CHRISTIAAN F. VAN DE BUND
Plant protection Service, Wageningen

Changes in the soil fauna caused by the application of insecticides

INTRODUCTION

The application of insecticides causes many changes in the composition of animal communities. With regard to the soil fauna much research has been done. It has been shown that DDT and BHC induce considerable quantitative changes in the *Acarina* and *Collembola* populations (GREGORJEWA, 1952; BAUDISSIN, 1952; SHEALS, 1955; BARING, 1957; KARG, 1961, 1964). Most impressive are the increased populations of Collembola and the absence or decreased numbers of the Mesostigmata caused by the application of DDT. All these mentioned investigations were obtained by examining soil samples taken periodically from plots which were treated with insecticides, once.

This investigation, which will be discussed, has been carried out on an experimental field (fig. 1) where the soil has been treated with the same quantity of insecticides each year from 1953 until now. The original purpose of the investigated field plot was to find out the persistance of insecticides in cultivated soil and the residual quantities of insecticides on the cultivated plants. It has been attempted to approximate the normal practice of application of insectides on arable soil.

This study of the soil fauna was started in 1962. This investigation concerns observations carried out from May 1962 until September 1964. The data were obtained from soil samples of field plots treated with respectively lindane, DDT, parathion and from four control plots.

In addition to the investigations in the field some observations have been done in the laboratory. The results of these investigations will be discussed in combination with the field results.

Boll. Zool. agr. Bachic., s. II, v. 7, 1965.
(Atti del 5° Simposio europeo d'Acarologia, Milano, 23-25.IX.1965)

Methods

The experimental field was divided into plots of each 12 m^2. These plots were separated by sunken concrete slabs and subdivided into six parts. These six parts were planted with different field crops. The plants used were potato, barley, turnip, beet, chicory and carrot. Crop-rotation was applied each year. Each plant species was planted into the next part of the plot in the direction of the clock after each year. The soil is light sandy and contains a little humus. Organic manure was applied every other year.

The insecticides were applied by pouring them on the soil of the plots. The plots were treated with the same quantity of insecticides each year. The quantities of applied DDT were respectively 300, 600, and 2000 mg of 25 % DDT emulsiviable liquid per square meter. For lindane these quantities were 56, 112 and 140 mg of 14 % lindane

Fig. 1 - View of the experimental plots.

emulsiviable liquid and for parathion 100, 200 and 800 mg of 25 % parathion emulsiviable liquid. The plots with the highest concentration of insecticides were treated once a year. In 1962 21/5, in 1963 5/6 and in 1964 15/5. The other plots were treated four times a year. In 1962 respectively 8/6, 10/7, 21/8, 26/9. In 1963 respectively 5/6, 2/7, 20/8, 9/9. In 1964 respectively 20/5, 10/7, 27/7, 18/8.

The soil samples were taken with a soil sampler which has a diameter of 5,5 cm at the mouth (fig. 2). 5 cm above the mouth the sampler is 0,5 cm wider. This prevents the core of soil from compressing during sampling. The sampler has a length of 20 cm. The soil sample is removed by a rod just fitting in the sampler. For analysis the cores were divided by cutting the parts representing the depths of 0-2,5 cm and 7,5-10 cm with a knife. The part representing the depth from 2,5 cm - 7,5 cm was not used for investigations. This was done to gain the possibility of obtaining more intakes from each plot. A

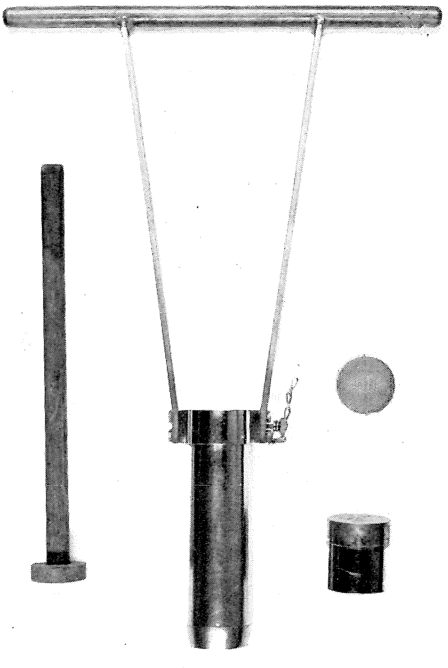

Fig. 2 - Soil sampler and a container of the cylinder extractor.

comparison of the composition of the fauna of the whole cores with the half cores did not give a real difference of the mean number of animals and species per ml of soil. From each plot six cores were taken each time. The soil samples were taken in March or April and in August or September, twice a year. The separated parts of the cores were placed into an aluminium cylinder with a perforated bottom. These perforations have a diameter of 1,5 mm. The diameter of the cylinders is 5,5 cm and the height is 2,5 cm. The filled cylinders were attached to chromed copper vials of identical diameter. These vials were filled with a little tapwater and placed in a tank with running tapwater . From above the samples were heated by 16 electric bulbs of 40 Watt (fig. 3). These lamps were placed in such a way that the surface of the samples reached a maximum temperature of ± 35° C when the soil had dried. The running water had an average temperature of ± 10° C. This method is derived from the highgradient

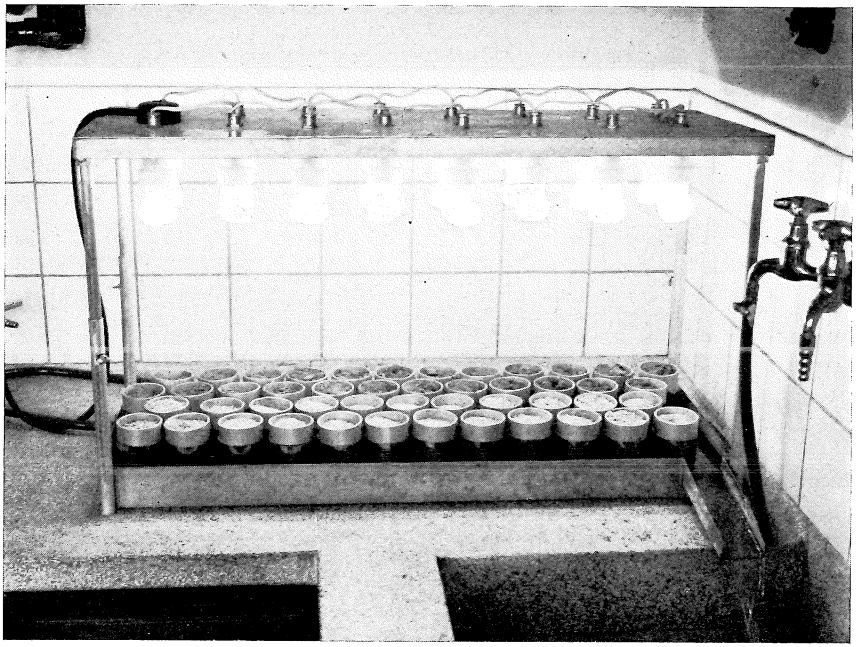

Fig. 3 - Cylinder extractor.

cylinder method of McFadyen. By this method the soil samples dry slowly and are getting a high temperature when the soil sample is completely dry. The drying process is going on from the top layer to the bottom part. This is agreeing with the normal conditions outdoors when the sun is shining. The samples are dry after 5-7 days. By these conditions the slow moving and delicate specimens will also have the opportunity to leave the soil sample. By the low temperature of the tapwater the caught animals are nearly all alive when the drying process is completed. All the *Collembola* and *Acarina* were collected after the drying process. All specimens were prepared, counted and identified. For this purpose the catch was poured into a petri dish and the vial was thoroughly rinsed with 96 % alcohol. This alcohol used for rinsing was also poured into the petri dish. There upon some alcohol 96 % was added to make the mixture about 3 parts alcohol and 2 parts water. After some days the mites and springtails were transferred into a cavity-slide filled with lactic acid with a micro needle with a small loop. These slides were closed with a coverglass. After storing at roomtemperature about two or three weeks the mites and springtails are suitable for microscopic identification.

