THE EFFECT OF PESTICIDES ON EVOLUTIONARY ECOLOGY OF PESTS

V. B. SAPUNOV
Sci. Res. Centre of Ecological Safety, Korpusnaya 18, St. Petersburg, 197110 Russia

Abstract - Pesticides may be both of chemical and physical nature. Every pesticide may have two biological effects: specific and unspecific. For example, specific effect of juvenoids (chemical pesticide) is mutagenic effect on regulatory genes. Specific effect of ultrasound is increase of temporal variability. Unspecific effects take place at different structural level. At cellular level that is paranecrosis. At organism level that is stress. Population effect consists of increase of pests variability. The high variability is a good material for natural selection of pesticide - resistant strains. Ecological level effect deals with pattern of interaction between pest and other species. Under decrease of pest population by pesticides, the free ecological niche may be occupied by other organisms. They may be resistant for pesticide and being dangerous for agriculture. Usual practice of pest control takes into account physiological and public health study of pesticide, that is not enough. Effective use of pesticide needs effective predictive model of all its effects. Such logical and mathematical models needs use of both genetical and ecological data. Such an effective model would be demonstrated at conference.
Key words - Pesticides, evolution, ecology

INTRODUCTION

Pesticides (P) - from latin - killers of plague - are chemical compounds for struggle with pests - dangerous plants or animals. More than 800 pesticides has legal use in the world (Reimers, 1991). But chemical P, physical agents of pesticide activity (PAPA) exist. They are: radiation, ultraviolet, ultrasound and so on. All living world has the same principles of genetic and biochemical organisation. That's why every P and PAPA have any effects for all organisms including man. But different organisms have different resistance for different pesticides. The resistance of pests for P increases because of natural selection. There are about 1000 insect species resistant for any insecticides. 150 microorganism species are resistant to any P. There are 60 mosquito species carrying malaria. 51 of them are resistant to widespread insecticides. Resistance for P may appear during some years (Reimers, 1991, Insects, 1995).

According to medical and veterinary rules, every pesticide needs two expertizes: physiological (toxicity for pests) and medical (damage for human health). The physiological tests deal with the rate of suffocation of the pests: mortality and reproductive potencies. Medical studies the rate of toxicity of P for man taking into account possible ways of getting human organisms by P. Indirect effects of use of P and PAPA are out of the consideration. At the same time P may induce complicated complex of ecological pathology (Slepyan, 1998). The aim of present work is study of the ways toward modeling of complex direct and indirect effects of P and PAPA on biota.

Specific and unspecific biotic effects

Every effect on organisms has both specific and unspecific components. Specific is accorded to effectors. Unspecific is general reaction for every noxious agents. Let us list most typical unspecific reactions. Paranecrosis is unspecific reaction at the cellular level (Nasonov and Alexandrov, 1940). Stress is unspecific reaction at the organism level (Selye, 1936). Increase of variability is unspecific reaction at population level (Sapunov, 1991). There is generalized reaction at the level of ecological systems (Sapunov, 1986). There is no theory of such a reaction. We are toward such a theory. According to global ecology (Vernadsky, 1926), this reaction must be dynamically resistant. That is, relation between species must be changeable and the changes may be accompanied by stability of general structure of ecological systems. Let us consider some examples of both specific and unspecific reactions of organisms on noxious agents.

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Reaction of insects on Juvenile hormone analogues (JHA)

During many years JHA were considered as perspective insecticides (Novak, 1971). Last year they began to exchange for insecticides of antihormone actions and others (Insects, 1995). JHA is P with specific effects on insects. Having ontogenic effect, they destroy individual development, increase mortality and sterility. There is no well detectable physiological effect on mammalia. That' s why there is opinion, that JHAs are not dangerous for man and biota. My previous study (Sapunov, 1991) contradicted to such an opinion. Unspecific effect of JHA consists of induction of some mutation. Table 1 demonstrates genetical effect of JHA (entacon, concentration 20%) treatment on *Drosophila melanogaster* - classic model insect (Line Canton - S). More detailed methods are described in literature (Sapunov, 1981,1991). The data means that JHA has genetic effect mainly dealing with mutation on chromosome 2. This chromosome posesses any important regulatory genes. Increase of mutability is effect by such agents but JHA as viruses, DNA and so on (Sapunov, 1981). Such a mutability increase variability at population level.

