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THE PHENOMENON OF PARTIAL RESISTANCE TO INSECTICIDES IN SOME ARTHROPODS*

(Ekol. Pol. 18: 351–359). The term partial resistance is proposed for the phenomenon of the simultaneous existence in a population of individuals which react to the insecticides applied as sensitive, resistant and intermediate. Partial resistance was obtained under laboratory conditions by crossing resistant and sensitive strains of *Tetranychus urticae* Koch. It was also observed in populations of *Trichogramma evanescens* Westw. and *Sitotroga cerealella* Oliv. at the beginning of selection in relation to Metasystox. It can also be characteristic of populations previously made resistant, in which resistance, as a recessive trait, begins to disappear after selection pressure is removed.

In order to obtain the characterization of the resistance of a given population to an appropriate insecticide, we expose the animals to a range of concentrations of suitable quantities of the relevant compound, and then determine the mortality. After plotting the percentages of the tested insects killed, on paper with an arithmetical scale against the doses expressed in logarithms we obtain a symmetrical, S-like curve (Fig. 1). On Figure 1 three theoretical intersecting curves are plotted, which characterize three populations with

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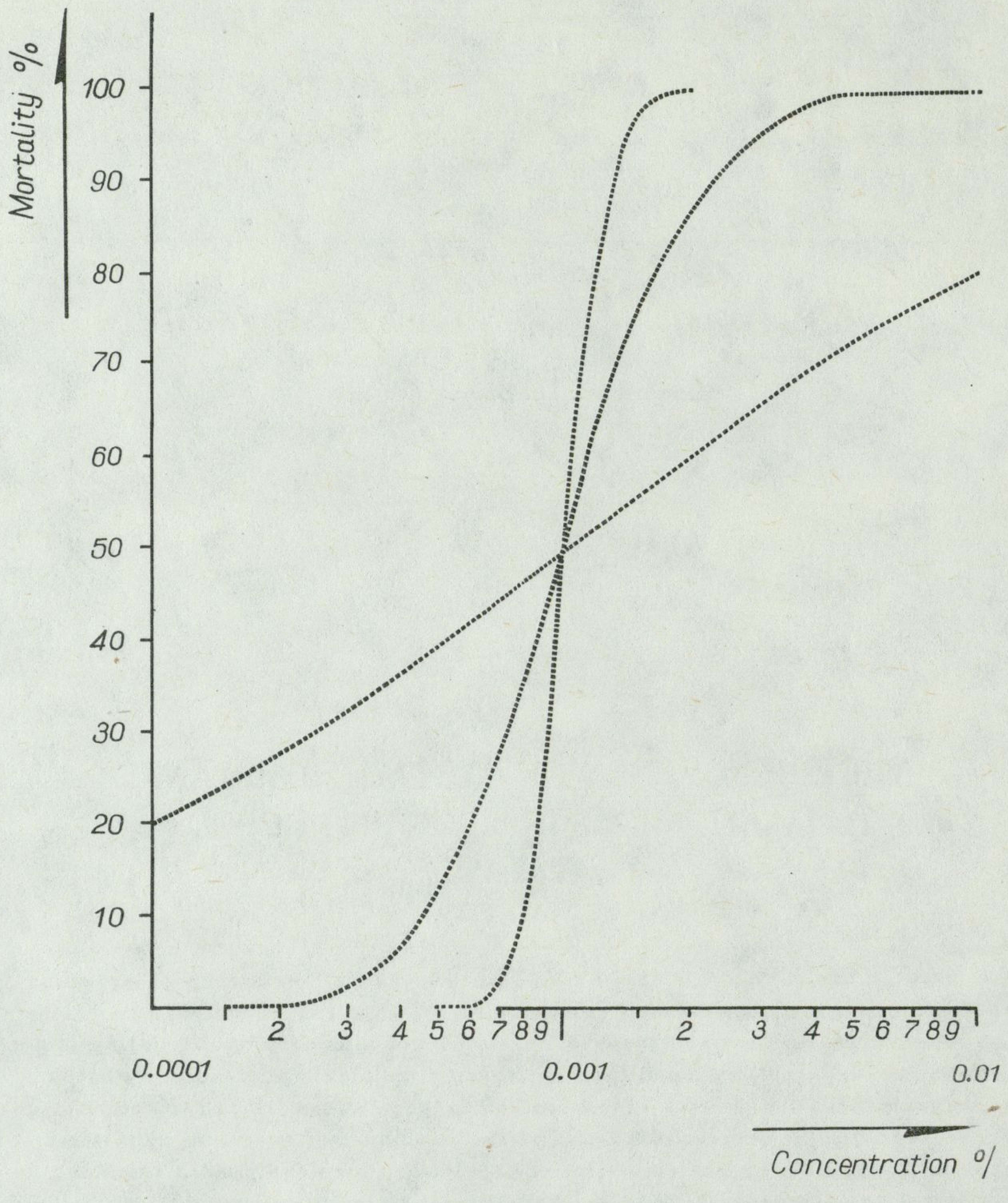

Fig. 1. Theoretical DM curves of insects treated with insecticides (logarithmic-arithmetical scale)

different degrees of heterogeneity. When the mortality is expressed in probits, and the concentration in logarithms, these curves can be transformed into straight lines. To simplify calculations, the results obtained are now plotted on standard paper with a log-probit scale (Finney 1952, Hoskins and Gordon 1956, Overmeer 1967). We thus obtain straight lines with different slopes (Fig. 2). Straight lines of this type can by very easily analyzed with respect to the degree of resistance by comparing their LC_{50}, that is the concentration which causes the death of 50% of the tested insects, or the LD_{50}, that is the amount of the chemical introduced into the insect's body which