RESULTS

The application of insecticides caused remarkable changes in the composition of the fauna as well as in the number of the specimens of each species. The greatest number of species was found in the untreated plots. In the untreated plots the mean number of species per sample of 62,5 ml of soil was 6,50 mite species and 3,16 springtail species. In the plots treated with DDT, 3,33 mite species and 4,16 springtail species. In the plots treated with lindane 5,00 mite species and 2,16 springtail species. In the plots treated with parathion 6,16 mite species and 2,33 springtail species (fig. 4). It is obvious that the mean number of species per sample decreases with an increasing concentration of the applied insecticide (tab. I, fig. 7).

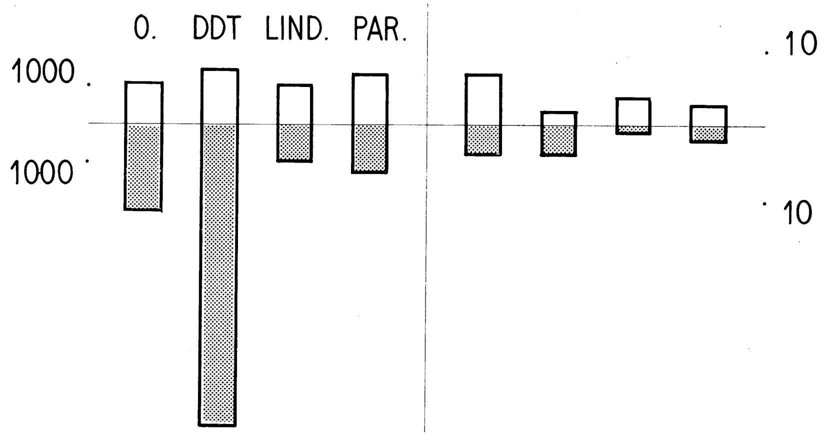

Fig. 4 - Left: Upper part, number of *Acarina* per 3,5 l of soil
Lower part, number of *Collembola* per 3,5 l of soil
Right: Upper part, mean number of *Acarina* species per sample of 62,5 ml of soil
Lower part, mean number of *Collembola* species per sample of 62,5 ml of soil.

TABLE I. - *Mean number of species per sample in September 1964*

			Range				Range
Control	6.77	Acari spp.	1-13	4,01	Collembola	spp.	1-8
DDT I 3600 mg*	4.58	» »	2-7	6.33	»	»	4-10
DDT II 7200 mg*	3.16	» »	0-5	5.91	»	»	1-11
DDT III 24000 mg* . . .	2.50	» »	0-5	4.08	»	»	3-6
Lindane I 672 mg* . .	5.91	» »	2-11	3.15	»	»	1-6
Lindane II 1344 mg* . .	3.66	» »	1-8	2.83	»	»	1-5
Lindane III 1680 mg* . .	4.00	» »	2-8	1.31	»	»	1-3
Parathion I 1200 mg* . .	6.75	» »	3-11	2.66	»	»	1-5
Parathion II 2400 mg* . .	6.08	» »	1-16	2.83	»	»	1-5
Parathion III 9600 mg* . .	2.75	» »	0-7	1.83	»	»	1-2

It is clear that the plots treated with DDT had a greater mean number of *Collembola* species than the other plots. The number of mite species is the smallest. The *Collembola* species were mostly affected in the plots treated with lindane and parathion. More impressive are the differences in the total number of specimens of the *Collembola* and *Acari* in general (fig. 4). Table IX and X show the number of specimens of *Acari* and *Collembola* in 4 $\times$ 3,5 liters of soil taken during the entire sampling period. The most important fact is the great increase of *Collembola* in plots where DDT is applied and the great decrease of the number of *Collembola* in the plots treated with lindane and parathion. The number of springtails in the DDT-plots is 5 times the number of mites. In the untreated plots this ratio was 2 : 1 and in the plots treated with lindane and parathion the number of springtails and mites was about equal.

There is also a remarkable change in the composition of the fauna. The most obvious is the disappearance of the predacious mites, the *Mesostigmata*, in plots where DDT is applied. These mites already decrease after an application of a low concentration of DDT.

In the plots with the highest concentration of DDT the *Mesostigmata* are lacking. The predacious mite, *Rhodacarus roseus* is very susceptible to DDT. This species was lacking in all soil samples from the plots treated with DDT (fig. 5 and 8). The reverse to this decrease of the predacious mites is the great increase of *Tyrophagus dimidiatus*, that forms the bulk of the *Acaridiae*. The *Oribatei*, e.g. *Oppia nova*, *Brachychthonius berlesei* and *Brachychthonius brevis* also increased in the plots treated with DDT. The increase of these populations was specially considerable in plots with the lowest concentration of DDT. This increase was even more pronouced with *Collembola* (fig. 8 and 9). The springtails, (specially *Tullbergia krausbaueri, Isotomodes pro-*

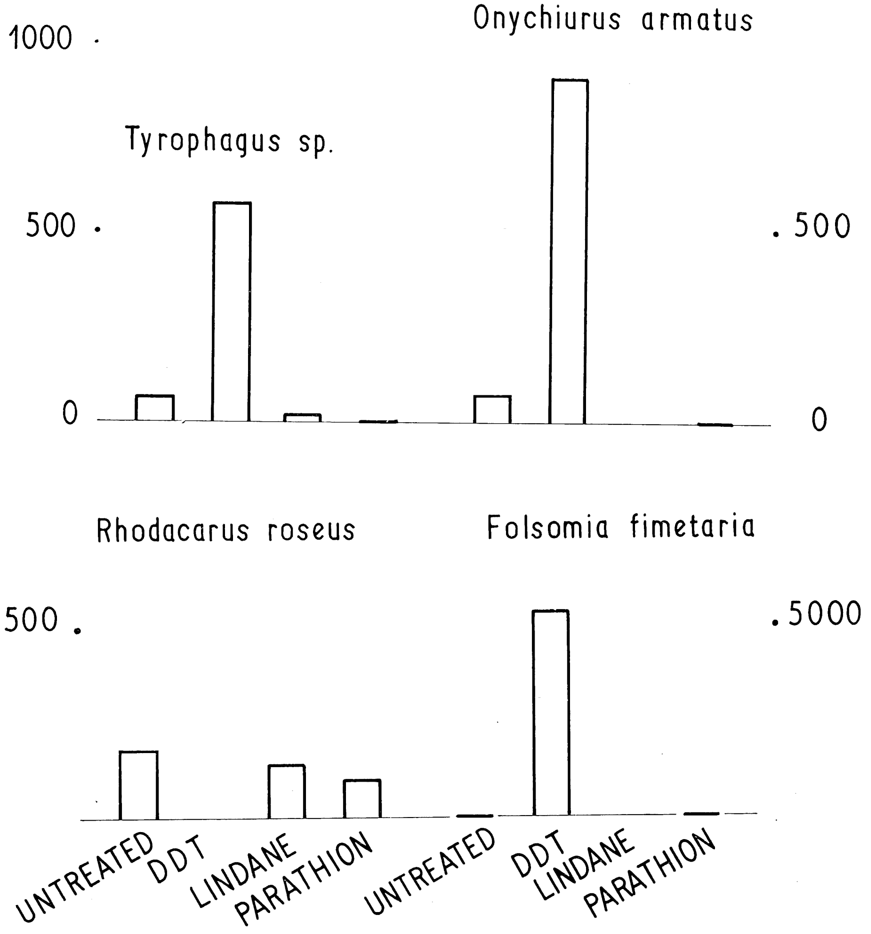

Fig. 5 - Number of specimens of *Tyrophagus* sp., *Onychiurus armatus, Rhodacarus roseus* and *Folsomia fimetaria* per 3,5 l of soil.

ductus, Isotomina bipunctata and *Heteromurus nitidus*) also occurred in the greatest populations in the plots with the lowest concentration of DDT. With the highest concentration of DDT the number of springtails decrease and the population of some species can be lower then in the untreated plots. The disappearance of *Isotomodes productus* in plots with the highest concentration of DDT was notable. Contrary to this the population of *Onychiurus armatus* increased proportionately with the increasing concentration of DDT.

