lasted an average of 16.3 d with a mean SET of 127.7°C (range 11 to 34 d and 54.8 to 194.2°C SETs). Development of the second generation (530 individuals) lasted an average of 20.3 d with a mean SET of 63.6°C (range 11 to 34 d and 30.8 to 118.4°C SETs; Fig. 5).

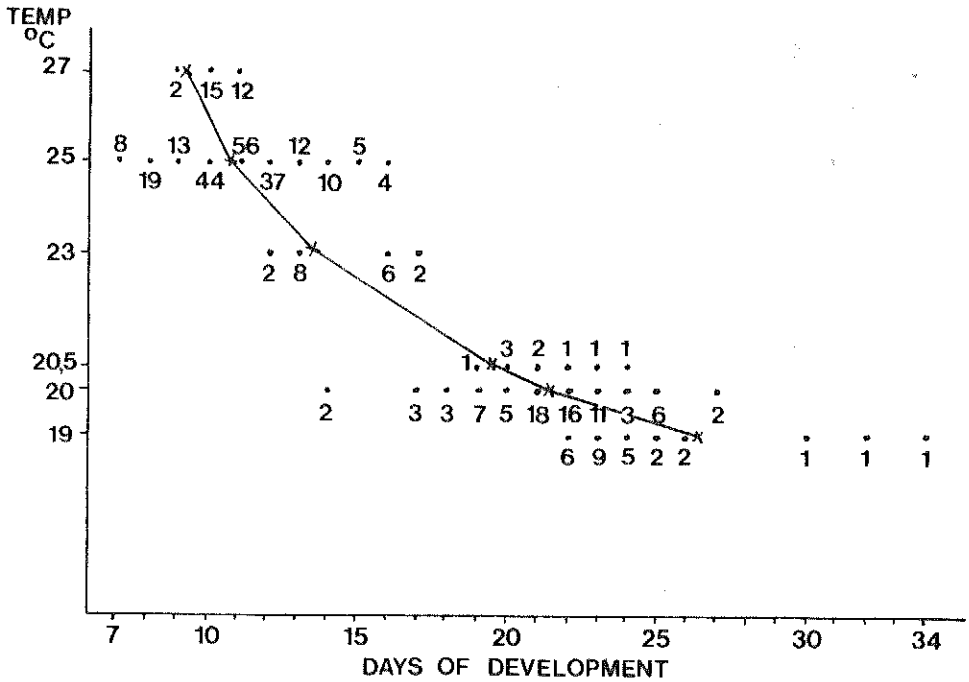

Figure 3. The influence of constant temperature on the duration of larval development of *Zygogramma suturalis* F.

The period in the soil of 729 individuals tested averaged 19.4 d with a hypothetical SET of 81.6°C. The discrepancies in the SETs are understandable because they were calculated using the same hypothetical larval threshold for the three different soil processes.

Egg-to-adult Development

A total of 155 individuals were tested at constant temperatures (Table 2). Again SET were calculated using the highest threshold (i.e., for the larval development) as a hypothetical threshold.

In trials at variable temperatures in the laboratory the development time (egg to adult) of the first generation (155 individuals) averaged 34 d with a mean SET of 314°C (range 26 to 55 d and 244.9 to 451.9°C SETs). In the glasshouse the development time of the first generation (50 individuals) averaged 47.3 d with a mean SET of 239.4°C (range 37 to 80 d and 126.6 to 373.7°C SETs). The development of the second generation (563 individuals) took an average of 43.9 d with a mean SET of 237.1°C (range 26 to 81 d and 115.9 to 338.7°C SETs; Fig. 6).

All together, the mean development time (egg to adult) of 768 individuals was 42.1 d with a mean SET of 252.9°C.