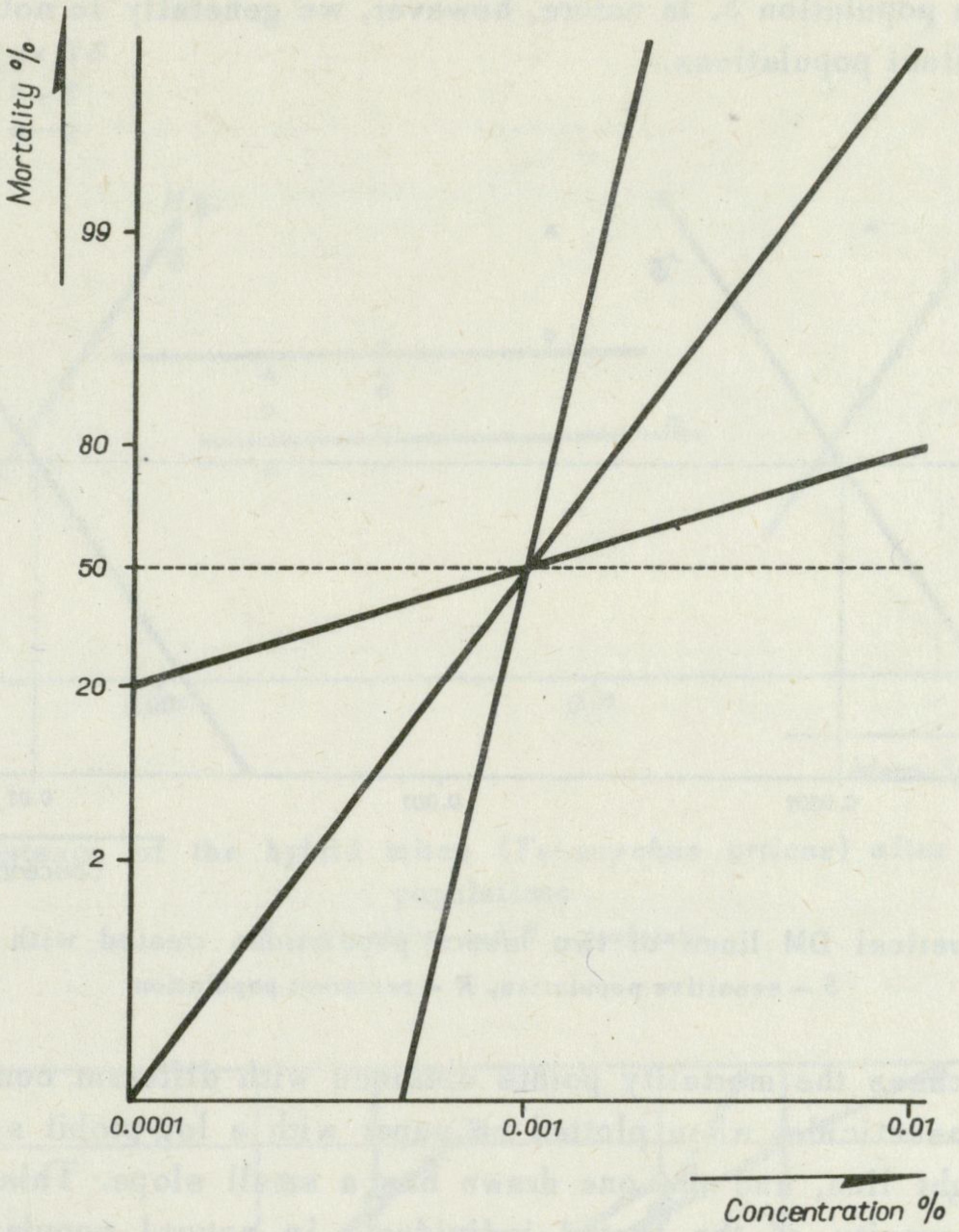

Fig. 2. Theoretical DM lines of insects treated with insecticides (logarithmic-probability scale)

causes 50% mortality (sometimes it is very useful to compare LC_{95} or LC_{15}). In the example given above the LC_{50} of the three straight lines has the same value, i.e. 0.001, but the slopes differ considerably, which shows a large differentiation of the degree of fitness of these populations. Populations which have been previously exposed to the given chemical often give straight lines forming a small angle with the x axis. These populations raised under laboratory conditions may be quickly made resistant to the given chemical by means of selection pressure. It must be stressed that populations showing heterogeneity in respect to pesticides often also show it in respect to indices vitally important to the population, such as fertility or life span.

In Figure 3 two theoretical straight lines characterizing the resistance of two populations, a susceptible one (*S*) and a resistant one (*R*), are shown. By comparing their LC_{50} we can say that population *R* is a hundred times more resistant than population S. In nature, however, we generally do not find homogeneous resistant populations.