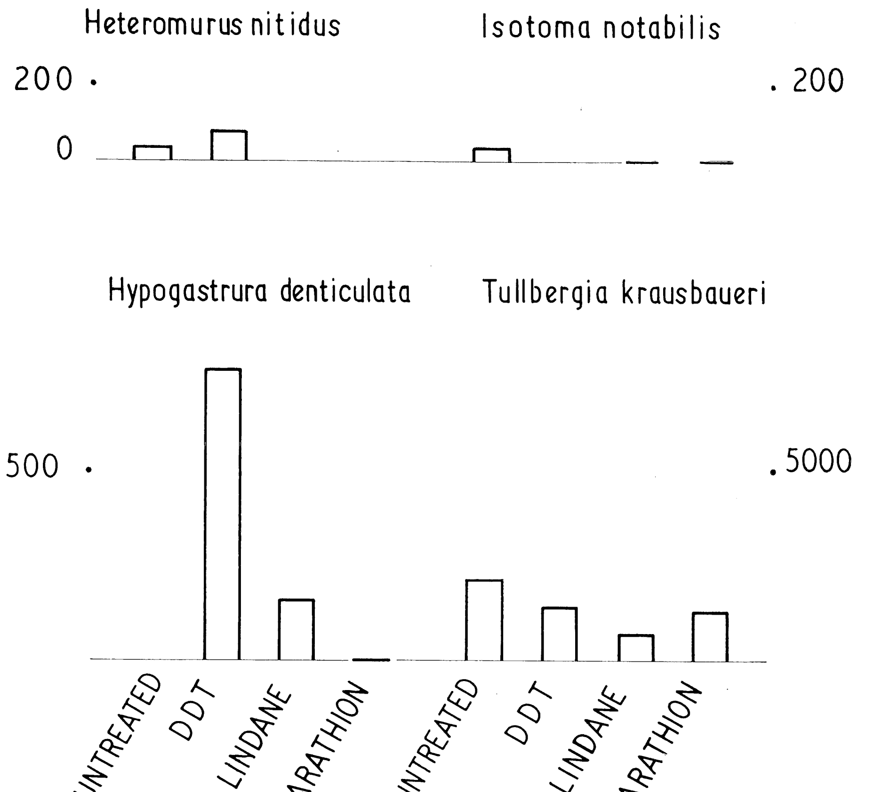

Fig. 6 - Number of specimens of *Heteromurus nitidus*, *Isotoma notabilis*, *Hypogastrura denticulata* and *Tullbergia krausbaueri* per 3,5 l of soil.

In the plots treated with lindane the populations of the mites and the springtails are decreasing in proportion as the concentration of this insecticide was higher (fig. 10). Exceptions were *Isotomodes productus* and the mite *Variatipes quadrangularis*. The population of *Isotomodes productus* increased with the two lowest concentrations of lindane, but with the highest concentration this species disappeared. *Brachystomella parvulus* was very abundant in the plots with the highest concentration of lindane. The predacious mites were slightly affected by the lindane especially with the highest concentration. Generally most species of *Collembola* disappear in the plots with lindane. The mites decreased heavily in number but most species do not disappear totally.

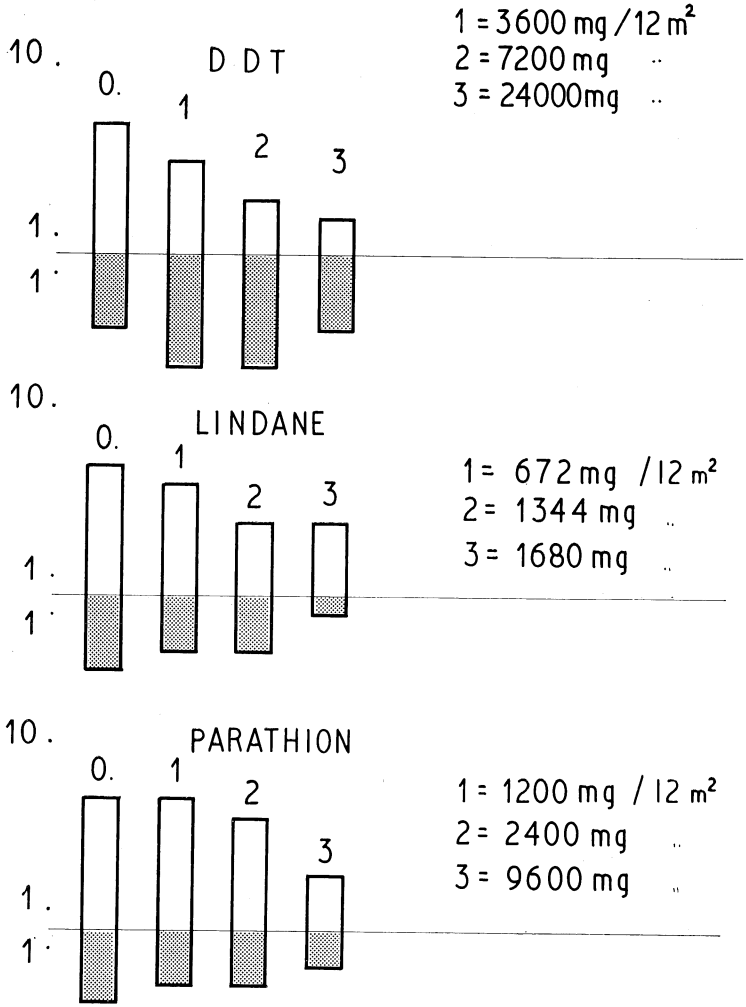

Fig. 7 - Upper part: mean number of Acarina species per 62,5 ml of soil
Lower part: mean number of Collembola species per 62,5 ml of soil.