Table 1. Effect of JHA treatment on mutability of *Drosophila melanogaster.*

type of mutations	Dominant lethal mutations	Recessive lethal mutations on X-chromosome	Recessive lethal mutations on chromosome 2
Control	0.8+-0.21	0.5+-0.23	0.5 +-0.22
Experiment	4.4+- 0.04	0.7+-0.17	4.8 +- 0.70

Quantitative rate of variability increase was studied in aphids (*Megoura viciae)* experiments (Table 2). Methods of such an experiments were described earlier (Sapunov, 1984). These experiments are model of real field situation after JHA treatment of the biota. Hence, unspecific action of JHA is variability increase under population stress. The same may be reaction on every stressor (Sapunov, 1991). Specific reaction is mutability increase on chromosome 2.

Table 2. Effect of JHA treatment of plant (pea) on phenotypical variability of aphids *M. viciae.*

Variability measure	Var. coef. lenght of body	Var. coef. of width of body	% of organisms with color abnormality
Variant			
Control	0.06	0.06	5+- 1
Treatment	0.18	0.13	30+-4

Reaction of insects on PAPA – ultrasound

Ultrasound is perspective agent for two purpose: suffocation of insect population; change of reproduction time. Flies *D. melanogaster (*Canton-S strain) and clone of aphid *M.viciae* were selected as an object. The effect was studied under ultrasonic pressure 0.05, 0.2, 0.4, 0.7 and 1 wt / cm2, frequency 0.88 Mgz. Regime was discontinuous. Correct methods are described earlier (Krasavina *et al.*, 1998). Table 3 demonstrates mortality of *Drosophila* in dependence on effect of ultrasound. Mortality of eggs increases after PAPA. The effect is pressure dependent. The more is pressure, the more is mortality. It is unspecific effect because mortality increases under every nocuous agents, e.g. external temperature has the same effect. Specific effect of ultrasound is chronovariability (time variability) increase. Distribution of larvae evaluation from eggs becomes more wide - see Fig. 1. General variability increase is unspecific effect. New peaks apportion is specific one. The new peak have coordinations: mean = 15.1, square deviation = 1.5. There is no such a peak under control condition. Hence, every P and PAPA may suffocate pests and induce unpredictable biological reactions.

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Table 3. Percent of suffocated *Drosophila* eggs in dependence of ultrasonic effect.

Variant	Pressure wt / cm^2					
	0	0.05	0.2	0.4	0.7	1.0
Control	2.9+-0.5					
Treatment of the eggs		14.3+-3.4	14.7+-3.4	12.0+-3.2	28.6+-4.5	53.5+-4.9

Microevolution results of damage for population

Both P and PAPA kill parts of pest specimens. Some organisms got the stress state. Stressed organisms produce progeny having high variability of every characters (Sapunov, 1991). Every population adapt for environment. Every environment changes. Population follows this exchange. Every P and PAPA change environment. Such a terrible change is lethal for some organisms. Adaptation for such a change

Figure 1. Dynamics of hatching out of larvae of *Drosophila* in control (A) and under ultrasonic treatment (B).

