10 THE INFLUENCE OF CITRICULTURAL PRACTICES ON THE COMPOSITION OF THE SOIL MESOFAUNA

Man can be regarded as a superbiotic factor, that affects the soil fauna by cultivation, drainage, irrigation, industrial pollution, the application of fertilizers and plant protection chemicals, dumping of materials, and various other means. All cultural practices change the environment for soil animals so that some species are favoured and others affected adversely. In general, agricultural practices tend to simplify soil animal communities. One of the main objects of this investigation was to establish the existing nature of the composition of the soil mesofauna from the cultivated citrus soils, and to correlate the results with that of undisturbed natural populations in the vicinity.

10.1 THE INFLUENCE OF CITRUS TREES ON THE COMPOSITION OF THE SOIL MESOFAUNA

For the evaluation of the effect of the citrus tree rhizosphere on the microarthropod composition, a comparison between the fauna recovered from plot A, the control plot, and plot D, the biological control plot, is proposed, as the last mentioned plot is excluded from the pesticide programme. Nevertheless, it is also necessary to refer to the routine citrus plots so as to define the differences and simularities between the first mentioned two plots.

It is generally known that agricultural practices tend to reduce the organic material content of the soil and degrade the structure and texture of the soil, with a resultant decrease in soil pore structure which supplies the "Lebensraum" and aeration for various forms of litter fauna. The abovementioned facts were ratified by the results obtained from the recent investigation at Zebediela Estates.

The order Trombidiformes is comprised of various families of hemi-edaphic litter arthropods. Representatives of these families were found to be abundant in the soils of the control plot (fig. 54) but were rarely found, or were entirely absent, in the citrus soils. This fact was also illustrated by the numbers of Trombidiformes families recorded on the different plots. Seventeen trombidiform families were recorded on the control plot, while plots B, C, D and E respectively had 10, 9, 12 and 3 families of this order (figs 55 - 58). The following families and species occurred on the control plot only: Erythraeidae, with the species *Smaris biscutatus* (Meyer) and *Leptus* sp., which had yearly mean recordings of $635/m^2$ and $44/m^2$ respectively. Anystidae, with a population density of $73/m^2$ for *Anystis baccarum* (Linn.). Cryptognathidae, with a yearly mean of $44/m^2$ for *Cryptognathus cucurbita* (Meyer). Pseudocheylidae, with the species *Pseudocheylus* sp., which had a yearly mean of $177/m^2$. Lordalychidae, with a population density of $29/m^2$ for *Lordalychus* sp.

Representatives of the following trombidiform species were found to be predominant on the control plot, but were also sampled on the citrus plot.

Nanorchestidae: A yearly mean of 9,399/m^2 was recorded for Speleorchestes sp. on the control plot, while yearly mean recordings registered for plots B, C, D and E were 709/m^2, 635/m^2, 354/m^2 and 309/m^2 respectively.

Cunaxidae: A yearly mean of 1,728 specimens per m^2 was extracted for Cunaxa sp. on the control plot, while the only representative specimens that occurred on the citrus plots were the yearly mean recording of 29/m^2, recorded at the biological control plot.

Bdellidae: From the Bdellidae, a yearly mean of 1,123 specimens per m^2 was recorded for Bdella sp. on the control plot, and a yearly mean of 44/m^2 for Cyta sp. The biological control plot had a yearly mean of 59/m^2 for Bdella sp., while on plot C, 14/m^2 was recorded for the same species.

Raphignathidae: For Acheles aethiopica (Meyer) a yearly mean of 591/m^2 was recorded on the control plot, while the only representatives of these predator mites from the citrus plots were extracted on the biological control plot. A yearly mean of 29/m^2 was recorded on the last mentioned plot.

Stigmaeidae: A yearly mean number of 29 specimens per m^2 was recorded for Ledermulleria sp. and 14/m^2 for Ledermulleriopsis sp. respectively on the control plot. The control plot had a yearly mean of 88/m^2 for both mentioned species. The two species of the genus Neophyllobius were recorded on the control plot only. Both species had a yearly mean of 14/m^2.