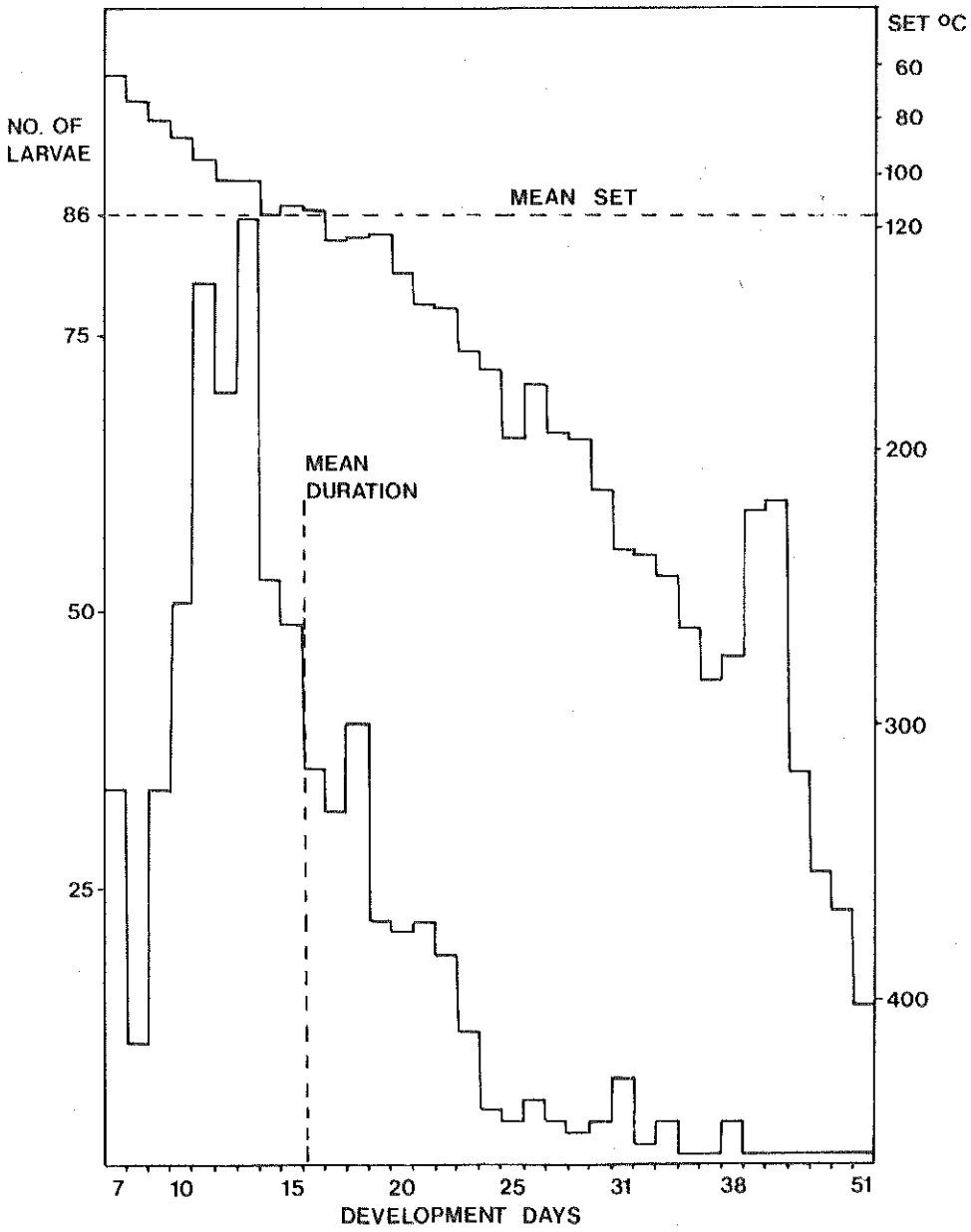

Fig. 4. Duration of larval development of *Zygogramma suturalis* F. at variable temperature with corresponding sums of effective temperatures (SET) (I gen. laboratory).