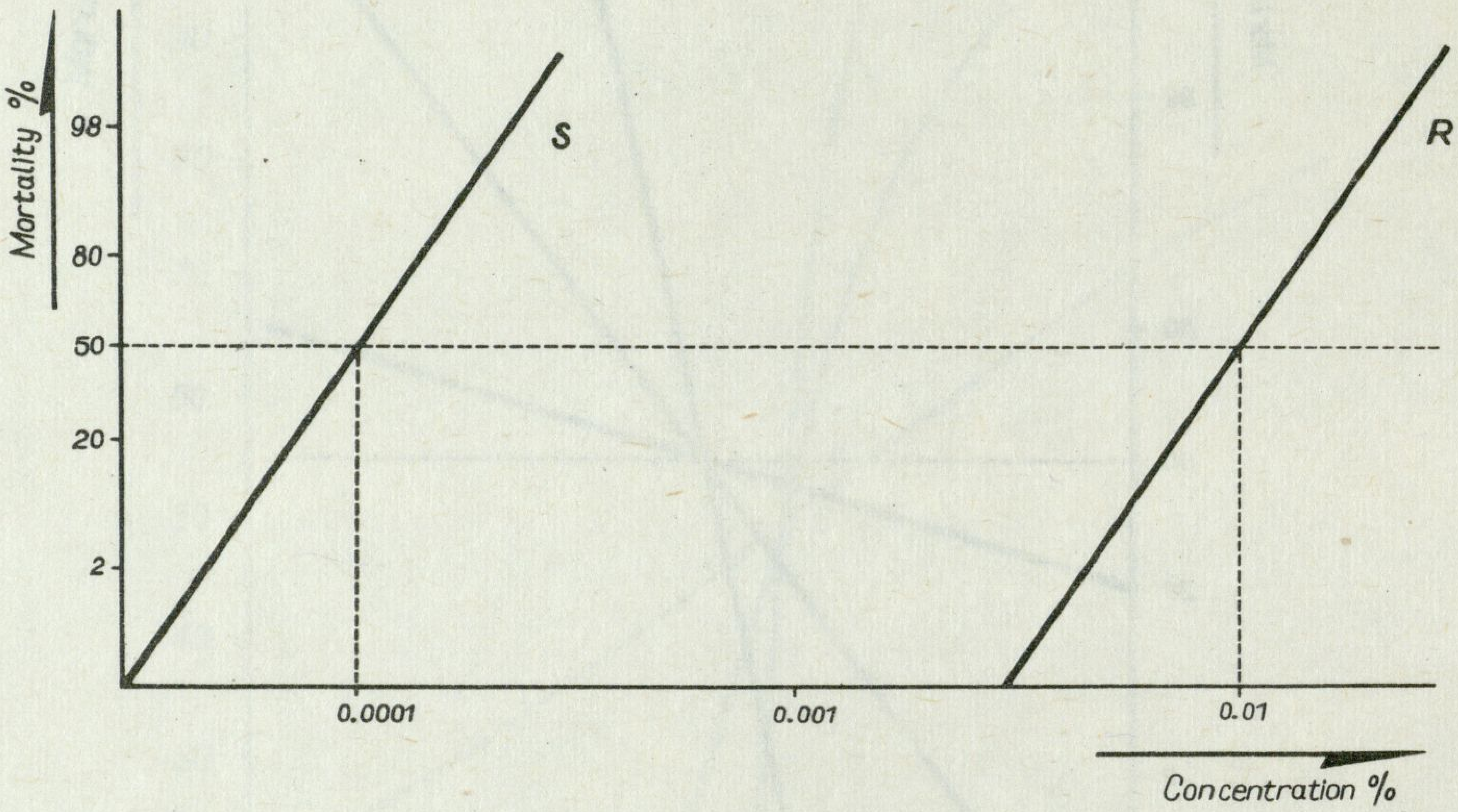

Fig. 3. Theoretical DM lines of two insect populations treated with insecticides
S — sensitive population, *R* — resistant population

In most cases the mortality points obtained with different concentrations of a given insecticide, when plotted on paper with a log-probit scale do not form a straight line, and the one drawn has a small slope. This shows the large heterogeneity of the tested individuals in natural populations; it is especially remarkable in material obtained from chemically protected areas. This is caused by a constant mixing and crossing of individuals from resistant and susceptible populations. Such a population may be obtained under laboratory conditions by crossing individuals from a resistant and a sensitive strain (Fig. 4). In Figure 4 the curve of the resistance of a population of hybrids obtained by crossing resistant and sensitive strains of *Tetranychus urticae* Koch. is shown. The hybrids give a curve lying between that of the resistant and the sensitive population (McEnroe and Kot 1968).

Tetranychus urticae collected in 1966 in an orchard in Nowy Sącz showed a curve of resistance similar to that of the hybrids obtained by crossing resistant and sensitive strains of this species (Fig. 5). The shape of this curve persisted for two years under laboratory conditions, but subsequently resistant individuals disappeared, which among other things shows the instability of resistance in this population.

An increase in the number of resistant individuals in a sensitive population as the result of selection pressure or in the number of sensitive individuals