Cheyletidae: *Paracheyletia* sp. had a yearly mean of 88/m^2 on the control plot and 14/m^2 on the biological control plot.

In contrast with the hemi-edaphic trombidiform mites, some eu-edaphic species live equally well, or might even be inhibited or promoted by the citrus rhizosphere habitat. In this connection, *Tydaeolus* sp. (Tydeidae), *Pygmephorus* sp. (Pyemotidae) and *Scutacarus* sp. (Scutacaridae) could be mentioned. *Tydaeolus* sp. attained yearly means of 5,793/m^2, 2,778/m^2 and 2,896/m^2 at plots B, C and E respectively. The control plot and biological control plot had notably larger recordings with 6,443/m^2 and 6,148/m^2 respectively. *Pygmephorus* sp. revealed the surprisingly high yearly mean number of 6,280/m^2 on the old citrus plot, in comparison with the 221/m^2, 354/m^2, 59/m^2 and 250/m^2 recorded on plots A, C, D and E. The biggest population density for *Scutacarus* sp. was also found on the old citrus plot. A yearly mean of 324/m^2 was recorded on the last mentioned plot, in comparison with the 59/m^2 and 29/m^2 recorded on plots A and D.

Certain Oribatei species were found in the three plots of Section 3 B only, apparently as a result of the higher percentage of organic material present in the plots. For plots A, B and C, 8.7%, 7.6% and 10.4% organic material was estimated, in comparison with the 3.3% and 2.2% recorded on plots D and E. The species that occurred at Section 3 B only were: *Liodes* spp. A and B, *Plateremaeus* sp., *Pedrocorticella* sp., *Passalozetes* sp., *Ryzotritia* sp. and *Cosmochthonius* sp.

For *Liodes* sp. A a yearly mean of $236/m^2$ was recorded on plot A and $73/m^2$ on plot B, while *Liodes* sp. B had $103/m^2$ and $44/m^2$ on the mentioned plots respectively. The bigger *Plateremaeus* sp. and *Rhizotritia* sp. occurred on the control plot only, probably because of more favourable habitat conditions, but the small *Cosmochthonius* sp. was also restricted to plot A. *Plateremaeus* sp., *Rhizotritia* sp. and *Cosmochthonius* sp. attained yearly means of $664/m^2$, $44/m^2$ and $177/m^2$ respectively on the control plot. *Pedrocorticella* sp. and *Passalozetes* sp. occurred in all the plots investigated in Section 3 B. As could be deduced from the yearly mean totals, both the mentioned species were less successfull in the agricultural soils. The yearly mean numbers recorded for *Pedrocorticella* sp. on plots A, B and C were $398/m^2$, $88/m^2$ and $73/m^2$ respectively. *Passalozetes* sp. attained $797/m^2$, $354/m^2$ and $88/m^2$ on plots A, B and C respectively.

In contrast with the general tendency of certain oribatid species to diminish in numbers in the citrus soils, the euedaphic *Epilohmannia* sp. apparently thrive in the sandy citrus soils of Section 2. The yearly mean numbers recorded on plots D and E were $501/m^2$ and $635/m^2$ respectively. The numbers of *Oppia nova* (Oudem.) also seemed to be inhibited by agricultural conditions. The yearly mean numbers recorded on plots B, C, D and E were $354/m^2$, $162/m^2$ $103/m^2$ and $236/m^2$ respectively. Though no specimens of these small mites were extracted on the control plot, it could, however, be assumed that they do occur in natural soil, as they have been recorded in the pasture soils of Potchefstroom. The dominant *Scheloribates* spp. were obviously also favoured by citricultural practices. The yearly mean numbers recorded for sp. A on plots B, C, D and E were 2,053/m^2, 945/m^2, 2,172/m^2 and 1,255/m^2 in contrast with the 620/m^2 extracted on plot A. Scheloribates sp. B had a yearly mean of 3,324/m^2, 915/m^2, 295/m^2 and 73/m^2 on plots B, C, D and E, with 206/m^2 on the control plot.

