THE INFLUENCE OF PESTICIDES AND PEST MANAGEMENT STRATEGIES ON WILDLIFE

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ABSTRACT

On base of 12 chemical-physical parameters and 10 ecotoxical and toxical parameters the model SYNOPS 1.0 to assess and compare the risk potentials of active ingredients of pesticides was developed. The ranking of the 6 compared substances is visualized by risk graphs.
A strong integrated pest management (IPM) can reduce the entry of pesticides. The main IPM-elements are: usage of thresholds, dosing of pesticides according to situation, use of resistant and tolerant cultivars, usage of forecasting models, use of biological methods etc..
Edges, linking biotopes and set-aside programmes do also have positive effects on wildlife.
In two production experiments the effect of intensity of production factors (fertiliser, pesticides) and different farm management systems (organic-traditional), respectivly, were investigated.
In the intensity-experiment only a slight negative influence on wildlife was observed, in the system-experiment (survey) a some bigger difference could be shown.

INTRODUCTION

For centuries man's agricultural activities have created a landscape which forms an essential basis for the diversity in biotopes and species reaching a height in the 19th century. However, intensification of agriculture over the last decades (fertilisation, pest management, specialisation and concentration in production) is regarded to have primarily caused the rapid decline in plant and animal species. For this reason, ways must be found to connect better nature and landscape conservation with crop and animal production without losing sight of the prime aim of agriculturists - the production of foodstuff. Such new strategies have to be elaborated based on scientific knowledge of the effect of crop management systems on wildlife.
In the following greater attention is given to the effect of plant protection. First the action of individual pesticides is investigated with the help of a model for the synoptic assessment of the risk potential of active ingredients of pesticides.
The development of mathematical models which show the effect of pesticides in ecosystems is still at the beginning and becomes very difficult with increasing complexity of the ecological system. It seems to be hardly possible to elaborate models which quantitatively forecast the effect of whole strategies within a crop management system. We

can only make general qualitative statements and produce individual quantitative results from comparative investigations.
Therefore, the second part of the present work attempts to compare the effect of components of integrated pest management, the role of edge and linking biotopes and the effect of land set-aside with the demands of nature conservation and to provide quantitative evidence for it. This is based on two long-term experiments and surveys at different agricultural sites of Germany comparing various intensities as well as forms of crop production (organic - conventional)(BARTELS and KAMPMANN (ed.), 1994; KÖNIG *et al.*, 1989).

THE COMPARATIVE ASSESSMENT OF THE RISK POTENTIAL OF ACTIVE INGREDIENTS OF PESTICIDES

As far as plant protection in Germany is concerned the amendment of the Plant Protection Act of 1986 has enhanced the attention to aspects of environment protection for the registration of pesticides. For instance, a large number of chemical and physical and ecotoxicological data with respect to the environmental fate of the chemicals have to be presented. Ecotoxicological risk assessments are mostly based on monospecies tests. In this connection the amount of aquatic (empiric) data is bigger than that of terrestrial ones. Investigations with the help of model ecosystems (mezocosmos) are still at the beginning and show a wide range of methodological difficulties (SCHLOSSER, 1994).
The available data form the basis of a model (SYNOPS 1.0) to assess and compare the risk potentials of active ingredients. To assess as many active ingredients as possible a compromise between the size of the assessment model and the available data had to be made. The necessary input data are:

<u>chemical physical parameters</u>

DT50	soil	(disappearance time 50)
DT90	soil	(disappearance time 90)
DT50	water	
DT90	water	
DT50	photolysis	
DT50	hydrolysis	
DT50	volatilisation	
VP	vapour pressure	
Kp	partition coefficient solid-water	
Koc	partition coefficient organic carbon water	
lPow	logarithmic partition coefficient n-octanol-water	
SOL	solubility	

<u>ecotoxicological and toxicological parameters</u>

LC50	earthworm (lethal concentration 50)
NOEC	earthworm (no observed effect concentration)
BCF	bioconcentration factor earthworm
LC50	Daphnia
NOEC	Daphnia
LC50	fishes
NOEC	fishes
BCF	fishes
NOEL	mammals (no observed effect level)
NOEL	birds

The assessment model consists of 8 steps. They will be below explained. A presentation of the mathematical formulas is renounced for reasons of space.