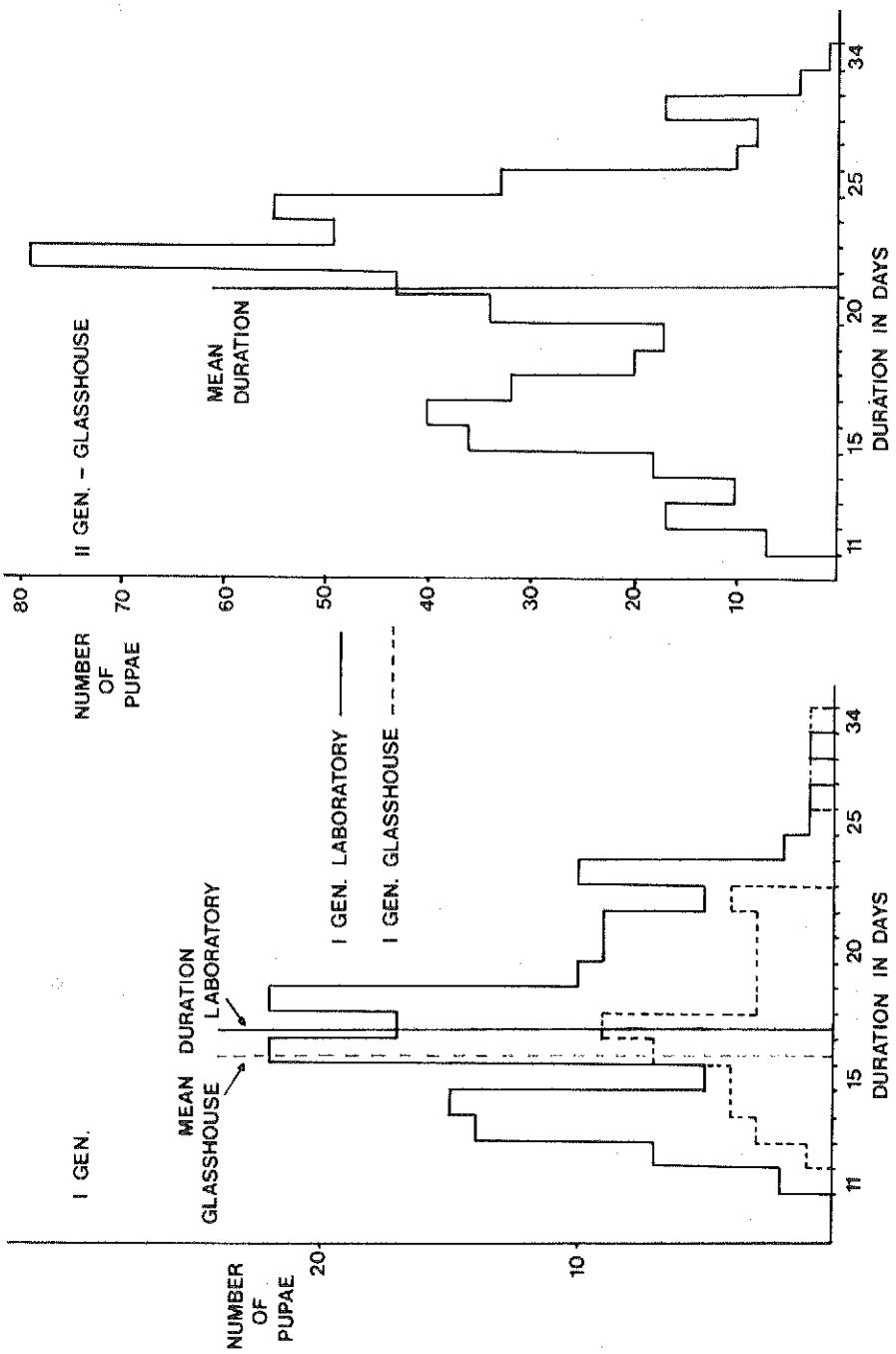

Figure 5. Duration of development of *Zygogramma suturalis* F. in soil.