The high population density of Collembola recorded on the citrus plots provided the most prominent example of the citricultural effect on the soil mesofauna. The yearly mean numbers for Collembola on plots A - E were 1,048/m^2, 4,344/m^2, 8,852/m^2, 13,936/m^2 and 29,926/m^2 respectively. The biggest individual contributor was Isotomina termophila (Axelson). The yearly mean numbers recorded for the last mentioned species at plots A - E were 457/m^2, 3,768/m^2, 7,935/m^2, 7,315/m^2 and 28,774/m^2 respectively. Apart from the Collembola, other members of the "Other Arthropoda" section in the citrus tree rhizosphere habitats distinctly decreased in numbers and variety. As a result of cultivation practices, the Diplopoda, Corrodentia Coleoptera and other insects, which attained high population densities on the control plot, were sparsely represented on the citrus plots.

From this investigation, it became evident that certain mesofaunal arthropods, especially the hemi-edaphic predatory trombidiformes, and some saprophagous Oribatei- and "Other Arthropods"-members were reduced and even exterminated by citricultural practices, as a result of the destruction and removal of their natural abode and food - the soil litter layer.

On the other hand, certain mite and insect species, mostly eu-edaphic in manner of living, were promoted by the citrus rhizosphere habitat and general citricultural practices.
It was further observed that, in relation to the quantitative and qualitative mesofaunal aspects, the biological control plot constituted an intermediate position between the natural soil population, represented by the control plot, and the routine citrus plots.

10.2 INFLUENCE OF REPLANTING OF CITRUS TREES ON THE COMPOSITION OF THE SOIL MESOFAUNA

The "soil-sickness" of "replant" problems of apple, peach, and citrus are problems of economic importance, particularly in areas where it is uneconomical to abandon the old sites. As indicated by Börner (1959, 1960), replant problems occur in many areas of the world. In many areas of Europe (Grümmer, 1955; Schander, 1956; Börner, 1959), young apple replants cannot be planted in old apple-orchard sites. Apple trees planted in such locations show retarded growth; the roots show varying degrees of discoloration, and growth of the tap-root is reduced. The plants recover when they are moved to soil that has not been used for growing apples. The peach-replant problem has been reported by Proebsting and Gilmore (1941) from California, and Upshall and Ruhnke (1935) and Koch (1955) from Canada. The research workers Proebsting & Gilmore suggested that one of the causes of tree failure is phytotoxin, produced from root residues. This postulate was investigated by Patrick (1955); Wensley (1956); Ward & Durkee (1956); Mountain & Boyce (1958); Harrison (1958) and Mountain & Patrick (1959).

Patrick (1955) and Ward & Durkee (1956) found that peach-root bark contains a cyanogenic glucoside, amygdalin, in relatively large amounts. Amygdalin is also present with the hydrolyzing enzyme, emulsine. Amygdalin, as such, was found not to be toxic to peach roots or peach seedlings, but its degradation products, benzaldenhyde and hydrogen cyanide, are highly toxic. According to the last mentioned authors, breakdown of amygdalin into the toxic components is readily accomplished by micro-organisms, normally found in the peach soils and by the enzime emulsine in the peach root cell.

It was further found by Mountain & Patrick (1959) that the nematode *Pratylenchus penetrans* Cobb., found in large numbers in the peach soils of southwestern Ontario, can bring about hydrolysis of amygdalin. It can do this directly, by means of its own enzyme systems, and indirectly by mechanical damage to the root cells. Cell damage allows the amygdalin and the enzyme, emulsine to be brought together and thereby releases the toxic components. On the basis of these studies, the foregoing authors suggested that the peach replant problem is a true root-rot complex, in which many causal factors appear to be involved, none of which alone can produce the entire disease. Any lesion-producing agency, however, fungi, nematodes or insects, that could bring about the rupturing of the cells containing the potentially toxic components, could act as incitant. Superimposed upon the pathology of root necrosis are the phytotoxic effects of root residues of former trees. Patrick & Toussoun (1965) are of the opinion, that, irrespective of the causal organism involved, the production of phytotoxic through the hydrolysis of amygdalin is the main mechanism involved in the entire etiological sequence of degeneration of peach roots.