<u>Sphere of application and load</u>

Starting point for the determination of the risk potential of each active ingredient is its sphere of application. It is mentioned in the registration and we understand by it the number of all possible applications against certain harmful organisms (group of harmful organisms) on a certain crop at a certain growth stage of this crop. In case of repeated applications against a harmful organism the maximum number given in the registration is assumed. On applying a pesticide not only the target (for instance the leaves of a crop) is loaded, but also other compartments (plant, soil, surface water). To calculate the load of the compartments a simple table is used containing the percentage distribution of the applied volume to plants, soil and drift. An example is shown in the following table:

Distribution of active ingredient after application

	from EC	to EC	plant (%)	Soll (%)	soilwater (%)
sugar beet	0	0	0	99,9	0,1
sugar beet	1	12	14,9	85	0,1
sugar beet	13	19	34,9	65	0,1
sugar beet	20	33	64,9	35	0,1
sugar beet	34	49	94,9	5	0,1
hop	0	0	0	96	4
hop	1	39	51	45	4
hop	40	59	71	25	4
hop	60	99	86	10	4
winter wheat	0	0	0	99,9	0,1
winter wheat	1	29	14,9	85	0,1
winter wheat	30	39	54,9	45	0,1
winter wheat	40	99	89,9	10	0,1

Indices and environmental exposure

Indices of the environmental exposure are the short-term predicted environmental concentration (sPEC) and the long-term predicted environmental concentration (lPEC) of the substance in the compartments soil, surface water and air. The short-term predicted environmental concentration reflects the amount of substance entering the above-mentioned compartments immediately after application. As a consequence of chemical-physical reactions, but mainly microbial processes, the active ingredient decomposes with time. How long how much of the substance is still present in the environment is calculated with the long-term predicted environmental concentration.

A proportion of the substance deposits to soil or sediment particles of the surface water in a way that it cannot decompose. It is also represented by an index (Cm).

Indices of the biological risk

The biological risk of the substance is calculated as an acute biological risk (abr) and a chronic biological risk (cbr) for earthworms, aquatic invertebrates and fish. The acute biological risk is the ratio of the short-term predicted environmental concentration to the lethal dose 50 of an active ingredient, i. e. the dose at which 50% of the load organisms die. The chronic biological risk is the ratio of the long-term predicted environmental concentration to the no observed effect level (NOEL) of the active ingredient, NOEL is the dose at which no effect on the organism under investigation could be observed.
To take into account the risk that a substance can accumulate in fatty tissue of an organism, the so-called bioconcentration factor (BCF) is determined for earthworms and fish as another index of the biological risk. The accumulation risk is compared with the NOEL of the substance for birds and mammals. The established ratio is called food chain risk (fcr). It expresses the risk that a substance also affects more highly-developed animal species.

