Some Regularities of the Effect of Pesticides on Soil Microflora

Y. V. KRUGLOV

All-Union Research Institute of Agricultural Microbiology, Leningrad /USSR/

The increasingly widespread application of pesticides in agriculture greatly necessitates the forecasting of the consequences of their application and the efficient monitoring of changes in environmental quality.

Since they are physiologically active substances the pesticides currently used produce a selective effect on microorganisms. Hence, the introduction of pesticides into the soil depresses the vital activity of some MO species and stimulates others, leading to a regrouping of the microflora. Its qualitative composition changes /Fig. 1/.

If a community of soil microorganisms is considered as a system wherein individual species and functional forms are interrelated, the most sensitive of them should obviously be considered as "targets". Hence, the kind and extent of ecosystem damage will depend on the place and role of these MO targets in the metabolism and the structural organization of the microbiocoenosis. Thus, the depressed vital activity of microscopic algae due to the

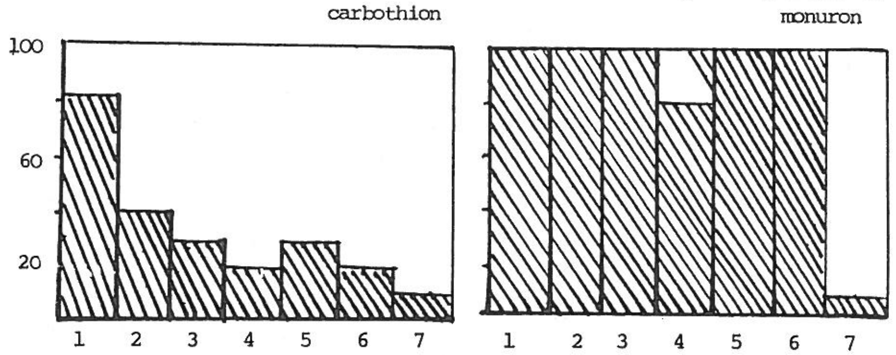

Fig. 1

Effect of herbicides on the microflora of podzolic soil /herbicide concentration - 10 mg/kg/. Vertical axis: Number of microorganisms. Horizontal axis: Microorganisms: 1. Saprophytic bacteria; 2. aerobic cellulose degrading bacteria; 3. nitrifying bacteria; 4. nodule bacteria; 5. actinomycetes; 6. micromycetes; 7. microalgae effect of sym-triazine and phenylamide derivatives will lead to the production of hundreds and thousands of kilogrammes fewer organic substances. Accordingly, the activities responsible for leaching out, rock destruction and soil formation will become blocked.

The decrease in the number of cellulose-decomposing microorganisms as a result of applying sodium-N-methyldithiocarbamate and certain other fumigants is responsible for a decline in the plant residue humification process and for the depressed vital activity of attendant microorganisms.

The suppression of nitrogen-fixing microorganisms results in significant losses of N from the N soil balance amounting to as much as 200-300 kg per hectare for rice fields, for example.

Thus, if the MO targets, their functional role and their place in the microbic system are known, it is possible /with a sufficient degree of accuracy/ to imagine the consequences of the systematic use of pesticides for the soil biota and the ground ecosystem as a whole.

The effect of pesticides on microorganisms is of a temporary nature. The change in their number and functional activity in the soil is expressed by an S-shaped curve. The microflora recovery rate depends mainly on pesticide persistence and occurs in the course of a year. So a single application of an operational dose of pesticides only produces an insignificant effect on the soil biota and soil quality as a whole, as is confirmed by a wealth of experience in research and in the current practice of applying chemical plant protective agents in agriculture.

The temporary pesticide effect on soil microorganisms is determined by a number of factors, the most important being the adaptation potential of the MO population and the heterogeneous soil texture.

It is a well-known fact that a major part of the pesticides currently used are made up of organic substances that are poorly soluble in water. They are prepared as emulsifying concentrates moistening powders, dusts, granules, or capsules. The sizes of the particles penetrating the soil range from a few micrometres to several millimetres, depending on the form of preparation. Consequently, however such pesticides are applied, they are unevenly distributed within the soil as individual particles, microdrops and films. These pesticides become diffused into the environment, their solubility being insignificant. It is natural that their diffusion gradient concentrations differ decreasing from the surface of the particles to the periphery.