It is of importance to know whether the main phytotoxic components are the result of specific toxic compounds, characteristic of the plant species, or the results of synthesis products of soil micro-organisms using the plant material as substrata.

It is probably impossible to generalize on the results attained by the research workers on the peach tree problem, as it is known that many plant species contain their own specific toxins. Nevertheless, it would appear that phytotoxicity, in combination with the faunal factors mentioned, could be the cause of the citrus replant problem.

Martin (1948) has done considerable work on the "slow decline of citrus", as the condition is commonly called. During a qualitative study on fungi of "old" and "new" citrus soils, the mentioned author discovered that a Phyrenocheta sp. occurred only in the old citrus soils where it was isolated in considerable quantities. He also ascertained that two Fusarium species, no. 1 and no. 2, had greater concentrations in the last mentioned soils, while sp. 1 were in most cases isolated from healthy citrus roots near the soil surface.

Through further investigations, he confirmed the statement, which implies that the reduction of the gorwth potential on old citrus soils was caused by concentrations of harmful micro-organisms and the accumulation of poisonous substances in the soil.

To ascertain the possible role of nutrition in this matter, Martin and his colleagues (1953) made various soil culture experiments. They illustrated that, irrespective of the mineral content of the soil, the second planting of orange trees always revealed a reduction of growth potential.

Practically no researchwork has been done on this problem in South Africa. The fact that the South African Citrus Committee requested a survey of all the available information relating to this problem, reveals its presence and extent in this country. Reports on the presence of this phenomenon have been received from Zebediela, Letaba, Muden, Mazoe, Rivulets, Witrivier, Rustenburg and Addo.

According to Marloth (1954), Dr. de Villiers of Zebediela reported on an experiment with citrus seedlings planted in pots with "old" and "new" citrus soil. The experiment took two years. From the results, de Villiers was able to declare that the young seedlings grew better in the "new" citrus soils, than those planted in "old" citrus soils. However, when both soil types were treated with a nutritional solution, no difference in growth and vitality could be observed. Thus the deduction was made that lack of nutrients and not poison accumulation was the main retarding factor in "old" citrus soils.

Rudd (1964) mentioned the effect of arsenic residue accumulation as a possible cause for retarded plant gorwth. He states (p. 164): "Accumulations of residues reached astounding levels in some crop soils. Levels were particularly high in soils beneath orchard trees and in soils dedicated to cotton culture. Almost all residues were confined to the top few inches, and established plants whose roots penetrated well below the cultivated layer showed no or little effect of these excessive amounts. However, vegetable crops fared poorly in soils heavily contaminated with arsenic, as did cover crops in orchards. Efforts to replace old orchard trees with young usually failed. Attempts to re-use orchard lands to produce cerial, forage, or vegetable crops proved economically disastrous over wide areas. The problem pyramided with increasing resistance of insects to arsenicals, and, particularly in apple orchards, this resulted in heavier, more frequent arsenic applications. This pattern was particularly marked in the Pacific Northwest, where some areas had accumulated amounts up to 1400 pounds of arsenic trioxide per acre. Legume crops became progressively poorer; alfalfa and beans often died on high arsenic tracts although they thrived on immediately adjacent sites that had no spray residues."

At Zebediela, calciumarsenate is administered as a maturing solution, to enhance citrus fruit ripening. The normal concentration is 1½ lbs. of calciumarsenate per 100 gallons of water. This treatment, however, applies only for the

Valencia section of the orchards, as they ripen first. There is a slight possibility that arsenic accumulation could have occurred.

As mentioned before in the description of the sampling plots, plot B was planted with citrus during 1918, while plot C remained uncultivated. After 40 years, the old citrus trees were removed, and in 1957, both plots B and C were tilled and planted with young citrus trees.

It soon became obvious that the trees on the old citrus plot B did not have the vitality and growth potential of plot C, a fact which was verified later when they came into fruit production. Both plots received identical treatments, i.e. the same amount of irrigation, nourishment and chemical spraying. To assume that plot B has been deprived of its mineral resources would be the most logical explanation, but chemical analysis showed that this was not the case. It was therefore obvious that the biological compositions of the soils should be investigated.