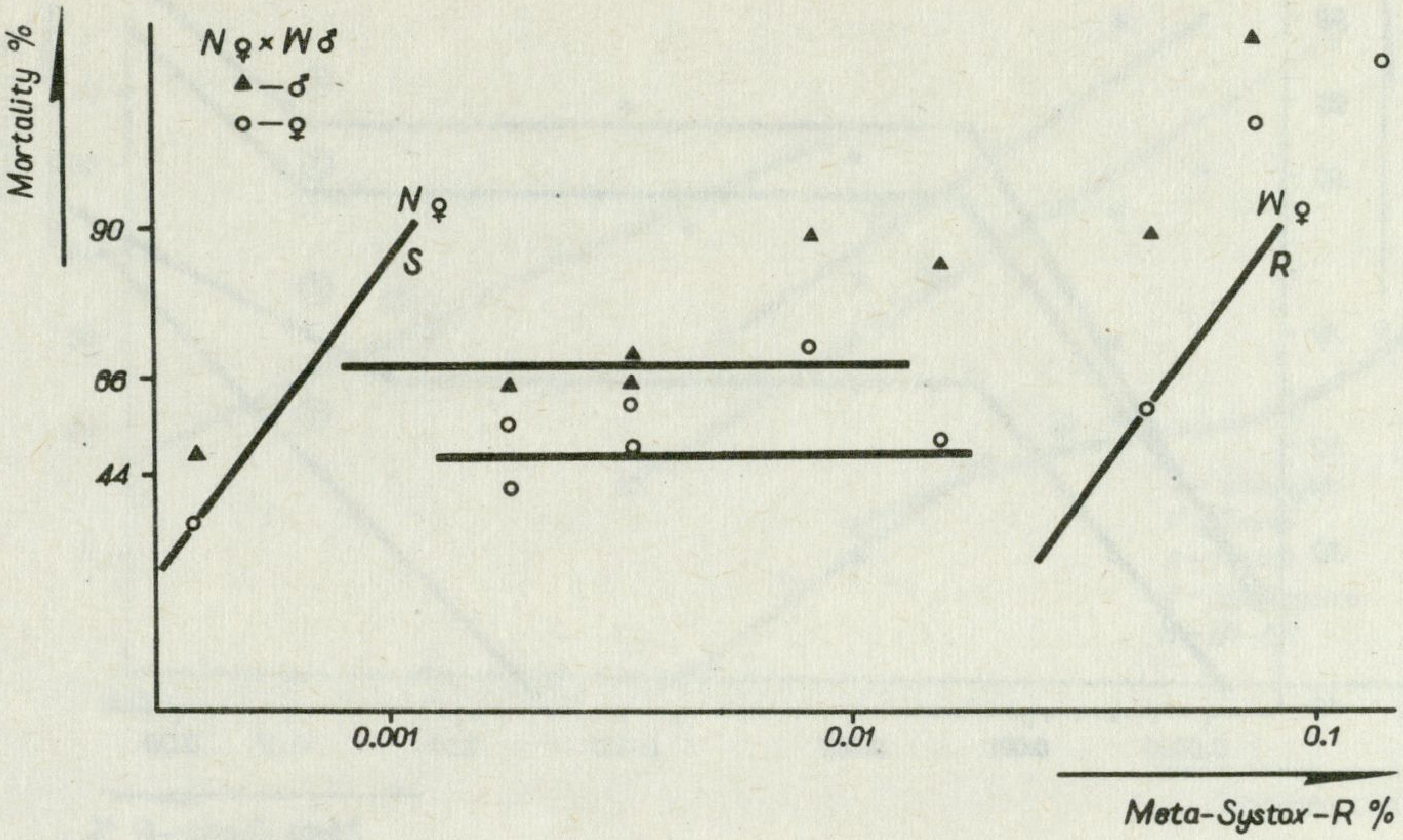

Fig. 4. Resistance of the hybrid mites (*Tetranychus urticae*) after crossing two populations