The mites were not or not much affected in the plots treated with parathion with the lower concentration. However the populations of the mites were considerably affected with the highest concentration (fig. 11). The predacious mites, the *Mesostigmata*, survived even with the highest concentration. Most of the observed *Collembola* species decreased in proportion to the higher concentrations of parathion. Exceptions were the springtail species *Isotomodes productus* and *Tull-*

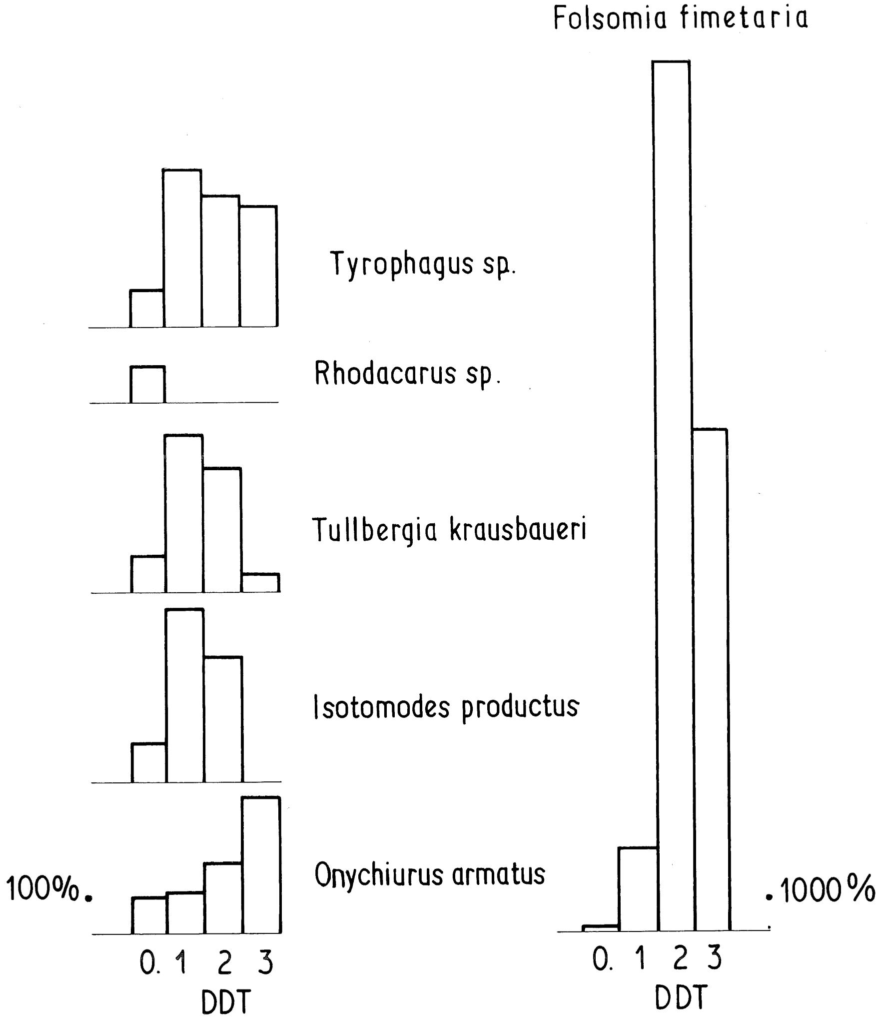

Fig. 8 - Number of Acarina and Collembola species in untreated plots and in plots treated with 300, 600 and 2000 mg of DDT per m^2. Untreated = 100 %

bergia krausbaueri. The largest populations of these species were found with the highest concentration. Also the mites of the genus *Pygmephorus* increased considerably in number.

Discussion

DDT, BHC and lindane are known as very persistant insecticides which appears from a residue in the soil long after application.

These insecticides affect the soil fauna for a considerably long period. Baring found that the populations of several species of mites of the *Prostigmata, Tyrophagus* species and *Tectocepheus velatus* were

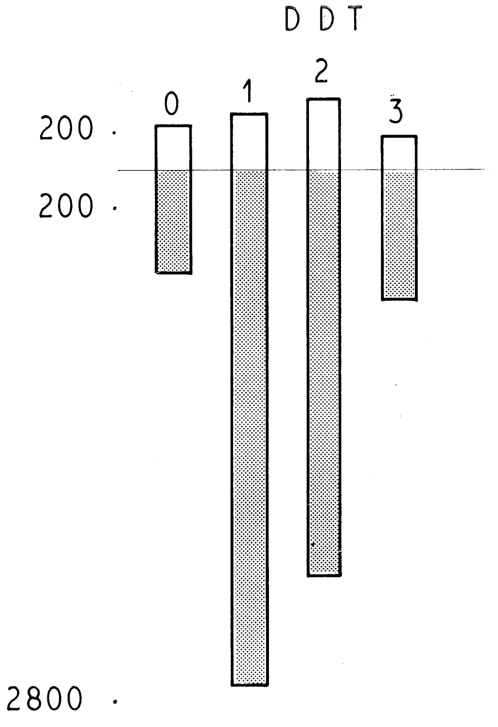

Fig. 9 - Number of specimens per 0,75 l of soil in untreated plots and in plots treated with 300, 600 and 2000 mg of DDT per m^2 in September 1964. Upper part: Acarina, Lower part: Collembola.

seriously reduced by an application of BHC after 392 days. Sheals also showed the effect of an application of DDT or BHC after a year. Karg found evidence of an effect of a BHC application even after 3½ years.

An investigation carried out by the Keuringsdienst van Waren at Amsterdam in 1962 has shown that the soil of the investigated experimental plots treated with DDT with the lowest concentration contained

1,52 ppm DDT as a residue in the soil layer of 0-5 cm and 2,07 ppm in the layer of 5-15 cm below the surface. With the medium concentration the soil contained respectively 6,57 ppm and 5,4 ppm DDT and with the highest concentration respectively 47,8 ppm and 48,2 ppm DDT. That means, that 25 %, 38 % and 43 % of the total quantity of the used DDT is recovered as a residue in the soil layer of 0-15 cm below the surface.

No residue is recovered in the plots treated with the lowest concentration of lindane. In the plots treated with the medium concentration of lindane 0,2 ppm was recovered in the soil layer of 0-15 cm below the

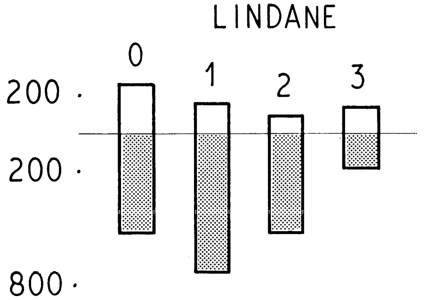

Fig. 10 - Number of specimens per 0,75 l of soil in untreated plots and in plots treated with 56, 112 anl 140 mg of lindane per m² in September 1964. Upper part: Acarina. Lower part: Collembola.

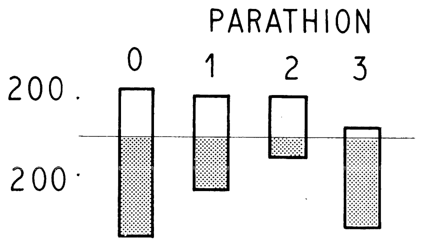

Fig. 11 Number of specimens per 0,75 l of soil in untreated plots and plots treated with 100, 200 and 300 mg of parathion per m² in September 1964. Upper part: Acarina. Lower part: Collembola.

surface. With the highest concentration 1,2 ppm was recovered in the same soil layer. In the soil treated with the medium and highest concentration of lindane respectively 7 % and 14 % of the total used quantity of lindane was recovered as a residue. The quantity of parathion residue that was recovered was 0-0,04 ppm, which was of no importance.

The observed changes in the population of the mites and springtails corrobate in many aspects with what was found by SHEALS, BARING and KARG. This is remarkable for these investigations had reference to a single treatment of DDT, lindane or BHC. It would be more probable that the consequence of the treatment with such persistant insecticides during 12 years were more severe. The most reasonable explanation may be that the insecticides are not homogeneously mixed with the soil even after 12 years of application. So the animals have enough possibilities to escape the spots with a lethal concentration of the insecticide. We have to regard that the humus content and the structure of the soil can be very important to retain quantities of insecticides. In the investigated plots organic manure was applied every other year. So there was also an adding of untreated particles and populations of mites and springtails. We had indeed observed these facts. In the plots treated with the lowest concentrations of DDT a great number of the predacious mite species *Hypoaspis aculeifer* and *Veigaia nemorensis* were found in partly rotten clods of manure. These mites predated on the huge populations of the springtail *Folsomia fimetaria*. These predacious mites were lacking in the treated soil outside these manure clods although *Folsomia fimetaria* was very abundant in this soil.