Plot B had a mesofaunal total of 1907 arthropods, or a yearly mean of 28,139 specimens per m^2. Plot C had a mesofaunal total of 1,119 arthropods which was equal to a yearly mean of 16,493 specimens per m^2. The latter plot had thus considerably smaller arthropod numbers. When consulting tables 16 and 17 of plots B and C, it will be noticed that:

(a) plot B had considerably higher Trombidiformes, Mesostigmata and Oribatei numbers than plot C;

(b) plot C had the largest Collembola total.

TROMBIDIFORMES

On plot B a total of 1,041 trombidiform mites or a yearly mean of 15,370 per m^2 was extracted in contrast with the 297 mites of plot C which were equal to a yearly mean of 4,374 specimens per m^2.

The Tydeidae were the most dominant trombidiform family for both plots. Though the highest numbers of *Tydaeolus* sp. and *Microtydeus* sp. were found on plot B, fair numbers of these species were also recorded on plot C. The occurrence of high *Pygmephorus* sp. numbers on plot B attracts attention. In none of the other four citrus plots did *Pygmephorus* sp. ever reach prominent numbers. During July, 4,551 specimens per m^2 of this species were extracted on plot B. In September the numbers dwindled to 886 per m^2, but in January 19,508 specimens per m^2 were recorded. In April, they again diminished drastically to 177 per m^2. In this connection it should be mentioned that Karg (1964) found that members of the family Pyemotidae were highly resistant to insecticides. They also multiplied and attained big population densities. Karg further deducted that as the Pyemotidae feeds on fungi and bacteria, extensive growth of these microbial forms must have occurred. The largest population density of *Pygmephorus* sp. that occurred on plot C was 827 specimens per m^2 during the January 1966 survey.

MESOSTIGMATA

Plot B recorded a yearly mean of 1,359 Mesostigmata per m^2 in contrast with the yearly mean of $236/m^2$ extracted on plot C. The greatest contributors to this order on plot B were: *Amblyseius usitatus* (van der Merwe), *Lasioseius* sp. and *Pachylaelaps* sp. Plot B had the highest number of Mesostigmata of all the plots investigated.

ORIBATEI

Plot B recorded a total of 439 oribatid mites, or a yearly mean of 6,443 per m^2, in contrast with the 157 or yearly mean of $2{,}128/m^2$ extracted on plot C. In both plots, *Scheloribates* spp. were the dominant contributors. *Oppia nova* (Oudem.) was also prominent in numbers on both plots.

ACARIDIAE

A yearly mean of 118 specimens per m^2 was recorded for *Tyrophagus* sp. on plot B in comparison with the $19/m^2$ recorded on plot C.

OTHER ARTHROPODA

The Collembola was the most prominent of the arthropods of this section, with *Isotomina termophila* (Axelson) as the dominant species for both plots. A yearly total of 4,315 Collembola per m^2 was recorded on plot B, against the $8{,}098/m^2$ of plot C. In contrast with the fauna of the control plot, the old citrus plot revealed a marked reduction of hemi-edaphic trombidiform predators. The Mesostigmata and Oribatei numbers, on the other hand, were surprising, being the highest of all the citrus plots. The occurrence of larger predator populations on plot B, such as the Mesostigmata, was most probably responsible for the smaller Collembola numbers in this plot. Plot C, on the other hand, had smaller predator numbers and bigger Collembola numbers.

In accordance with the theory of phytotoxicity, it is obvious that only the saprophagous section of the soil fauna has direct importance. The predators, though, most certainly do have an indirect effect on problem, by predation on the saprophagous feeders.

A considerable quantity of work has already been done on this problem in connection with fruit trees other than citrus. It is, however, absolutely clear that, for the solution of this citrus soil problem, an intensive research project is required in which the collaboration of chemists, microbiologists, mycologists and entomologists, for instance, is essential.