S – sensitive and *R* – resistant

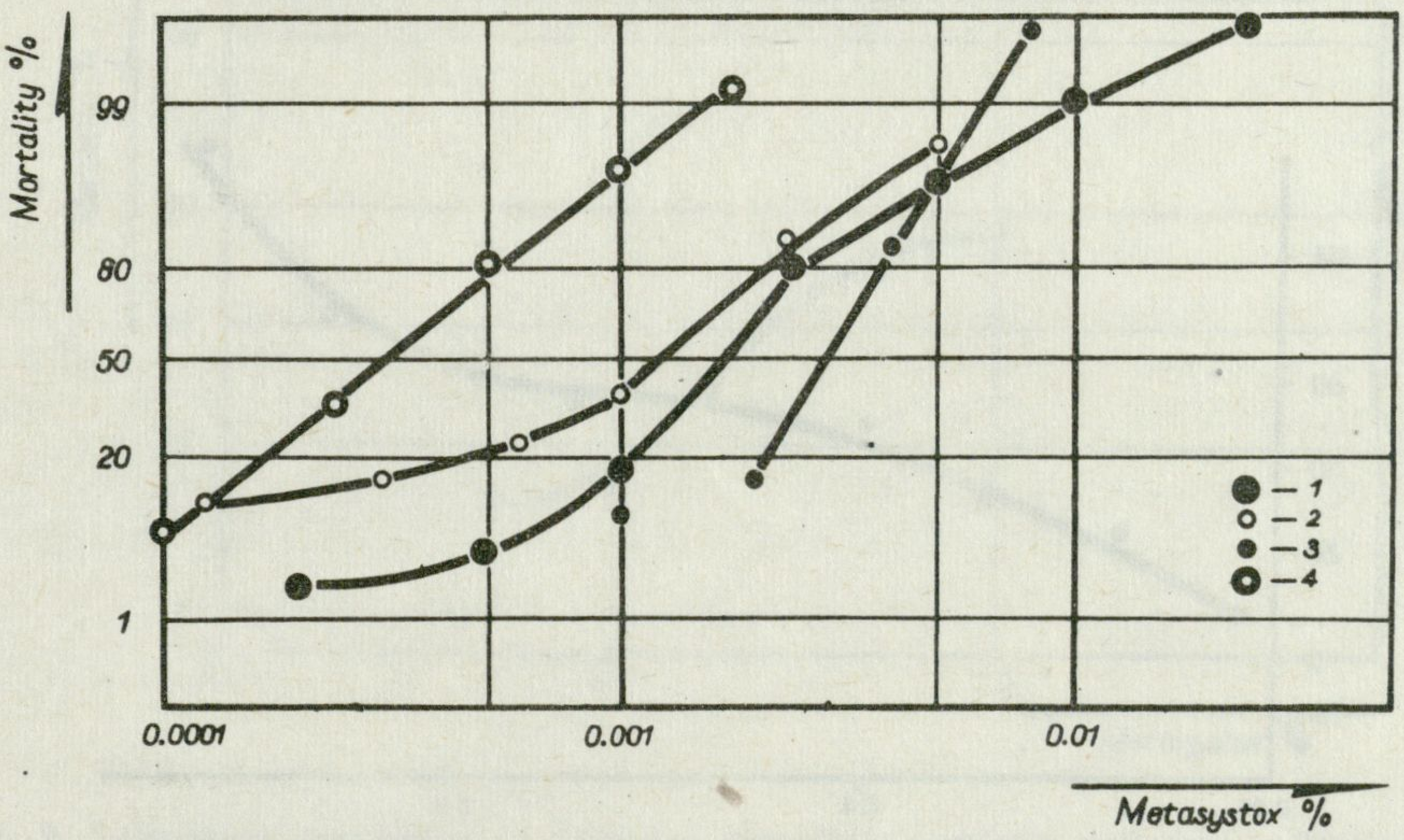

Fig. 5. Initial and final DM responses of *Tetranychus urticae* population from Nowy Sącz orchard

1 – Aug. 17. 1966, *2* – Feb. 7. 1967, *3* – July 16. 1968, *4* – Feb. 25. 1969

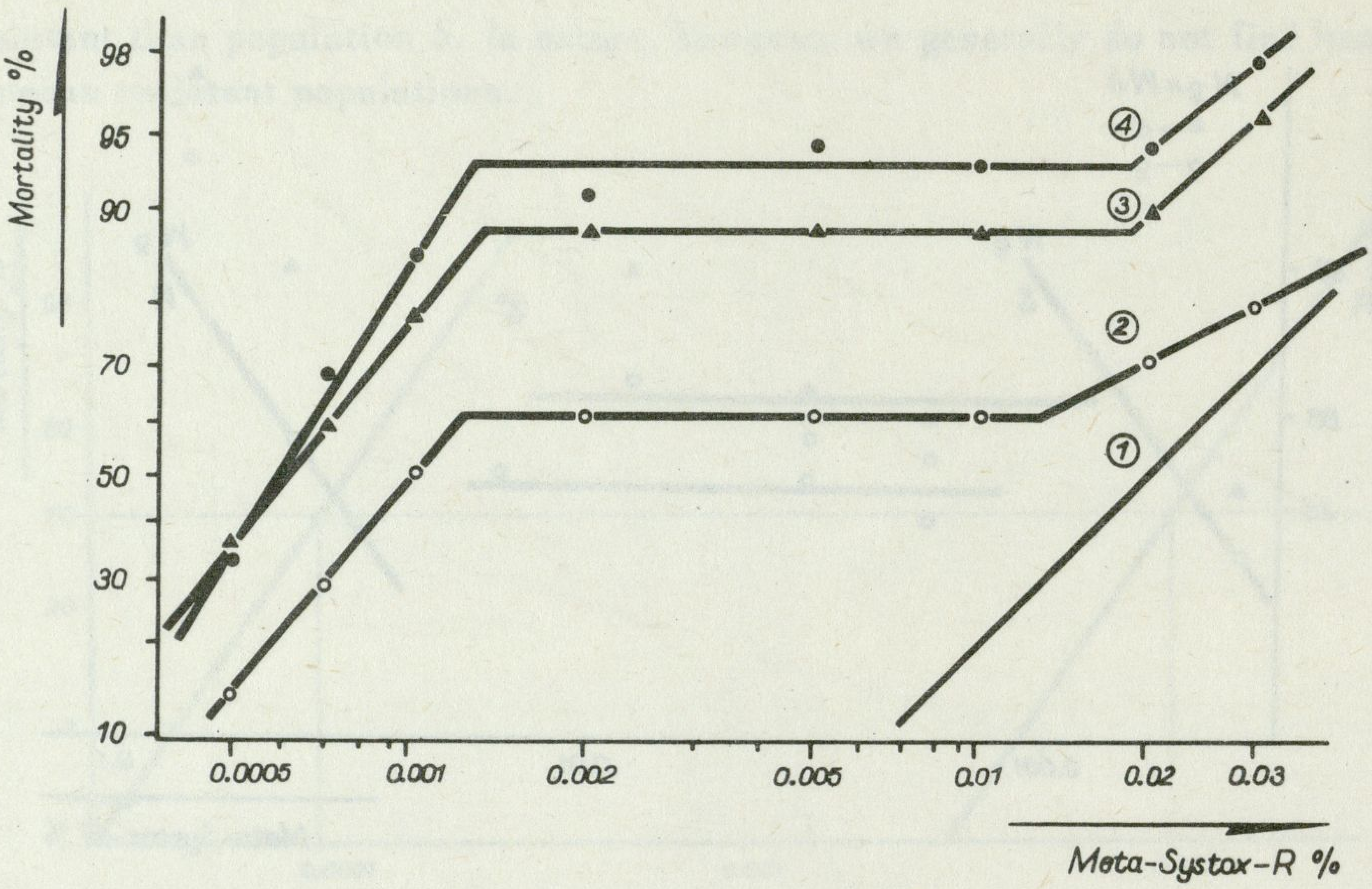

Fig. 6. Changes in the resistance of *Tetranychus telarius*

1 — homozygous resistant population, *2* — the same strain 3 generations after determination, *3* — the same strain 5 generations after determination, *4* — the same strain 8 generations after determination