It is known that DDT easily fixes in humus and organic matter. However this insecticide is not soluble in water and has a very low vapour pressure. So in soil with fixed DDT it is not probable that this insecticide will penetrate in the manure which is freshly applied into the soil. It is also probable that there will be a number of spots in the mineral soil with a very low content of DDT or without this insecticide. So it will be possible to escape the insecticide.

With lindane and parathion the relations are quite different. Parathion is slightly soluble in water and both insecticides have a greater vapour pressure. It is also known these insecticides can be more or less absorbed in plant tissue and they will be fixed in humus and organic matter. It is possible that lindane and parathion already present in the soil can penetrate freshly added manure by the vapour phase and with parathion also more or less by solution in water. There is also a possibility of poisoning of an important part of the food e.g. fungus hyphae and dead organic matter. This may be partly an explanation of the great decrease of the *Collembola* and the mites belonging to the *Sarcoptiformes*. KARG (1964) showed that *Collembola* and *Acarina* can be killed by the vapour phase of lindane and BHC. He also showed that lindane, which has a considerably higher vapour pressure, causes a greater decrease of the *Collembola* and *Acarina* population than technical BHC and 80 % BHC.

The great increase of the *Collembola* after application of DDT into the soil will probably be caused by the eradication of their most important predators, the *Mesostigmata*. With the highest concentration of DDT the populations of several species of *Collembola* and also of

Sarcoptiformes decrease or those of some species disappear. So it is very probable that these animals are also susceptible to DDT at least in the higher concentrations.

Observations in the laboratory

Tests of the susceptibility of *Onychiurus* to insecticides in glassvials.

Methods: To test the susceptibility of *Collembola* to DDT a great number of specimens of *Onychiurus bicampatus* Gisin was tested to insecticides in the laboratory. The animals were placed in cavity-slides with a little piece of wet filterpaper and a piece of cotyle of white clover as food. Before putting the insect in the vial the arranged cavity-slides were sprayed with the insecticide. The insecticide was sprayed with a fog sprayer in such a way that by the speed of a conveyor combined with the quantity of the sprayed insecticide the right quantity was placed on the cavity-slide. The insecticide was dissolved in water. After the water of the spray had evaporated the insect was transferred to the cavity with a brush. After that the slide was closed with a couverslip. To prevent drying these slides were put on an island in a glass tank which was filled with water and closed with a plate of glass. Each slide was provided with one specimen of *Onychiurus bicampatus*. In each investigated series 100 cavityslides were used. After 7 days the observations were carried out.

Results: From the results it was possible to calculate the susceptibility expressed in the L.D. 50 and L.D. 90 values.

TABLE II.

L.D. 50 - DDT	0,22 mg/L	L.D. 90 - DDT	8,3 mg/L
L.D. 50 - parathion . .	0,07 mg/L	L.D. 90 - parathion . .	0,87 mg/L
L.D. 50 - lindane . . .	0,09 mg/L	L.D. 90 - lindane . . .	0,7 mg/L

It was shown that *Onychiurus bicampatus* was indeed susceptible to DDT. The susceptibility to lindane and parathion was considerably greater.

Tests of the susceptibility of *Onychiurus* to insecticides in soil.

Methods: To test the susceptibility of *Onychiurus bicampatus* in soil thoroughly mixed with insecticides, the insects were placed in small glass vials with a diameter of 12 mm and a height of 15 mm. These vials were provided with a layer of hardened plaster of Paris and active coal in a ratio of 10 : 1. On this layer was deposited a layer of homogeneous, sieved, sterilised sand (fraction 0,6-1 mm) of 1 cm height. The treated sand was previously mixed with DDT or parathion dissolved in aceton and thoroughly shaken. After the evaporation of the aceton the soil is sufficiently mixed with the insecticide and ready for the experiments.

Three adult *Onychiurus bicampatus* were put in each vial. In each concentration of the used insecticides 17 vials were used. The observation was carried out after two days.

Results: The calculated L.D. 50 and L.D. 90 values are given in table III. It is also quite clear *Onychiurus bicampatus* is susceptible to DDT in soil thoroughly mixed with this insecticide. The found L.D. 90 value was 35,5 ppm which was considerably lower than the maximum content of DDT residue found in field conditions. This value was 48 ppm. In this field plot *Onychiurus armatus* was very abundant. It was also shown that the springtails are much more susceptible to parathion as to DDT.

TABLE III.

L.D. 50 - DDT	21,88 ppm	L.D. 90 - DDT	35,5 ppm
L.D. 50 - parathion . .	8,51 ppm	L.D. 90 - parathion . .	14,13 ppm

The possibility to escape the insecticide in the soil.

Methods: To test the possibility that *Collembola* are able to avoid a dangerous concentration of an insecticide a great number of *Onychiurus bicampatus* were put in small vials filled one half with soil mixed with an insecticide and the other half filled with untreated soil.

Small glass vials of a diameter of 30 mm and a height of 15 mm were filled with a layer of hardened mixture of plaster of Paris and active coal in a ratio of 10 : 1. On this layer of plaster of Paris one half of the vial was filled with a layer of untreated sand of ± 10 mm height. The other half was filled in the same way with sand that was treated with an insecticide. An equal number of vials was arranged in the same way but here one part of the vials had an untreated island in the control part, surrounded by treated soil in size about half of the total surface. The other part was arranged as a treated island surrounded by untreated soil. In each vial 15 springtails and some germinating cloverseeds as food were put on the borderline between treated and untreated soil. After a week it was checked how many springtails were alive and on which part of the vial they were situated. Totally 72 vials were studied in this way.

Results: It was obvious the springtails preferred the untreated parts of the vial and nearly all studied animals survived the experiments even in the vials with the highest concentration of DDT. With a low concentration of DDT there was no preference between the treated and untreated part.

TABLE IV. - *Vials one half treated soil and one half untreated soil*

Number of animals on the untreated part	Number of animals on the treated part
50 ppm DDT 78 out of 90 springtails = 87 % from that 3 spr. dead	12 out of 90 springtails = 13 % from that 5 ex. dead
25 ppm DDT 73 out of 90 springtails = 81 % all alive	17 out of 90 springtails = 19 % from that 6 ex. dead
12,5 ppm DDT 49 out of 90 springtails = 54,5 % all alive	41 out of 90 springtails = 45,5 % all alive

The results of the experiments with the vials with an island of treated or untreated soil were similar.

TABLE V. - *Vials with an island of treated soil surrounded by untreated soil and the opposite*

Untreated part	Treated part
50 ppm DDT 73 out of 90 springtails = 81 % from that 2 ex. dead	17 out of 90 springtails = 19 % from that 12 ex. dead
25 ppm DDT 70 out of 90 springtails = 78 % all alive	20 out of 90 springtails = 22 % from that 10 ex. dead
12,5 ppm DDT 47 out of 90 springtails = 52 % all alive	43 out of 90 springtails = 48 % all alive

The vials partly filled with soil treated with parathion did not give a real preference between the treated and untreated part and there was a high mortality.

Discussion

The laboratory tests with *Onychiurus bicampatus* have shown that the springtails are susceptible to DDT in a lower concentration than the found residue value in the experimental plots in the field. The springtails are considerably more susceptible to lindane and parathon. The amount of DDT needed to reach the value L.D. 50 is 2,5 $\times$ greater than that of parathion. It has also been shown that the springtails are able to survive a lethal concentration of DDT when they have the opportunity to retreat to an untreated refugium. Probably the vapour pressures of lindane and parathion are the main causes for the decrease of the populations of *Collembola.* Of course there may be also a specific susceptibility to the used insecticides. By the vapour the animals are less capable to avoid a dangerous concentration of the insecticides. So it will also be probable that lindane and parathion can spread in a greater quantity of soil and there will be less refugia available without the lethal concentration of the insecticide.