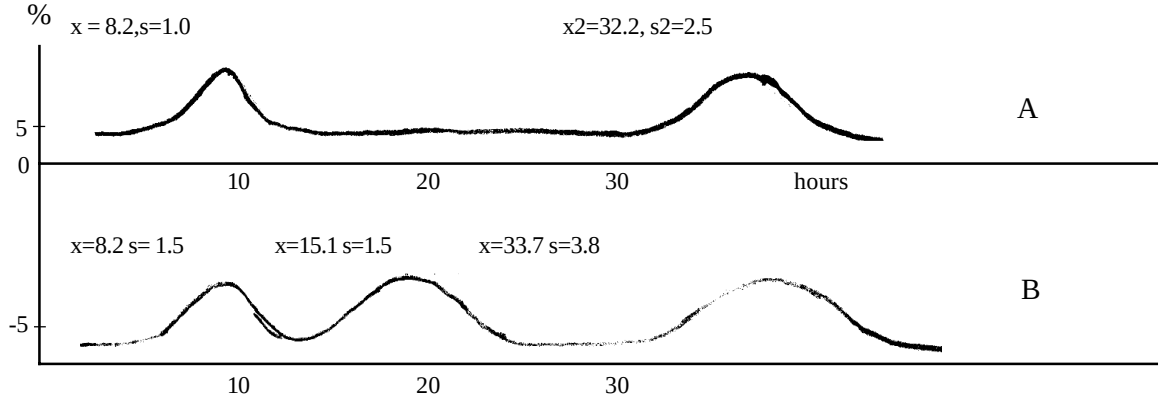

Figure 2. Adaptation under directional selection (I) and under genetical destabilization (II).
ox - measure of trait, oy - distribution of the trait in population, oz - generations. „a“ - old adaptive zone, „b“ - new one

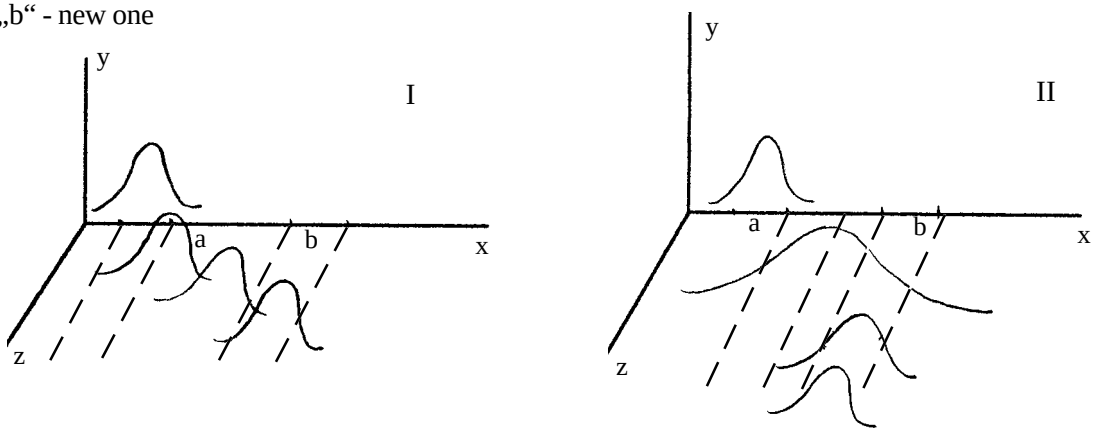

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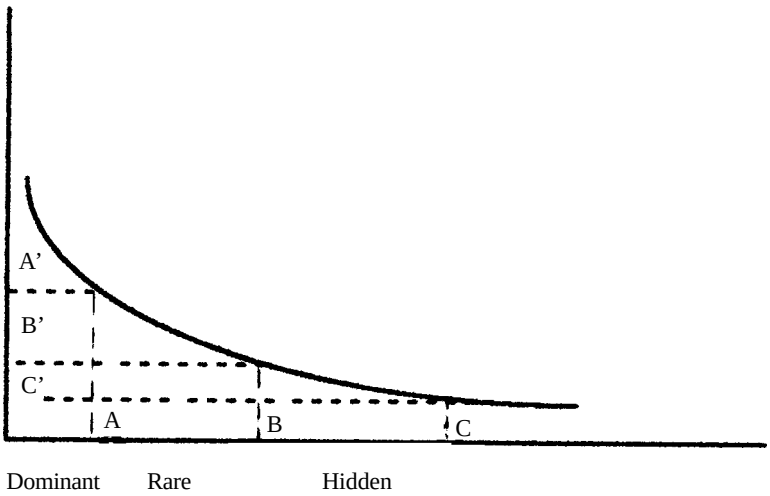
Figure 3. Distribution of species in ecological system.



is complicated biological task. There are two variants of adaptation at the population level. The first is moving selection. The second is adaptation through genetical destabilization. Both variants are described at Fig. 2. The first variant (I) is possible under relatively little environment change. Percent of organisms in population, preadapted to a new environment are sufficient for foundation of a new population by means of natural selection. Such situation may be after weak effect of P or PAPA. Alternative situation, that is significant change of environment may take place too. A new circumstances („b“) may have a big quantitative differences from old one („a“). In this situation, number of organisms, preadapted to a new environment, may be small. Preadaptation is original resistance to P or PAPA. Under last situation (Fig 2- II) majority of organisms would get uncomfortable state. They would be dead or decrease their fertility. If anybody will make offspring, this offspring would have a high variability. Stress state will induce genetical destabilization of progeny. Natural selection will have possibility to select adapted for P and PAPA organisms between them. The quantitative characters of such population adaptation was described above (Sapunov,1991).