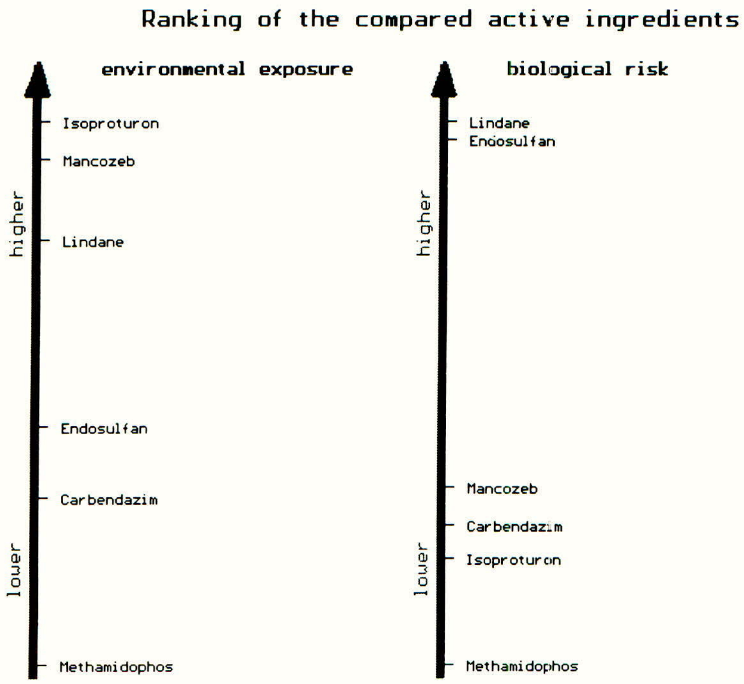
Visualisation of the risk potentials

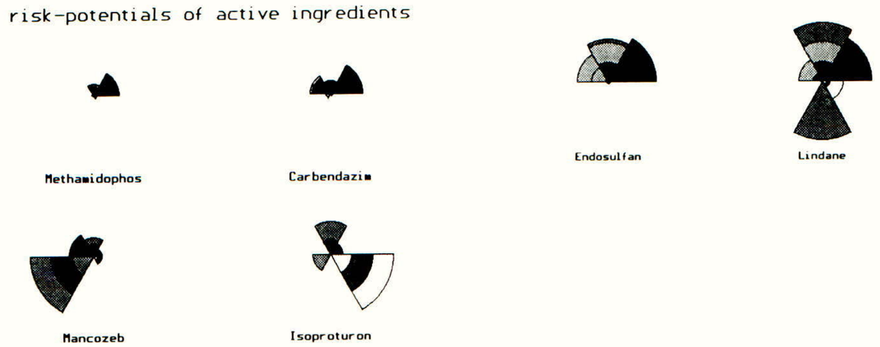
It is a general problem of technology assessment, which comprises also risk assessment of active ingredients, to visualise complex situations in such a way that they are understandable at first glance.
Finally SYNOPS procedure results in a ranking of the compared active ingredients. The ranking is illustrated with the help of a risk graph.

This risk graph is a circle divided into six sectors. Each sector is in turn divided into segments corresponding to the individual indices. The lower 3 sectors characterise the presence of the substance in the environment. Left the environmental exposure in water, right in soil and in the middle in the air. The upper 3 sectors represent the biological risk. Left to aquatic life, right to soil life and in the middle accumulation and food chain risk.

Example assessment of the risk potentials of six active ingredients

The following active ingredients were assessed: the insecticides methamidophos, endosulfan and lindane, the fungicides mancozeb and carbendazim and the herbicide isoproturon.
Methamidophos, mancozeb and isoproturon are according to the Industrieverband- Agrar e.V. (IVA) (Federation of Agricultural Industries) the best-selling active ingredients of their respective groups in Germany in 1993. Endosulfan and lindane are two "old" active ingredients which are not registered any more or only with restrictions.
To enable an overall assessment of their risk potentials, the registration situation of 1990 is assumed. Consequently various groups of active ingredients as well as "old" and "new" active ingredients are compared. The number of potential applications varied between 7 and 11 with the exception of mancozeb. Because of the high number of repeated treatments 26 possible applications are assumed.





The figure shows risk ranking and risk potentials. A difference is made between environmental exposure and biological risk. No doubt the more important group is the biological risk because the mere presence of a substance in the environment does not provide a risk. The risk graphs of the active ingredients demonstrate the ranking procedure. Large areas correspond to a high risk potential, small ones to a low one.
The "old" active ingredient lindane has both the highest total and the highest biological risk. Although isoproturon ranks second in the total risk, its biological risk is far lower. Its risk graph reveals that the relatively high environmental exposure (lower segments) does not change to a high biological risk (upper segments). The fungicidal active ingredient mancozeb shows a similar assessment. The situation is dramatically reversed for endosulfan. Despite a low environmental exposure it involves a high biological risk.
The new active ingredients reach only 50% of the biological risk potential of the "old" ones, whereas methamidophos, mancozeb and isoproturon, the best-selling ones, have the lowest biological risk potentials.

POSSIBILITIES TO REDUCE THE ENTRY OF PESTICIDES BY MODERN PEST MANAGEMENT

The observation of the principles of integrated pest management is theoretically part of good conventional farming. But in practice there is especially in arable farming a considerable deficit. In the following we explain several elements of integrated pest management which lead to a reduction of the entry of chemical-synthetic pesticides into the environment and thus contribute to the conservation of wildlife.