SUMMARY

The application of insecticides in the soil causes considerable changes in the composition of the animal communities. After application of DDT the *Collembola* and several species of the *Acaridiae* and *Oribatei* greatly increase in number. This increase is probably caused by the eradication of their most important predators, the *Mesostigmata.*

By the application of lindane and parathion the *Collembola*, several species of the *Acaridiae* and *Oribatei* decrease in number considerably.

The *Collembola* are susceptible to DDT, at least *Onychiurus bicampatus.* The springtails are able to avoid dangerous concentrations of DDT in the soil by the low vapour pressure of this insecticide and the persistant fixation on some spots.

RIASSUNTO

La somministrazione di insetticidi al suolo determina considerevoli mutamenti nella composizione della sua fauna. Collemboli e alcune specie di *Acaridiae* e di *Oribatei* aumentano in notevole misura dopo somministrazione di DDT e tale incremento è probabilmente dovuto all'eliminazione dei loro più importanti predatori, i *Mesostigmata.*

Con lindano e parathion i Collemboli e alcune specie di *Acaridiae* e di *Oribatei* diminuiscono considerevolmente.

I Collemboli, o quanto meno l'*Onychiurus bicampatus* sono sensibili all'azione del DDT. Tuttavia la bassa tensione dei vapori di questo insetticida e la sua persistente fissazione ad alcune particelle del terreno non permettono che vengano raggiunte concentrazioni dannose per l'insetto.

LITERATURE CITED

BARING H. H., 1956-1957 - Die Milbenfauna eines Ackerbodens und ihre Beeinflussung durch Pflanzenschutzmittel. I und II. *Z. angew. Ent.* 39, 410-444; 41, 17-51.

BAUDISSIN G. V., 1952 - Die Wirkung von Pflanzenschutzmitteln auf Collembola und Milben in verschiedenen Böden. Zool. Jahrb. Ab. Syst. Tiere 81: 47-90.

BROWN E. B., 1954 - Springtail damage to tomatoes. *Pl. Path.* 3, 87-88.

EDWARDS C. A., 1962 - Springtail damage to bean seedlings. *Pl. Path.* 11, 67-68.

EHRENHARDT T., SCHNEIDER H., 1955 - Toxitätsstudien an der Collembole *Onychiurus armatus* Tullb. *Z. angew. Ent.* 37, 358-371.

GRIGORJEVA T. G., 1952 - Wirkung des in den Boden gebrachte Hexachlorcyclohexans auf die Bodenfauna. Ber. alruss. Akademie Landwirtsch. Moskau 12: 16-20 R.A.E. 41: 336.

KARG W., 1956 - Untersuchungen über die Wirkung der Hexa Behandlung Landwirtschaftlich genutzter Sandböden und Wiesenböden auf die Mesofauna in besonder auf Collembolen. *NachrBl. dt. PflSchutzdienst, Berl.* 6, 117-120.

KARG W., 1961 - Ueber die Wirkung von Hexachlorcyclohexan auf die Bodenbiocönose unter besonderer Berücksichtigung der Acarina. *NachrBl. dt. PflSchutzdienst, Berl.* 15, 23-33.

KARG W., 1964 - Untersuchungen über Wirkungensunterschiede von Lindan, gereinigtem technischem Hexaclorcyclohexan im Boden unter Verwendung der Microarthropoden als Testorganismen. *NachrBl. dt. PflSchutzdienst, Berl.* 18, 169-178.

RICHTER G., 1953 - Die Auswirkung von Insektiziden auf die terricole Makrofauna. Hexa Mitteln auf die Kleinarthropoden, ins besondere Collembolen. *Naturwissenschaften* 38, 480.

RICHTER G., 1953 - Die Auswirkung von Insektziden auf die terricole Makrofauna. *NachrBl. dt. PflSchutzdienst, Berl.* 4, 61-72.

SHEALS J. G., 1955 - The effects of DDT and BHC on soil Collembola and Acarina. (In KEVAN: Soil Zoology, 241-252).

Acknowledgements:

The writer thanks mr. R. G. RENS for the performing of the laboratory tests with *Onychiurus bicampatus*. Dr. J. VAN DER DRIFT, Dr. F. E. LOOSJES and Prof. Dr. D. M. DE VRIES for reading the manuscript.

APPENDIX I

Scale of increasing abundance and tables with the number of soil samples with *Acarina* and *Collembola* referring to the scale of increasing abundance.

TABLE VI. - *Scale of increasing abundance referring to the number of animals represented in the soilsamples*

I	0	VI	32-63
II	1-3	VII	64-127
III	4-7	VIII	128-255
IV	8-15	IX	256-511
V	16-31	X >	512

TABLE VII. - *Number of soil samples* * *with* Acarina *referring to the scale of increasing abundance in 1964*

	Untreated	DDT 1	DDT 2	DDT 3	Lindane I	Lindane II	Lindane III	Par. I	Par. II	Par. III
	I	I	I	I	I	I	I	I	I	I
	II	II 2	II 2	II	II	II	II	II	II	II 1
	III	III	III 1	III 2	III	III	III 1	III	III	III 2
	IV 1	IV 1	IV 1	IV 3	IV 1	IV 2	IV 3	IV	IV	IV 3
	V 5	V 2	V 2	V 2	V 4	V 8	V 6	V 3	V 2	V 3
	VI 4	VI 4	VI 1	VI 2	VI 4	VI	VI	VI 5	VI 5	VI
	VII	VII	VII 2	VII 1	VII 1	VII	VII	VII 2	VII 3	VII 1
	VIII	VIII 1	VIII 1	VIII	VIII	VIII	VIII	VIII	VIII	VIII
	IX	IX	IX	IX	IX	IX	IX	IX	IX	IX
	X	X	X	X	X	X	X	X	X	X
Total number . .	289	342	468	259	363	191	192	478	475	175
Mean number . .	29	34	47	26	36	19	19	48	47	17
Minimum number per sample . . .	15	2	2	7	8	11	4	28	21	3
Maximum number per sample . . .	47	128	157	108	56	28	29	117	77	66

TABLE VIII - *Number of soil samples with* Collembola *referring to the scale of increasing abundance in 1964*

	Untreated	DDT 1	DDT 2	DDT 3	Lindane I	Lindane II	Lindane III	Par. I	Par. II	Par. III
	I	I	I	I	I	I	I	I	I	I
	II	II	II	II	II	II	II	II	II 1	II
	III	III	III	III	III	III	III 4	III 1	III	III
	IV	IV	IV	IV	IV	IV 1	IV 1	IV	IV 4	IV
	V 2	V	V	V	V 1	V 1	V 3	V 3	V 3	V 2
	VI 3	VI	VI	VI 1	VI 4	VI 4	VI 1	VI 3	VI 1	VI 4
	VII 2	VII 2	VII 3	VII 3	VII 3	VII 1	VII 1	VII 3	VII 1	VII 3
	VIII 3	VIII 3	VIII 2	VIII 6	VIII 1	VIII 3	VIII	VIII	VIII	VIII 1
	IX	IX 2	IX 2	IX	IX 1	IX	IX	IX	IX	IX
	X	X 3	X 3	X	X	X	X	X	X	X
Total number .	824	3445	3666	1325	949	793	233	442	223	679
Mean number . .	82	344	367	132	95	79	23	44	22	68
Minimum number per sample . . .	18	74	69	59	19	10	4	5	1	21
Maximum number per sample . . .	217	818	1218	214	369	219	84	97	68	137

(*) Each sample is represented by a core of 125 ml of soil.