Adaptive potencies of every population are high but limited. Stress state increases variability and adaptive potencies of population. Example is effect of ultrasonic stress at population of aphids, Table 4, methods (Krasavina *et al.*,1998). During some generations depression is followed by increase of fecundity. Hence, use of P and PAPA may have results reciprocal to needful. Fertility of pests may increase after humans efforts. Hence, any struggle against pests needs take into account any direct or indirect ecological results of P and PAPA use. Modern population biology and ecology may help us to make such a prediction.

Table 4. Fecundity of aphids *M. viciae (*during 100 hours per one mother female) of the following generations after ultrasonic treatment.

Variant	Number of offspring
Control	40+-4
Chilling,1st generation - F1	23+-5
Ultrasonic treatment, 20 min, F1	31+-5
F2 after ultasonic treatment	52+-5
F3 after ultasonic treatment	40+-5
F4 after ultasonic treatment	42+-3

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Ecological results of struggle against pests

Every population is element of ecological system. Decrease of number of any pest doesn't close ecological niche of the pest. It may be occupied by other species. They may be unprofitable too. So, proliferation of ragweed *Ambrosia* sp. at Caucasus leads to some medical and agricultural problems (Sapunov, Kovalev, 1987). One of the results of the struggle against *Ambrosia* was making prerequisite for distribution of the ragweed *Cyclachaena* (*Iva)*, that is more dangerous species.

Ecological prognosis of effect of P or PAPA must keep in mind global ecology by Vernadsky (1926). According to such a science no free niche exists. General pattern of biological mass distribution within niches is constant. The general mass of biospera is constant. The occupation of every free niche is obligate. The occupation prolongs till use of all ecological resources within niche. Biospere is very stable because of:

1) Big adaptive potencies of every organisms;
2) Big potential variability at the population level, that may be bustered by P or PAPA;
3) Geometrical progression of reproduction of the organisms having maximal fitness for the environment;
4) A big number of biological species. Between them exist species, having preadaptation to almost every possible ecological change including artificial one. For majority of P and PAPA exist resistant species. Some species need P or PAPA for development. Species within ecological system may be divided into three groups: dominant, rare and hidden (Sapunov, 1996). Hidden species have a population sufficient for regular detection of them by usual ecological methods. Between hidden species exist not described, which number may get many millions (May *et al.*, 1986). Mathematical description of dependence number of specimens - number of species was described (Sapunov, 1996):
   $n = p \exp(-qN)$

where N - number of species, n - number of specimens, p, q - constants.The curve see in fig. 2. A, B, C - boundaries between 3 variants of species, C' - limit number, genetic minimum for existence of species. The number of dominant species is:

$$nd = \int_0^A f(N)dN$$

rare

$$nr = \int_A^B f(N)dN$$

hidden

$$nh = \int_B^C f(N)dN .$$

The biological mass of hidden species is small. But they have a big potencial ecological meaning. According to some specialists, the number of species decrease 10 000 per year (Carpenter, 1991). But this data doesn't mean destruction of biosphere and global ecological crisis. Many "extincted" species prolongue their life as hidden one. After next ecological change, they may become dominant again. Hence, extreme pressure including anthropogenic on ecological systems doesn't destroy them. Ecological stress changes relation between different species. The mass of ecological system is constant. Global ecology data may help us to predict results of use of P and PAPA. The general struggle against pests is the following. Pests must be change for less dangerous species.