Use of thresholds

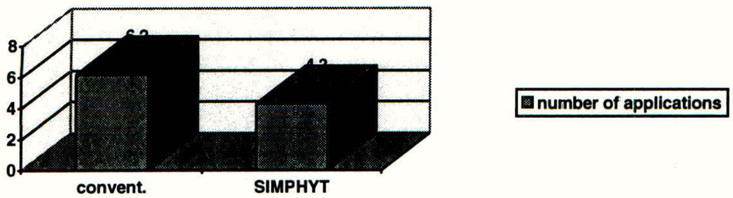
Germany has known thresholds for more than a hundred harmful organisms (including weeds). They are partially based on careful examination of the infestation-damage ratio, partially on simple calculations and experience (FREIER *et al.*, 1994). From a critical point of view the use of fixed thresholds is doubtful because infestation and infection, yield formation and economic efficiency of pest management are subject to strong dynamics (LAUENSTEIN, 1991). Therefore scientists have the task to provide variable thresholds depending on the situation for the most important harmful organisms.
Initial considerations are concerned with beneficial thresholds for pest enemies in agroecosystems. Beneficial thresholds represent the minimum density of beneficial organisms to control pest populations (FREIER, 1993). They are important especially when pest pressure is low.

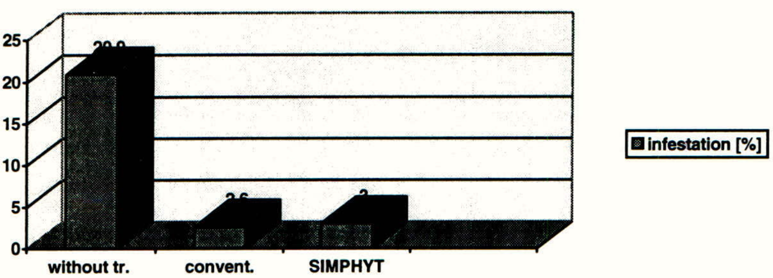
Dosing of pesticides according to situation

The reduction of dose rates, especially of fungicides and herbicides, is of growing importance in German pest management. Numerous experiments have been carried out by the Plant Protection Services of the Lands and the results are used for advising agriculturists. A reduction of the dose rate by 25-50% is not unusual. For fungicides there are investigations to make the dose rate dependent on infection pressure. It is planned to use epidemic models for the calculation of the infection pressure.

Use of forecasting models for pests and diseases

Model forecasting procedures for important harmful organisms should be possible to reduce prophylactic chemical treatments. At present a model project supported by the Bundesministerium für Ernährung, Landwirtschaft und Forsten (Ministry for Food, Agriculture and Forestry) tests nation-wide 11 model-based forecasting procedures and introduces them into practice. The below figure shows as an example the result for potato blight. It reveals a considerable potential to economy on numbers of spray applications.





Use of modern technology

Feedback/Recovery sprayers (tunnel devices) can economise to 1/3 of the dose rate in fruit and wine growing (GANZELMEIER *et al.*, 1993). This leads to a considerable reduction of soil load through pesticides and airborne drift and is especially important for the conservation of the environment.

Use of resistant and tolerant species

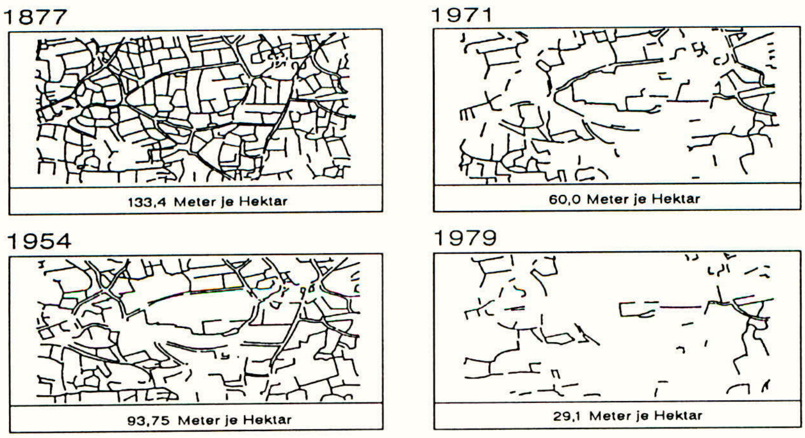
Classical breeding as well as genetic engineering are more and more aimed at disease resistance. In addition research is concerned with the induction of defence mechanisms inherent in plants by specific pathogens, microbial metabolic products or saprophytes (induced resistance). Resistance or increased tolerance to plant diseases means automatically renunciation or strong reduction of fungicide applications.