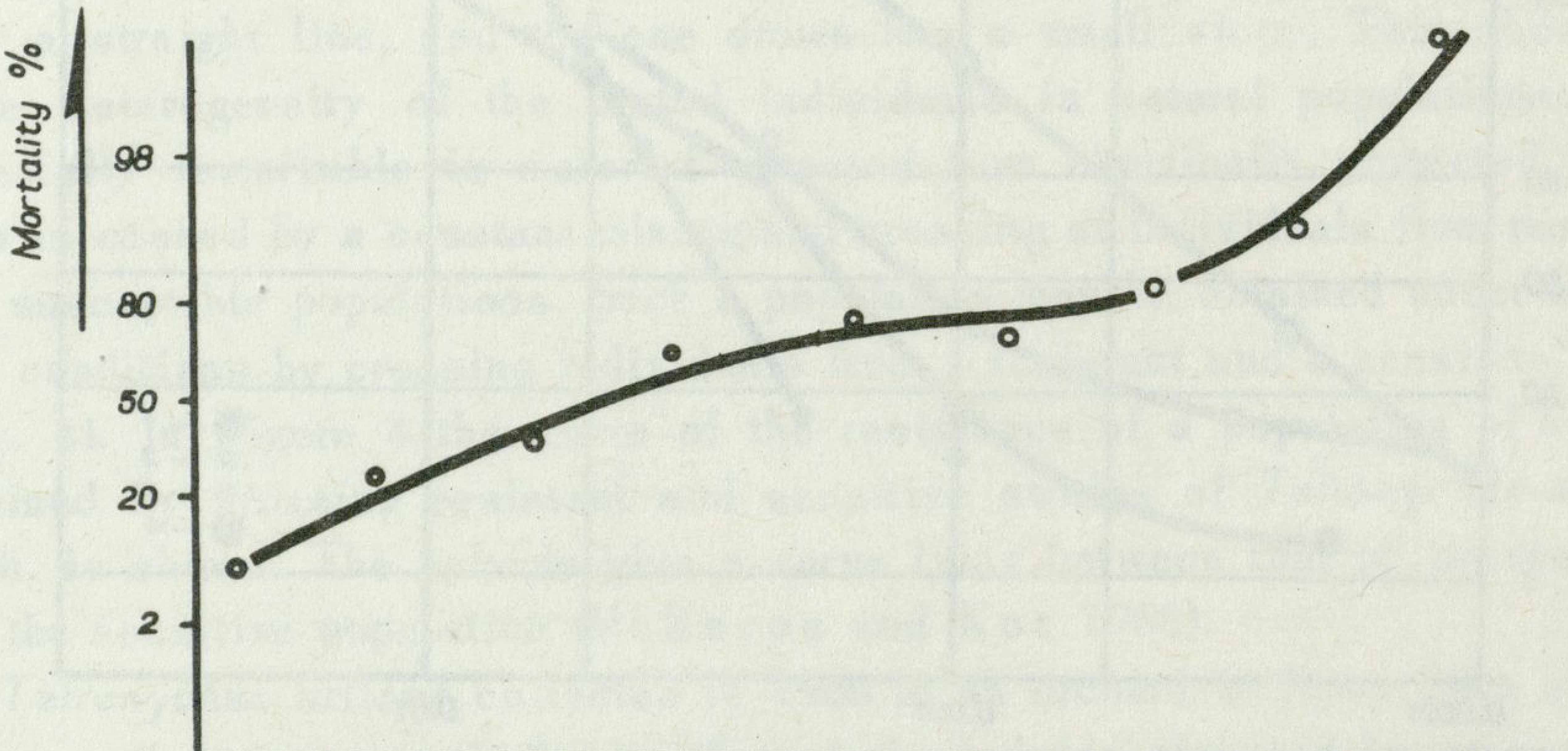

Fig. 7. Dosage-mortality curve of the Colorado beetle (*Leptinotarsa decemlineata*)