TABLE IX. - *Number of soilsamples * with* Acarina *referring to the scale of increasing abundance from 3,5 liter of soil*

	Untreated		DDT 3		Lindane 3		Parathion 3	
	I		I		I	1	I	
	II		II	1	II	1	II	1
	III	1	III	2	III	4	III	2
	IV	1	IV	5	IV	5	IV	5
	V	14	V	6	V	8	V	8
	VI	9	VI	8	VI	4	VI	6
	VII	3	VII	5	VII	3	VII	4
	VIII		VIII		VIII	2	VIII	1
	IX		IX	1	X		IX	1
	X		X		IX		X	
Mean number per sample	37,8		54,7		37,8		50,9	
Total number . .	1135		1532		1059		1427	
Minimum number per sample . . .	6		1		0		3	
Maximum number per sample . . .	144		419		197		351	

TABLE X. - *Number of soilsamples * with* Collembola *referring to the scale of increasing abundance from 3,5 liter of soil*

	Untreated		DDT 3		Lindane 3		Parathion 3	
	I		I		I		I	
	II		II		II	2	II	
	III	1	III		III	7	III	
	IV	1	IV	1	IV	2	IV	3
	V	6	V		V	8	V	8
	VI	7	VI	1	VI	4	VI	10
	VII	7	VII	6	VII	4	VII	5
	VIII	5	VIII	12	VIII	1	VIII	2
	IX	1	IX	5	IX		IX	
	X		X	3	X		X	
Mean number per sample	74,3		281		34,4		43,2	
Total number . .	2229		7869		964		1331	
Minimum number per sample . . .	7		12		1		9	
Maximum number per sample . . .	339		1627		196		137	

TABLE XI. - *Number of soilsamples with* Mesostigmata *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	1	I	27	I	6	I	
	II	1	II		II		II	1
	III	3	III	1	III	4	III	8
	IV	5	IV		IV	4	IV	8
	V	15	V		V	4	V	4
	VI	4	VI		VI	10	VI	3
	VII	0	VII		VII		VII	4
Mean number per sample		11,1		0,1		10,6		10,7
Total number . .		335		3		298		301
Minimum number per sample . . .		0		0		0		1
Maximum number per sample . . .		38		3		28		35

TABLE XII. - *Number of soilsamples with* Veigaia *spp. referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	14	I	0	I	17	I	15
	II	14	II		II	5	II	9
	III				III	5	III	3
	IV				IV	1	IV	1
	V				V		V	
	VI				VI		VI	
	VII							
	VIII							
	IX							
	X							
Mean number per sample		1		0		1,8		1,7
Total number . .		31		0		53		48
Minimum number per sample . . .		0				0		0
Maximum number per sample . . .		3				15		14

TABLE XIII. - *Number of soilsamples with* Hypoaspis aculeifer *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	22	I	28	I	18	I	20
	II	6	II		II	8	II	8
	III		III		III		III	
					IV	2		
					V			
Mean number per sample		0,2		0		1		0,5
Total number . .		7		0		30		14
Minimum number per sample . . .		0				0		0
Maximum number per sample . . .		2				11		2

TABLE XIV. - *Number of soilsamples with* Rhodacarus roseus *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	2	I	28	I	7	I	4
	II	8	II		II	7	II	10
	III	10			III	7	III	10
	IV	6			IV	5	IV	4
	V	1			V	2	V	
	VI	1			VI		VI	
	VII				VII		VII	
	VIII							
	IX							
	X							
Mean number per sample		6,1		0		4,9		3,6
Total number . .		184		0		138		102
Minimum number per sample . . .		0				0		0
Maximum number per sample . . .		35				18		10

TABLE XV. - *Number of soilsamples with* Pygmephorus *spp. referring to the scale of increasing abundance*

	Untreated	DDT	Lindane	Parathion
	I 24	I 3	I 6	I 7
	II 2	II 6	II 8	II 9
	III 2	III 3	III 10	III 3
	IV	IV 8	IV 1	IV 6
		V 5	V 2	VI
				V 2
		VI 3	VI 1	VII 1
		VII	VII	VIII 1
				IX
Mean number per sample	5,3	11,3	6,1	17,7
Total number . .	159	318	171	498
Minimum number per sample . . .	0	0	0	0
Maximum number per sample . . .	63	39	49	241

TABLE XVI. - *Number of soilsamples with* Variatipes quadrangularis *referring to the scale of increasing abundance*

	Untreated	DDT	Lindane	Parathion
	I 24	I 21	I 6	I 7
	II 2	II 6	II 8	II 9
	III 2	III	III 10	III 3
	IV	IV 1	IV 1	IV 6
		V	V 2	V 2
			VI 1	VI
			VII	VII 1
				VIII 1
				IX
Mean number per sample	0,4	0,9	8,3	5,4
Total number . .	13	26	233	153
Minimum number per sample . . .	0	0	0	0
Maximum number per sample . . .	5	14	114	54

TABLE XVII. - *Number of soilsamples with* Oppia nova *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	8	I	2	I	15	I	6
	II	14	II	4	II	7	II	7
	III	3	III	5	III	2	III	8
	IV	2	IV	7	IV	4	IV	5
	V		V	6	V		V	1
	VI	1	VI	3	VI		VI	1
	VII		VII	1			VII	
Mean number per sample		4,5		16,9		2,1		6
Total number . .		137		475		61		170
Minimum number per sample . . .		0		0		0		0
Maximum number per sample . . .		60		73		15		33

TABLE XVIII. - *Number of soilsamples with* Tyrophagus *spp. referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	13	I	9	I	19	I	23
	II	8	II	6	II	7	II	4
	III	6	III	4	III	2	III	1
	IV	1	IV	2	IV		IV	
	V		V	4				
	VI		VI	1				
			VII	1				
			VIII					
			IX	1				
			X					
Mean number per sample		1,6		20,8		0,7		0,2
Total number . .		55		584		22		8
Minimum number per sample . . .		0		0		0		0
Maximum number per sample . . .		12		335		7		4

TABLE XIX. - *Number of soilsamples with* Hypogastrura denticulata *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	28	I	7	I	18	I	25
	II		II	2	II	1	II	3
			III	3	III	0		
			IV	5	IV	5		
			V	5	V	3		
			VI	1	VI	1		
			VII	0	VII			
			VIII	1				
			IX					
			X					
Mean number per sample		0		12,9		5,7		0,1
Total number . .		0		363		162		3
Minimum number per sample . . .				0		0		0
Maximum number per sample . . .				148		57		1

TABLE XX. - *Number of soilsamples with* Heteromurus nitidus *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	21	I	14	I	27	I	28
	II	2	II	1	II	1	II	
	III	3	III	8	III			
	IV	2	IV	4				
			V	2				
Mean number per sample		0,6		2,9		0		0
Total number . .		19		82		1		0
Minimum number per sample . . .		0		0		0		
Maximum number per sample . . .		13		16		1		

TABLE XXI. - *Number of soilsamples with* Folsomia fimetaria *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	16	I		I	28	I	26
	II	12	II	1	II		II	1
	III		III	1	III		III	
			IV				IV	
			V	2			V	1
			VI	4			VI	
			VII	9			VII	
			VIII	5			VIII	
			IX	4			IX	
			X	2			X	
Mean number per sample		0,5		193,2		0		0,7
Total number . .		17		5411		0		23
Minimum number per sample . . .		0		1				0
Maximum number per sample . . .		2		1289				22