Use of biological measures

This is above all the use of microorganisms and of predators and parasitoids against harmful organisms or the disturbance of their behaviour by pheromones and repellents. Biocontrol is already of great importance for glasshouse crops. For outdoor crops there are only a few examples (*Trichogramma evanescens* against the corn borer, virus preparations against the codling moth, *Bacillus thuringiensis* against butterfly larvae and the Colorado beetle).

THE ROLE OF EDGE AND LINKING BIOTOPES FOR NATURE CONSERVATION

Consolidation and extension of plots have produced monotonous agricultural landscapes in many parts of Germany. This is a very serious problem in the East German Lands, where arable fields of more than 100 ha are not unusual. This increase has a decisive influence on the area of edge biotopes (hedges, arable field margins, boundary strips). An example of changing of hedge structure in a agricultural landscape between 1877 and 1979 is given in the following figure (KNAUER, 1988).



Edge biotopes are of eminent importance for the maintenance of the natural species diversity in agricultural landscapes. A compromise has to be made between economic field size and biotope linking. In this connection those calculations on the basis of the data collection of the Kuratorium für Technik und Bauen in der Landwirtschaft (Committee for Technology and Construction in Agriculture) (DOHNE, 1989; HEISSENHUBER and HOFMANN, 1992) are of interest which say that the amount of labour increases dramatically for fields smaller than 5 ha, but does not decrease significantly for fields larger than 10 ha.

All Lands of Germany have schemes facilitating the maintenance and creation of edge and linking biotopes (PLANKL, 1995).
The following facts have been gleaned from various scientific investigations regarding the role of edge and linking biotopes for nature conservation.

Hedges
(GLÜCK and KREISEL, 1989; NACHTIGALL, 1994; STECHMANN and ZWÖLFER, 1988; ZWÖLFER *et al.*, 1984)

- An increasing number of woody plants is increasingly ecologically important for animals.
  Hedges are an important habitat for birds. A study in Hessen Bundesland (Hesse Land) recorded 60 species within 2 years.
- Hedges are an important habitat for beneficial organisms. Out of 55 species 83% were entomophagous ones.
- Hedges are linking elements especially for soil-living animals with high mobility (e.g. Carabidae).
- They form a greater reservoir for beneficial arthropods than for pests.

Boundary strips
(KOTKA, 1984; MOLTHAN, 1990; NACHTIGALL, 1994; SCHWENNINGER, 1987; WELLING, 1990)

- They are an important source of food for carabid species.
- Margin width, number of flowers and number of syrphid flies form a positive correlation.
- Their flowering plants are a source of food for a large number of beneficial insects.
- Boundary strips 0.6 m wide had 18 species of syrphid flies, field margins 1.5 m wide had 28.
- Minimum width of strips should be 1-2 m, otherwise they have insufficient effect.
- Aphid infestation on a field edge adjacent to a field margin of 3-4 m was found to be 50% lower than in the field.
- Migration of carabids up to 200 m into the field has been reported.
- Herbaceous boundary strips showed a larger number of species (carabids) than gramineous ones.

Arable fields margins
(KLINGAUF, 1988; NACHTIGALL, 1994; SCHUMACHER, 1984; WELLING *et al.*, 1988)

- Field margins of arable fields are of special importance for the maintenance of arable weeds.
- 160 arable weed species have been found on uncultivated margins.
- The number of arable weeds showed only a slight increase in species diversity even after a 5-year experiment (Rheinland-Pfalz Bundesland (Rhineland-Palatinate Land)), because the whole region had been intensively cultivated for many years. The seed potential was presumed to be exhausted.