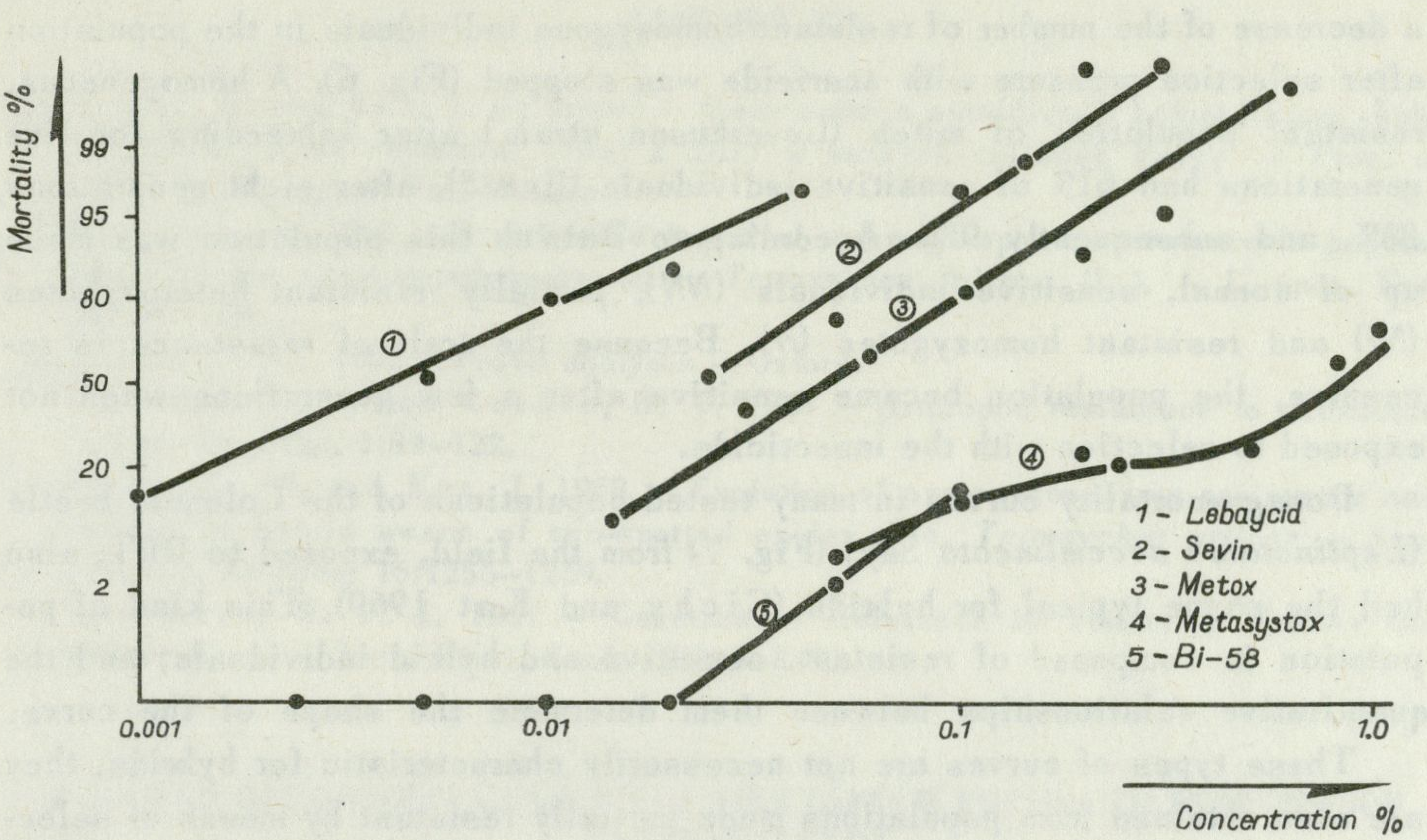

Fig. 8. Dosage mortality lines of the prepupal stage of *Trichogramma evanescens* treated with different pesticides while in host's eggs