Depending on the physical state and toxicity of the pesticide, the effects on the soil microflora may differ greatly. At least two main types of MO distribution can be demonstrated in the vicinity of the pesticide particles.

The first is typical of substances having a wide spectrum of microbiocidal action. In this case a sterile zone is formed around the pesticide particles and MO development starts some distance from the particles. At a certain distance, the MO reproduction increases drastically, i. e. according to the diffusion gradient, at a certain distance the substance concentrations formed produce a stimulating effect on the microorganisms.

This latter effect is typical of physiologically active substances. As a rule, a single kind of bacterium is developed, or sometimes two kinds. Thus, when discretely distributed, pesticides of this type produce both positive and negative effects on the same microorganisms simultaneously. Under heterogeneous soil conditions this effect is disconnected in space.

The second type of microflora formation is characteristic of pesticides having narrow selective action. In this case there are no sterile zones around the pesticide particles. Some time after these particles enter the soil, they become covered with microorganisms. On the very surface of the particles and in their immediate vicinity fairly large bacterial groups, microcolonies and films are formed, giving a picture similar to that of natural polimers /cellulose, chitin, India rubber, etc./ becoming covered. In this case, as a rule, an MO monoculture is formed by the first microorganism to contact the pesticide particles and colonize them. The accumulation of bacterial biomass around the preparation proceeds slowly and in different ways for different particles disconnected in space. Thus, in the case of hexachlorocyclohexane and atrazine, even 5 months later almost sterile crystals were detected alongside pesticide crystals overgrown with a dense bacterial film. The latter demonstrates the specificity of the microflora overgrowing the pesticide and to the microzonal character of its distribution within the soil.

Beyond the limits of a small zone adjacent to the particle, no significant microflora changes are observed. Consequently, the effect of pesticides on soil microorganisms is limited to a relatively small soil volume.

Calculations indicate that with a pesticide dose of 1 kg per hectare and a particle mass of 10 μg, 1 cm^3 of treated area contains one particle. If we bear in mind that pesticides are mainly distributed within the upper 10 cm layer, a single particle will be contained in 10 cm^3. In practice, for superficial soil treatment with pesticides their content decreases drastically with depth. Therefore, the most active soil layer /5-20 cm/ from the microbiological point of view contains only a small fraction of what is distributed on the surface. Hence, it can be concluded that the interparticle distance is hundreds or thousands times greater than their physical size. Therefore, under heterogeneous soil conditions there always exist recesses where no pesticides are present or where very low concentrations of them are found.

Observations indicate that the hyphas of fungi and actinomyces actively avoid contact with particles of tetramethylthiuram-disulphide, basudin and hexachlorocyclohexane, by bypassing them. Hence, it may be supposed that negative chemotaxis is of significant importance for the self-preservation mechanism of these microorganisms.

It follows from the above that the pesticide resistance of the soil microbiological processes is determined not only by the chemical nature of a compound and the MO physiological resistance to it, but also by the uneven, discrete distribution within the soil and the presence of pesticide-free zones. This provides a significant safety factor for the soil as a biological system and makes it capable of recovering its potential after these substances are eliminated.

It should also be pointed out that the prolonged, systematic application of pesticides eventually leads to disastrous consequences for the trophic group of microorganisms that represent targets.

The negative effect accumulates as the years go by. A number of species prove to be entirely excluded from the microbiocoenosis. There is a change in the predominant species. The specific diversity index decreases drastically. The whole of the microbiocoenosis structure changes.

It is thus obvious that soil-microbiological monitoring should be organized.

This monitoring should be based on an analysis of the most sensitive target microorganisms for each group of pesticides.

Integral indicators of biological activity, such as the overall MO biomass or soil respiration, are less informative, as the destruction of some species is compensated for by the more intensive development of the others. Accordingly, a negative pesticide effect on some soil biota components is levelled out by a positive effect on the others.