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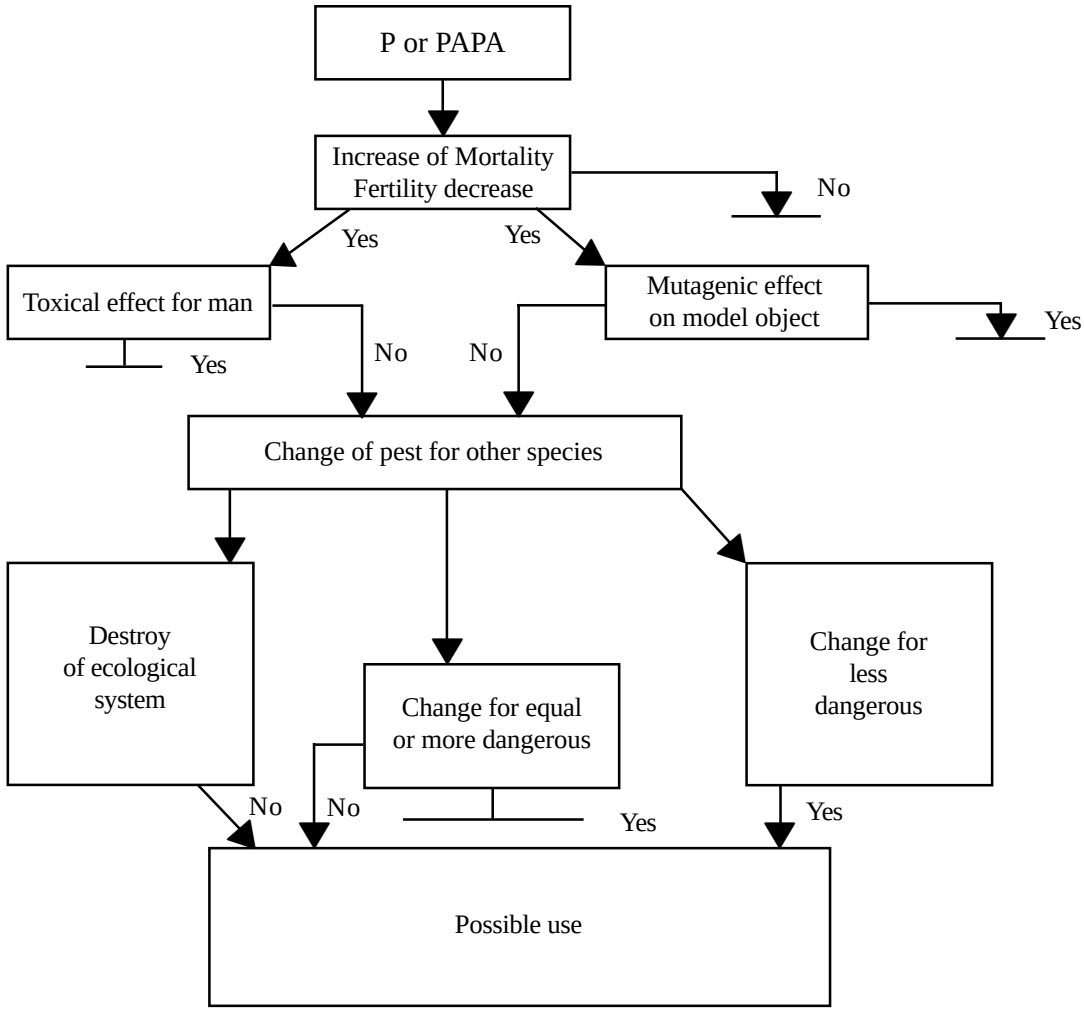
Figure 4. Scheme of control of P and PAPA use



CONCLUSION

Modern era of biosphera evolution is noosphera (Vernadsky, 1926). The social control of ecological processes increase. But till now natural processes are stronger than human will. The struggle against nature is not perspective. The perspective task is understanding and using laws of global evolution. The strategy of P and PAPA use must be based on the following scheme (Fig. 4). 1. Check of toxicity of P or PAPA, study of mortality increase and fertility decrease of pests. 2. Study of sanitation results from man taking into account possible ways of distribution of P and PAPA in nature and possible doses for man. 3. Check of possible genetical effects of P and PAPA using laboratory mutagenic test system (*Drosophila melanogaster*). 4. The check of possible microevolution results of use of P and PAPA, taking into account variability increase and natural selection. 5. Check of possible ecological results taking into account interaction of pests with other species within ecological system.

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