10.3 THE INFLUENCE OF INSECTICIDES ON THE COMPOSITION OF THE SOIL MESOFAUNA

The uses of pesticides in the present-day plant and animal protection are clear and widely accepted. We realize, for example, that successes in pest control have, along with other technological applications, greatly changed the yields in food, forest and forage production. Nevertheless, certain problems concerning chemical control are still unsolved. Soil animals are good biological indicators of soil conditions. Not only can different soil types be distinguised on the basis of the soil animals, but these animals also react sensitively to the changes occurring in the soil. The change in the soil fauna is often a better indicator than the most sensitive instruments, of the changes taking place in the physical structure, the chemical composition, the fertility etc., of the soil. It is already well known that the reduction in the complexity of soil communities in agricultural soils is a natural consequence of cultivation practices. It is also believed that long term changes in arthropod complexes follow from the continued use of nonspecific chemicals, whatever their chemical nature. The chemical control of insects, although primarily an entomological and chemical problem, also enters the realm of ecology, since organisms other than the intended victim may be affected. The ecologist must sometimes put a damper on the enthusiasm of the chemist and the chemical engineer, who can synthesize new poisons and develop effective methods of application faster than the total effects in nature can be determined. This is especially true when poisons are to be used in complex ecosystems such as orchards and forests without any knowledge of the effect the poison might have on natural control mechanisms. It has been observed that extensive ecological studies on soil communities are seldom conducted by tegnologists of pesticide factories.

The chemicals used to control agricultural insects are normally directed at the leaf surfaces of plants. A good proportion misses the plant and is deposited on the surface of the ground. More is added to the ground surface by runoff from the plant. Chemical mixtures falling on the plant or ground form a deposit, the presence of which is necessary for pest control. This deposit does not normally retain its original character for long. Change in the deposit comes about as it is acted on by living systems and by the physical effects of heat, light and water, Fahmy (1961), Lichtenstein & Schulz (1961). The remainder of the transformed deposit is generally called a residue. This residue may contain reduced portions of the original toxic ingredient, metabolic derivates of this chemical, physically transformed derivates of quite different chemical structure, and surviving portions of the 'carriers' of the original material. All pesticide chemicals produce residues that could survive for some time. The persistence of some may be for only a day or two while others can survive for fifteen years or more after a single application. In most instances residues on foliage or on the soil do not have pesticide value for more than three weeks. The chemicals that survive for longer than these periods are classified as 'systemic' chemicals, which depend on delayed action, either chemically or physiologically for their pesticidal value, while the 'chlorinated hydrocarbon' insecticides are most stable chemicals that lose their primary structure only slowly and are accordingly pesticidally active for long periods.

The critical aspect of residues is the survival time of the stable chemical. This is normally described as a percentage loss or disappearance over a certain period. The normal expression is: residual 'half-life' (RL50 values), which describes the time required for half the residue to disappear.

The vast numbers of papers published on pesticide residues during the last decade, reveals the importance of this problem. In connection with this Rudd (1964) declared that next to insecticidal resistance, no problem of chemical pest control today has more significance. Increasing scientific attention is being devoted around the world, to the control of the amount of residues on, and in our food (Gunther & Jeppson, 1960). These efforts include the promulgation of regulations for treatment application, determination of the magnitudes and locales of persisting residues as well as the minimum intervals between applications and harvests.

The important fact is that the soil provides a reservoir for chemical residues which tend to persist much longer than those on the foliage. DDT, BHC, chlordane, dieldrin and heptachlor last for long periods in the soil. Lichtenstein (1957), in a study involving 14 orchards, reported a recovery of 26.6% of the total amount of DDT applied as sprays for a ten year period. DDT appears to be one of the most persistant insecticides.

Lichtenstein & Schultz (1964) conducted extensive experiments on parathion to determine its persistance and metabolism in the soil. After the application of 5 lb./acre parathion to Carrington silt loam soils, it took 90 days before the chemical reached a residue level of 0.1 p.p.m. or 3.1% of the applied dosage. They found that parathion was not lost through volatization, as in the case with some insecticides. Degradation of parathion was either by hydrolysis or by reduction to its amino form by populations of soil micro-organisms. The insecticide was most persistent in dry soils and less persistent in permanently wet conditions. In soil with low numbers of micro-organisms (autoclaved soil) or of low micro-organism activity (dry soils) parathion persisted for a relatively long time. No aminoparathion was formed in autoclaved soils. The faster disappearance of parathion in a medium with high biological activity was manifested by the results of an experiment in which yeast and soil water was added.