THE EFFECT OF LAND SET-ASIDE

The primary aim of the European set-aside scheme (VO 2293/92 EEC) is an easing of the market. The scheme allows one-year rotational fallows and five-year permanent fallows. Both options have secondary effects on nature conservation.
Rotational fallows are distinguished by naturally regenerated, sown and bare fallows. They have different effects on wildlife. Bare fallows have to be considered to be inappropriate from an ecological point of view and because of the risk of erosion and stronger nitrate leaching. They have been forbidden in Germany.

Naturally regenerated fallow
(BURTH, 1993; ELSEN and GÜNTHER, 1992; MAYKUHS, 1989; OBERGRUBER, 1990)

- A large number of species in arable weed communities is often reported.

- The contrary is also known. Many plots in Brandenburg Land (fertilised sand soil) were nearly completely covered with *Erigeron canadensis*.
- The prehistory of the fallow (nutrients, seed bank) and water content of soil are decisive for the formation of a floristic species diversity.
- In case of a species-rich flora, rotational fallows are of similar importance for carabids and syrphids to flower- rich field margins.
- Naturally regenerated fallows can raise problems with soil-borne harmful organisms (nematodes, cereal diseases), but also with snails and mice in subsequent crops. The same is true of the increase in the seed potential of weeds for subsequent crops.

Sown rotational fallow
(BAUER and ENGELS, 1992; RUPPERT, 1993; NACHTIGALL (1994))

- They are used to prevent above all nitrate leaching and an increase in the weed seed bank.
- The frequent mixture of annual flowering plants with a high proportion of *Phacelia tanacetifolia* is favourable for bees, but not optimal for syrphid flies and Hymenoptera.
- However, a mixture of indigenous weeds and weak competitive grasses (rapid soil cover) seems to be very favourable for various beneficial arthropods.

Permanent fallows
(HARRACH and STEINRÜCKEN, 1990; NACHTIGALL, 1994; SCHUMACHER, 1990)

- Permanent fallows precede scrub and woodland consequently reducing species diversity.
- Only in the first two to three years can species-rich pioneer communities be observed.
- Permanent fallows are negatively assessed in regions with extensive farming because they evolute from species-rich arable weed communities into grass and ruderal communities.

COMPARATIVE INVESTIGATION OF THE EFFECT OF DIFFERENT FARM MANAGEMENT SYSTEMS:

The results of a comprehensive production experiment and a production survey are shown. The experiment was carried out on loess soil in the Ostbraunschweiger Hügelland (East Brunswick Hills) examining four types of intensive crop production (intensity trial). The survey was made at a loess site in the Kölner Bucht (Cologne Embayment) comprising two farms with different farm management systems (organic - conventional) (farm management trial).

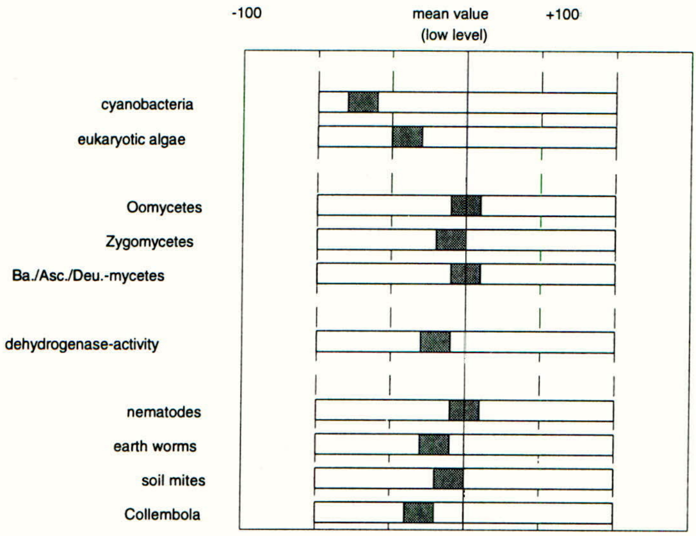
Intensity trial (1987-1989)
(BARTELS and KAMPMANN (ed.), 1994)

Rotation:	Sugar beet, winter wheat, winter barley.
Intensity degree I_0:	Without pesticides, little application of N fertiliser.
Intensity degree I_1:	Suboptimal application of pesticides and N fertiliser.
Intensity degree I_2:	Application of pesticides and N fertiliser according to recommendations of integrated crop production. Optimisation of natural yield with minimum production costs.
Intensity degree I_3:	Employment of all admissible production factors. Maximisation of natural yield.