TABLE XXII. - *Number of soilsamples with* Onychiurus armatus *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I	15	1	1	I	25	I	28
	II	8	II		II	3	II	
	III	2	III	4	III		III	
	IV	3	IV	8	IV		IV	
	V		V	7	V		V	
	VI		VI	3	VI		VI	
	VII		VII	4	VII		VII	
	VIII		VIII	1	VIII		VIII	
Mean number per sample		2,3		32,6		0,1		0
Total number . .		69		915		5		0
Minimum number per sample . . .		0		0		0		
Maximum number per sample . . .		12		170		3		

TABLE XXIII. - *Number of soilsamples with* Tullbergia krausbaueri *referring to the scale of increasing abundance*

	Untreated		DDT		Lindane		Parathion	
	I		I		I		I	
	II	1	II		II	3	II	
	III	1	III	2	III	8	III	
	IV	3	IV	3	IV	3	IV	4
	V	5	V	10	V	8	V	10
	VI	5	VI	7	VI	4	VI	7
	VII	10	VII	3	VII	1	VII	6
	VIII	2	VIII	2	VIII	1	VIII	1
	IX	1	IX	1	IX		X	
	X		X		X		IX	
Mean number per sample	68,6		50,6		26,6		45,2	
Total number . .	2065		1417		749		1266	
Minimum number per sample . . .	1		6		1		9	
Maximum number per sample . . .	328		259		161		131	

APPENDIX II

Checklist of species found in the experimental plots from 1962-1965 (°).

COLLEMBOLA

* *Brachystomella parvula* Schäffer
* *Hypogastrura denticulata* (Bagnall) Gisin
* *Onychiurus armatus* (Tullberg) Gisin
* *Tullbergia krausbaueri* (Börner)
Tullbergia quadrispina (Börner)
Tullbergia callipygos Börner
Anurophorus isotoma Börner
* *Isotoma notabilis* Schäffer
Isotoma violacea Tullberg
Isotoma olivacea Tullberg
Isotoma viridis (Bourlet) Börner
Isotomiella minor (Schäffer)
Isotomina bipunctata (Axelson)
* *Isotomodes productus* (Axelson)
* *Folsomia fimetaria* (L.) Tullberg
Pseudosinella alba (Packard)
Pseudosinella wahlgreni Börner
Pseudosinella sexoculata Schött
Lepidocyrtus sp.
Sinella coeca (Schött)
* *Heteromurus nitidus* (Templeton)
Orchesella sp.
* *Neelus minimus* Folsom
Sminthurinus sp.

ACARINA

MESOSTIGMATA

Platyseius montanus (Willmann)
Dendrolaelaps strenzkei Hirschm.
Dendrolaelaps zwoelferii Hirschm.
Dendrolaelaps sp.
Arctoseius cetratus (Sellnick)
Ameroseius sp.
Kleemannia plumosus Ouds.
Lasioseius paucisetus Westerboer
Typhlodromus sp.
Cosmolaelaps cuneifer (Michael)
Alliphis siculus (Ouds.)
Haemolaelaps casalis (Berlese)
* *Hypoaspis aculeifer* (Can.)
Prozercon fimbriatus (Koch)
* *Rhodacarus roseus* Ouds.
Rhodacarellus silesiacus Willm.
Rhodacarellus strenzkei Willm.
Pachylaelaps pectinifer Berlese
Amblygamasus septentrionalis Oudemans
Pergamasus crassipes (L.)
* *Pergamasus runcatellus* Berlese
Parasitus coleoptratum (L.)
Macrocheles penicilliger (Berlese)
Macrocheles decoloratus Koch

* *Veigaia nemorensis* (Koch)
* *Veigaia serrata* (Willmann)
Dinychura sp.
Uropodidae Gen. sp.

SARCOPTIFORMES

Oppia obsoleta Paoli
Oppia falcata Paoli
* *Oppia nova* Ouds.
Oppia minus (Paoli)
Suctobelba subtrigona Ouds.
Thrypochthonius badius (Berlese)
Thrypochthonius excavatus (Willmann)
Hypochthonius luteus (Ouds.
* *Brachychthonius berlesei* Willmann
* *Brachychthonius brevis* (Michael)
Tectocepheus velatus (Micheal)
Rhizoglyphus solani Ouds.
Tyrophagus putrescentiae Schrank
* *Tyrophagus dimidiatus* Herm.
Tyrophagus longior Gerv.
Histiostoma litorale Ouds.
Histiostoma sp.

TROMBIDIFORMES

Tarsonemus interuptes Vitzthum
* *Pygmephorus antiquissimus* Krczal
Pygmephorus suecicus Krczal
* *Pygmephorus sellnicki* Krczal
Pygmephorus arboris Krczal
* *Pygmephorus blumentritti* Krczal
Pygmephorus tarsalis Hirst.
Pygmephorus haarloevi Krczal
Pygmephorus silvestris Jacot
Tarsonemoides sp.
Scutacarus sp.
* *Variatipes quadrangularis* Paoli
Tetranychus urticae Koch
Rhagidia sp.
Alicorhagia plumipes Berlese
Coccorhagidia clavifrons Can.
Coccotydeus tenuisclaviger Thor.
Coccotydeus sp.
Eupodes sp.
Cocceupodes sp.
Tydeus sp.
* *Microtydeus* sp.
Nanorchestes spp.
Madiolata sp.
Cheyletus eruditus Schrank
Eustigmus sp.
Allothrombidium sp.

(°) The with * mentioned species are frequently recovered in the samples. That means 33 % or more of the samples or in a great number of specimens in a few samples.

All identifications are carried out by the author. These identifications are based on:

BAKER E. W., WHARTON G. W., 1952 - An introduction to Acarology, New York, 465 pp., 377 figg..

BERLESE A.. 1905 - Monografia del genere *Gamasus* Latr. *Redia* 3, 66-304.

EVANS G. O., 1955 - An introduction to the British *Mesostigmata* with keys to families and genera. *J. Linn. Soc.-Zoology* XLIII, 203-259.

GISIN H., 1960 - Collembolafauna Europas, Museum d'Histoire Naturelle, Genève.

HAMMEN L. v. d., 1952 - The Oribatei of the Netherlands. *Zool. Verh., Leiden* 17, 1-139.

HUGHES A. M., 1961 - The Mites of stored Food, London.

KARG W., 1961 - Zur Systematik der *Rhodacaridae* Oudemans 1902. *Zool. Anz.* 166, (3/4), 127-135.

KARG W., 1962 - Systematik der Gamasiden (*Acarina, Parasitiformes*). *Mitt. zool. Mus. Berl.* 38 (1), 23-119.

NESBITT H. H. J., 1951 - A taxonomic study of the *Phytoseiinae* (family *Laelaptidae*) predacious upon *Tetranychidae* of economic importance. *Zool. Verh., Leiden* 12, 1-64.

SCHWEIZER J., 1949-1957 - Die Landmilben des Schweizerischen Nationalparkes. *Ergebn. wiss. Unters. schweiz. NatnParks.*

STAMMER H. J., 1957-1963 - Beiträge zur Systematik und Oekologie mitteleuropäischer Acarina, Bd. I, Bd II. Akad. Verlagsges., Leipzig.

THOR S., 1931 - *Bdellidae, Nicotetiellidae, Cryptognathidae. Tierreich* 56.

THOR S., 1933 - *Tydeidae, Ereynetidae. Tierreich* 60.

THOR S., 1941 - *Eupodidae, Penthalodidae. Penthaleidae, Rhagidiidae, Pachynathidae, Cunaxidae. Tierreich* 71.

VITZTHUM H. v., 1929 - Acari. In: *Tierwelt Mitteleur.* III, 112 S.

WILLMANN C., 1931 - Moosmilben oder Oribatiden (*Cryptostigmata*). *Tierwelt Dtl.* 22, 79-200.