The fact that parathion could be converted by micro-organisms to their benefit was a major discovery. Soil micro-organisms represent the basis of the terrestrial food chain or pyramid. It might be possible that they eventually inhibit extensive growth of the resistant Collembola and other saprophagous organisms, such as Pygmephorus sp. and Scheloribates sp. In connection with the interrelationships between soil dwelling micro-organisms and invertebrates, Ghilarov (1963) notified that the bulk saprophagous invertebrates depend on the microflora for food. He mentioned that Oribatei, Tyroglyphidae and Collembola are principal consumers of lower plants.

From the work of various authors, evidence was found that the different chemicals applied to the soil do not totally destroy the faunal communities, but proved to work selectively. Karg (1964, 1967), Satchel (1965), Whitehead (1965) and various other authors demonstrated the resistance of certain Collembola, Acari and other insects to insecticides and herbicides, while predators on the other hand are generally less resistant and killed off. The development of resistance to insecticides is the most important problem in modern pest control research. As Rudd (1964) p.141 remarked: "The Utopia envisaged two decades ago, with freedom from insect pest assured by DDT began to fade as insect resistance appeared." Resistance means that the segment of a population able to withstand exposure to toxic chemicals has enlarged. When this segment becomes a prominent fraction of a population, and resistance is continued in subsequent generations, whether or not further exposed to chemicals, a resistant strain is formed. The occurrence of resistance is related to the widespread use of insecticides. It was first recognised in 1908 with the lime sulphur treatments of San Jose scale in apples, but only reached significant proportions after the discovery of DDT.

10 31 Review and present state of pest control programs on Zebediela

In earlier pest control programs, up to 1948, (Schoeman 1960), HCN fumigation of the citrus trees with a supplimentary oil spray was applied during November to July against the red scale, *Aonidiella aurantii* (Mask.). In addition this was followed by cryolite or sodium fluosilicate dustings during the middle of September against the cotton bollworm, *Heliothis armigera* (Hb.), and three lime sulphur sprays or three lime sulphur dustings at 9-day intervals during the end of September to the end of the October period against the citrus thrips, *Scirtothrips aurantii* (Faure). For control against the citrus aphids, *Aphis citricidus* (Kirkaldy), nicotine sulphate sprays were given during the period July to September.

With the introduction of the new organic synthetic insecticides, a change was made to parathion in the 1949-1950 season, and two thirds of the orchards were sprayed with this chemical annually, at a concentration of 0.075% active ingredient, against red scale during the November to July period. By the next season, HCN fumigation was completely replaced by parathion spraying. Parathion application proceeded regularly in the November to July period up to the 1954-1955 season, when the time of application was altered to early spring, just after the fruit picking. The application of this insecticide resulted in the effective control of red scale, citrus thrips, cotton bollworms and citrus aphids, but, as van Blerk (1962) pointed out, this was not the final answer to pest problems. He states (p. 5 & 7): "Two years after the introduction of Parathion, the first "new" pests made their appearance and quickly attained economic importance - Red Spider and Citrus Measuring Worm. D.D.T. earial spraying was employed against Citrus

Measuring Worm, but resulted in heavier and more widespread outbreaks of Red Spider, while the combined Oil-Parathion sprays applied against the latter in turn disturbed the biological balance of Citrus Measuring Worm.

Then the repeated D.D.T. and Parathion treatments brought Soft Brown Scale to the fore in the 1956-1957 season, and the position deteriorated during the following two years with phenomenally heavy outbreaks against which use was made of Malathion-Parathion and Gusathion-Parathion sprays.

Meanwhile Citrus Aphids, Soft Green Scale and Waxy Scale became increasingly difficult to control, probably due to a reduction of its natural enemies.