These considerations form the basis for the soil microbiological estimation and pesticide monitoring scheme presented in Fig. 2.

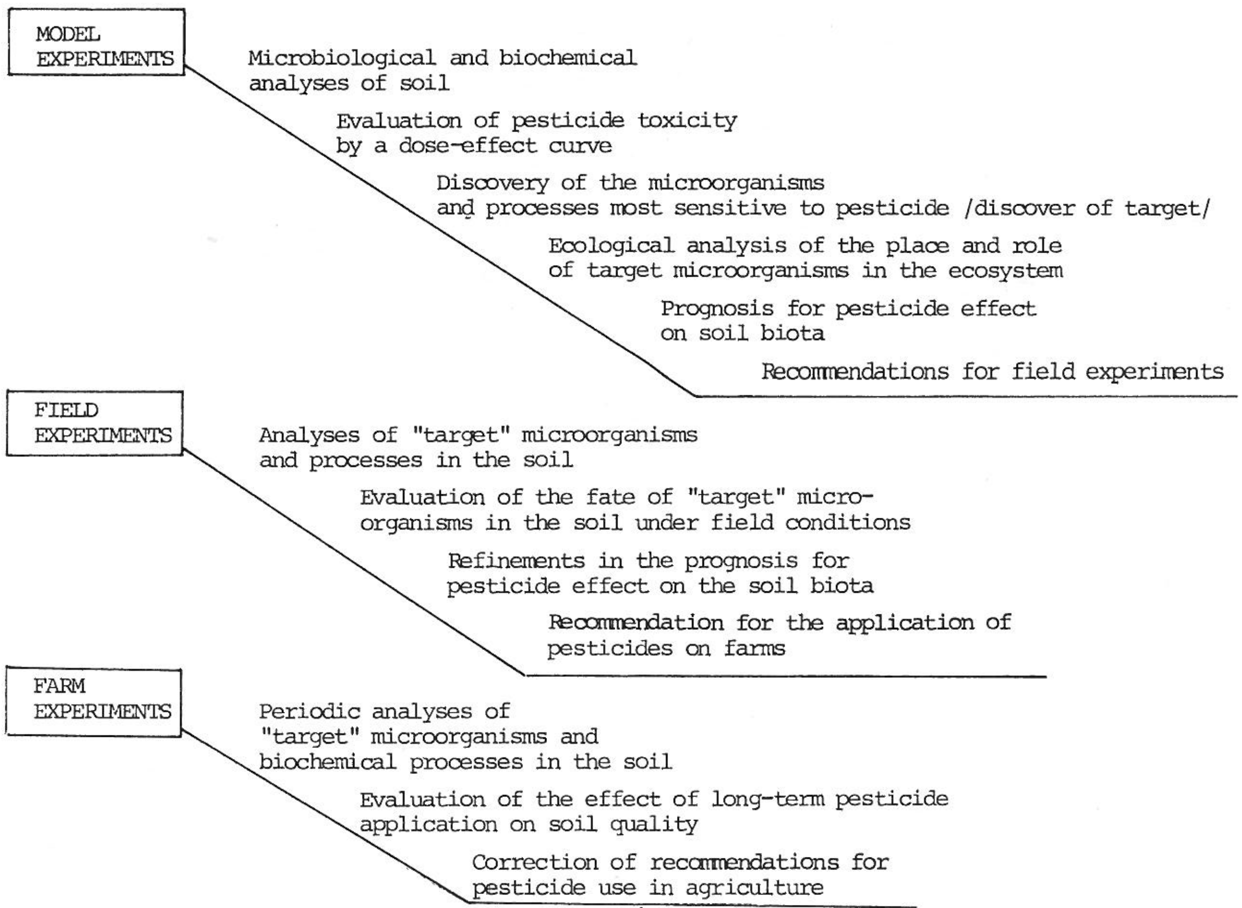

Fig. 2

Scheme for the soil microbial evaluation of pesticide toxicity