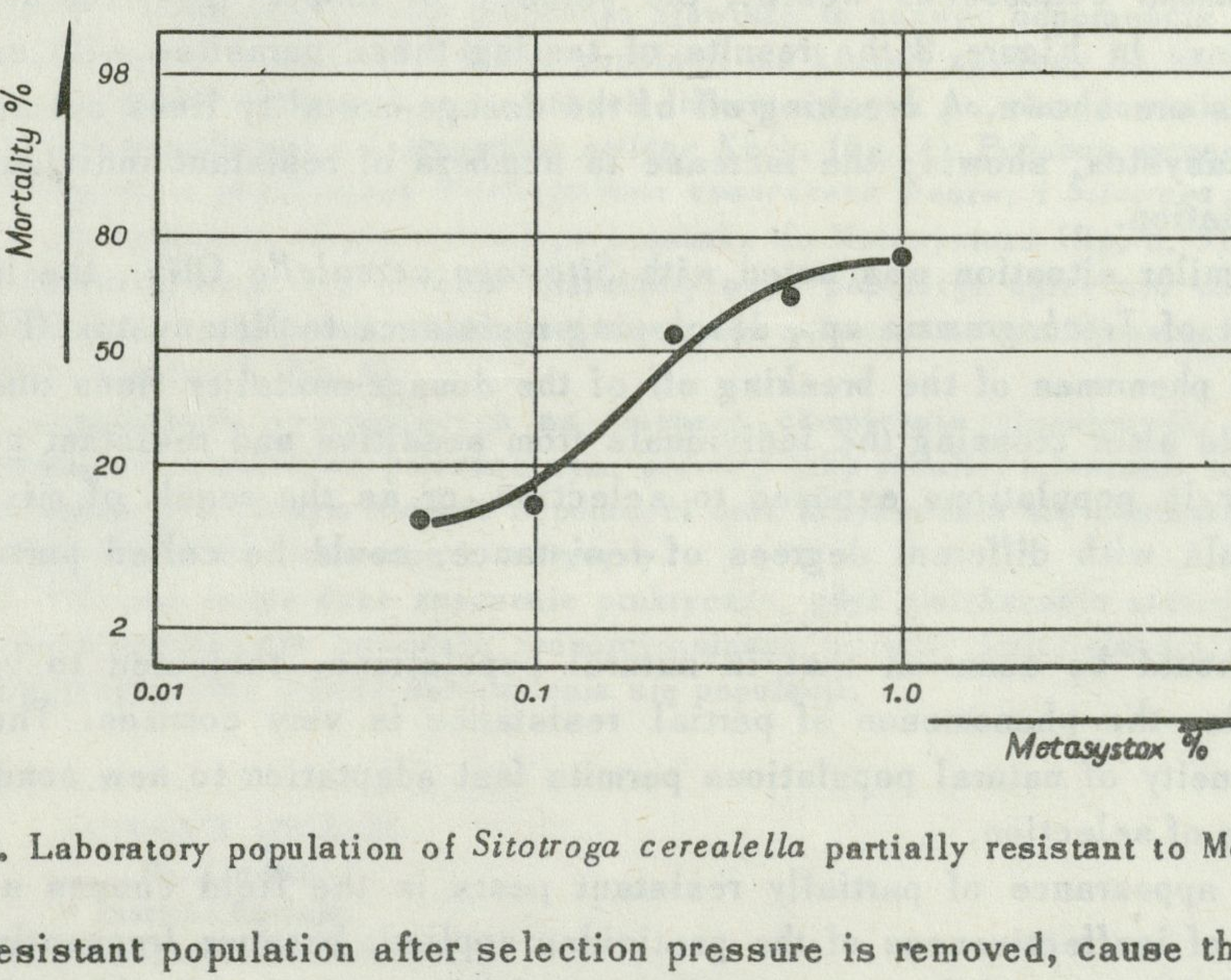

Fig. 9. Laboratory population of *Sitotroga cerealella* partially resistant to Metasystox

in a resistant population after selection pressure is removed, cause the breaking off of the dosage-mortality line. Analyzing the changes occuring in a resistant population of *Tetranychus telarius* (L.), Dittrich (1963) noted

a decrease of the number of resistant homozygous individuals in the population after selection pressure with acaricide was stopped (Fig. 6). A homogeneous, resistant population of mites (Leverkusen strain) after inbreeding for five generations had 61% of sensitive individuals (line *3*), after eight generations 88%, and subsequently 95%. According to Dittrich this population was made up of normal, sensitive individuals (*NN*), partially resistant heterozygotes (*Nr*) and resistant homozygotes (*rr*). Because the trait of resistance is recessive, the population became sensitive after a few generations when not exposed to selection with the insecticide.

Dosage-mortality curves in many tested populations of the Colorado beetle (*Leptinotarsa decemlineata* Say) (Fig. 7) from the field, exposed to DDT, also had the shape typical for hybrids (Cichy and Kot 1969). This kind of population is composed of resistant, sensitive and hybrid individuals, and the quantitative relationships between them determine the shape of the curve.

These types of curves are not necessarily characteristic for hybrids, they are also obtained from populations made partially resistant by means of selection. The breaking off of the dosage-mortality lines occurs as a result of the formation in the population of a group of resistant individuals. This state may persist for quite a long time until the sensitive animals become eliminated.

In 1965 research was started on the possibility of obtaining strains of *Trichogramma evanescens* Westw., the parasite of insect eggs, resistant to Metasystox. In Figure 8 the results of testing these parasites with several chemicals are shown. A breaking off of the dosage-mortality lines occurs only with Metasystox, showing the increase in numbers of resistant individuals in the population.

A similar situation was noted with *Sitotroga cerealella* Oliv., the laboratory host of *Trichogramma* sp., developing resistance to Metasystox (Fig. 9).

This phenomen of the breaking off of the dosage-mortality lines observed in hybrids after crossing the individuals from sensitive and resistant populations, or in populations exposed to selection, or as the result of mixing of individuals with different degrees of resistance, could be called partial resistance.

It should be assumed that in natural populations, subjected to various chemicals, the phenomenon of partial resistance is very common. The high heterogeneity of natural populations permits fast adaptation to new conditions by means of selection.

The appearance of partially resistant pests in the field causes a large degree of ineffectiveness of the pesticides applied, because frequently even a tenfold increase of the concentration used does not considerably raise the mortality of the insects.

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ZJAWISKO ODPORNOŚCI CZĘŚCIOWEJ NIEKTÓRYCH POPULACJI STAWONOGÓW NA INSEKTYCYDY

Streszczenie

Badania odporności niektórych populacji stawonogów na insektycydy wskazują na jednoczesne występowanie w wielu testowanych populacjach osobników odpornych, wrażliwych i pośrednich. Autor proponuje zjawisko to nazwać odpornością częściową populacji. Krzywa wrażliwości takiej populacji ma kształt zbliżony do litery S. Częściową odporność otrzymano w warunkach laboratoryjnych po skrzyżowaniu populacji odpornych z wrażliwymi u *Tetranychus urticae* Koch. (fig. 4). Podobną sytuację stwierdzono również w populacjach *Trichogramma evanescens* Westw. i *Sitotroga cerealella* Oliv. w początkowym etapie selekcji,w stosunku do Metasystoxu (fig. 8, 9). Odpornością częściową mogą się również charakteryzować populacje uprzednio uodpornione, w których po ustaniu presji selekcyjnej następuje sukcesywne zmniejszanie się liczby osobników odpornych (fig. 6).

W populacjach występujących na terenach chemicznie chronionych, odporność częściowa jest zjawiskiem powszechnym, głównie jako rezultat mieszania się osobników z populacji o różnym stopniu odporności oraz krzyżowania się osobników wrażliwych z odpornymi na stosowane insektycydy.

Stwierdzenie to ma duże znaczenie praktyczne, gdyż zwiększanie stężeń stosowanych insektycydów nie powoduje proporcjonalnego wzrostu śmiertelności, natomiast znacznie przyspiesza proces uodpornienia się populacji.

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