With this all resulting in control expenditure snowballing while control efficiency was taking a dangerous slide, the futility of campaining chemically against one insect species while ignoring the impact of the chemical on other species was brought home forcibly. An ecological approach to the pest problems had become essential and in 1958 a policy of combined biological and chemical control was introduced and followed. It included these modifications:

1 Aerial applications of D.D.T. replaced by Paration ground sprays.
2 An intensive campaign against ants with Dieldrex spray banding of tree trunks and Parathion soil treatments.
3 Minimizing repeated applications of any chemicals during summer and autumn and limiting applications to spot treatments.

4 Collection of two Coccinellid predator beetles, Chilocorus angolensis and Exochomus flavipes from areas of declining Soft Brown Scale infestations for dispersal in heavy infested groves.

Less than 18 months later Soft Green Scale and Waxy Scale were almost out, Red Spider was limited to local situations, and Soft Brown Scale had slid to a minor place on the pest list. Only in the Citrus Measuring Worm situation was there little or no change, but intensive study of this pest since its sudden rise to problem status gave promise of effective biologic control by rearing and release of its natural enemies.

Pursueing this policy of balanced control has paid off handsomely - with considerable cuts in control costs going hand in hand with increasing effectiveness of the control measures employed."

The parathion applied during September 1965 at Zebediela Estates was estimated at a mean of 10 gallons per tree (at a concentration of 3 lbs. per 100 gallons of water) for plot E, and 8.8 gallons per tree for plots B and C. This amount of poison was enough to saturate the soil surface immediately below the citrus trees, killing and gradually exterminating the more vulnerable and slower reproducing predator arthropods.

The soil population in plot D revealed its general affinity to the routine citrus plots, but in connection with the trombidiform predators, it corresponded more with that of the control plot. Various of the predatory trombidiform mites which occurred at the control plot were also present at the biological control plot, but in much smaller numbers (see heading 10.1). They were, however, absent or rarely present on the routine citrus plots. This situation could be ascribed to the action of the insecticides applied on the routine citrus plots. Collyer (1953) in a study comparing mite and insect faunas of commercial and neglected orchards in south eastern England also found a more varied fauna in neglected orchards. She observed that in neglected orchards, many different species occur, but none in excessive numbers. Hurlbutt (1958) also noted the less varied arthropod fauna of predatory mites in heavily sprayed orchards. The mentioned author ascribed this phenomenon to the selective action of the insecticides.

Another distinguished feature of the citrus mesofauna at Zebediela was the occurrence of large population numbers of certain members of the mesofauna, after chemical application. From the Collembola, species such as Isotomina termophila (Axelson) recorded up to 88,000 specimens per m^2 in one routine plot, while some of the Acari such as Pygmephorus sp. had an unusual population density of nearly 20,000 per m^2 after parathion application.

The ultimate question that arises will be; was chemical application, zoologically speaking, profitable to the citrus soil or not? From the soil faunal analysis it became evident that the cultivation practices and poison application in particular, exterminated or reduced organisms that promoted soil fertility. The diplopods are a good example in this connection. However, some of the usefull soil organisms such as *Scheloribates* sp., *Isotomina termophila* (Axelson), *Onychiurus camerunensis* (Schött) and *Brachystomella parvula* (Schaeffer) not only resisted chemical extermination in the citrus plots, but multiplied vigorously. The Collembola are very active animals. Macfadyen (1963) estimated their daily energy need as 144/cal./g/day at 16°C in comparison with Oribatei, which he calculated at 24 cal./g/day at 16°C. As the Collembola are fungi- and detritus feeders, the big collembolan numbers in the citrus plots most certainly converted considerable proportions of plant residue and fungi into organic material.

It is suggested that the normal predators of certain Collembola and Acari were exterminated or greatly reduced in the course of persistant agricultural treatments on the citrus plots. Some Collembola and Acari, however, not only proved to resist chemical extermination in the citrus plots, but strongly multiplied in the absence of their natural predators. But insecticidal resistance, nor the absence of predators could be fully credited for the phenomenal population densities of certain collembolan and acarine species. It is speculated that extensive fungal growth and microbial activities must have occurred, possibly as a result of stimulation by the chemicals, which in turn provided food for the large mesofaunal population numbers.