The effect of the various intensities on soil flora and fauna was studied. The following indicator groups were used:

Algae:	cyanobacteria, eukaryotic algae;
Fungi:	oomycetes, zygomycetes, basido-, asco- and deuteromycetes;
Fauna:	nematodes, earth worms, soil mites, collembolans.
Microbial activity:	dehydrogenase activity.

The most important results are summarised as follows:
1. Cultivation and varying conditions over the three trial years had a stronger influence on the indicators than the intensity of chemical production factors.
2. The intensity of production had hardly any influence on the number of species.
3. Degree 3 led to a significant reduction of the abundance of algae and collembolans.
Dehydrogenase activity was slightly reduced. The same is true of the earth worm abundance (compare the following figure).



Altogether a slight negative influence was observed, and algae and collembolans recovered rapidly during the vegetative period because of their fast multiplication. But it has to be taken into account that the experiment was carried out in a region with many years' intensive agricultural management and drastic changes in the agroecosystem took place a long time ago. It can be assumed that the soil biocenosis consists now of euryoecious species which are hardly sensitive to disturbances.

Farm management trial (1982-1986)
(KÖNIG *et al.*, 1989)

Organic farm	Conventional farm
- 60 ha more than 10 years organic farming mixed cattle breeding - livestock number 0.5-0.6 per ha	- 100 ha - crop including form wheat, barley and sugar beet
8-year rotation	3-year rotation
Fertilisation with stable manure and rock meal	Mineral nitrogen, phosphate, potassium, magnesium and lime fertiliser
As pesticides only siliceous and herb extracts	Chemical-synthetic pesticides - herbicides (partially pre-emergence) - insecticides against aphids - fungicides (partially repeated)

Cultivation of soil showed hardly any difference. The indicators under investigation were:

1. soil physics, humus and nutrient contents;
2. microflora and soil fauna: microbial activity, earth worms, enchytraeids, collembolans, soil mites, diplopods and wood lice;
3. arable weeds;
4. arable fauna: Carabidae, Staphylinidae, Catopidae, Chrysomelidae, Silphidae, Nematocera, Brachycera, Syrphidae, Heteroptera, Homoptera, Arenae, Lycosidae, Opiliones, Diplopoda, Chilopoda, Isopoda.

The following conclusions can be drawn from the survey with respect to the indicator groups:

Soil physics, humus and nutrient contents
- Conventionally cultivated soils have a stronger tendency to drying up; other physical soil parameters did not show any difference.
- Organically cultivated soils show a tendency to acidification.
- Humus content and quality, substance content and C/N ratio did not differ.

Microflora and soil fauna
- Only earth worms are facilitated in organically cultivated soil.
- The other parameters are by far strongly influenced by natural site factors. An influence of the farm management system could not be proven.

Arable weed vegetation
- Organically cultivated soil produced in general the whole species spectrum of arable weed communities.
- The percentage of weed cover was substantially higher on organic soil.
- Conventional soil produced only fragmented communities which indicated an accumulation of nitrogen.
- Organic soil also exhibits in the long run an increase in nitrogen indicators (general eutrophication of agriculture).

Arable fauna
- Faunistic data are in close correlation with the species diversity of weeds.
- In 8 of 13 arthropod groups under investigation, the mean number of species is far higher on organically cultivated plots than on conventional plots.
- Mean catch number (or activity abundance) was higher on organic plots for 11 groups of animals and on conventional plots for three groups.
- Ground beetles (Carabidae) and spiders (Arenae) were significantly more numerous on organic plots. The other 8 animal groups did not reveal any difference.

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