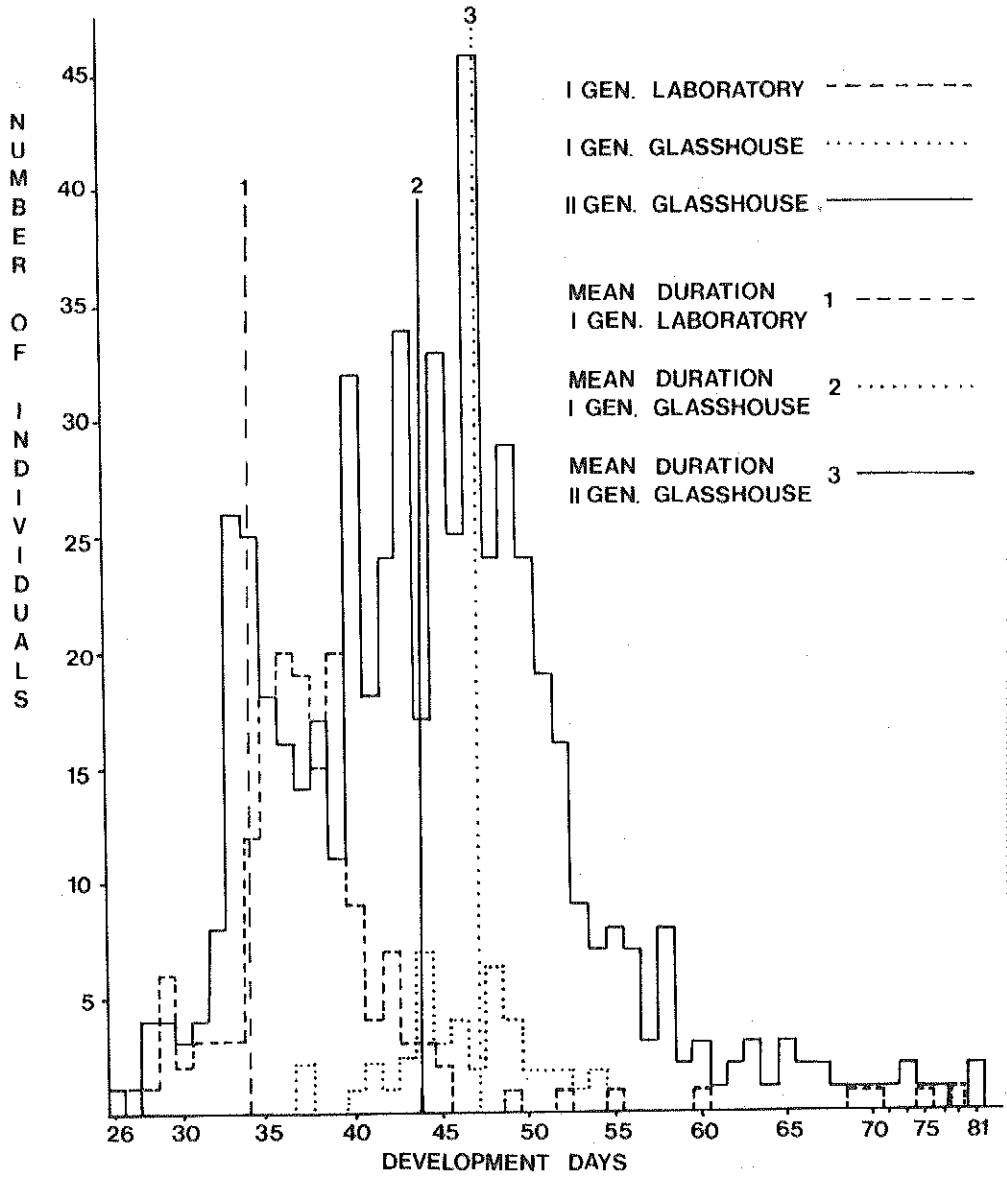

Figure 6. Duration of *Zygogramma suturalis* F. development from egg to adult at variable temperatures.

Conclusions

Our experiments show that development of *Z. suturalis* is possible under moderate temperature conditions. The temperature threshold for the egg development (12.5°C) is higher than the threshold needed for germination of the host plant (8 to 10°C; Anonymous 1978). Considering the dependence to temperature an acclimatization of *Z. suturalis* in Middle and South Europe is possible.

Significant differences in the duration of development of individuals grown in identical conditions were observed. Genetic heterogeneity is supposed to cause this non to uniform development.

Table 2. Development time, egg to adult and needed SET at constant temperatures.

Temp. (°C)	Development (d) Range	Mean	SET[1]°C
19	47-57	52.2 ± 0.41	214.6
20	45-59	51.7 ± 0.16	268.8
20.5	46-50	48.3 ± 0.41	275.3
23	32-36	34.3 ± 0.43	281.3
25	25-34	29.0 ± 0.73	295.8
27	25-29	27.1 ± 0.29	333.0

[1] Hypothetical temperature threshold 14.8°C.

Acknowledgments

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