Observations on earthworm populations in orchard soils

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Summary

The investigation related to a study of earthworm populations in connection with soil management; at the same time the structure of the soil was studied by evaluating the stability of aggregates. For this purpose use was made of three experimental fields laid down in apple orchards at Nieuwland, Heiningen and Beuningen which for some years had been employed in soil management experiments. All sites consist of a fairly light soil with a silt content varying from 23 % to 25 %.
It was confirmed that only orchards with a grass cover afford good facilities for a favourable development of earthworms. In the three sites this was shown by the maximum densities of about 300, 500 and 430 per sq. m on the grass plots, 25 and 150 per sq. m in the plots bearing green manures at Nieuwland and Heiningen, and 30 per sq. m in the clean cultivated experimental plots at Beuningen. Considered qualitatively, the small species (*Allolobophora caliginosa, rosea* and *chlorotica*) responded more clearly to the various soil treatments than did the large ones (*Lumbricus terrestris* and *Allolobophora longa*). Generally speaking, plots with short grass were more densely populated than those with long grass. The effect of sprinkling on worm activities is still doubtful.
The connection between earthworm density and the various soil treatments, which was clearly observed after only three to five years whatever the original state of the experimental plots, indicates that earthworm activity is greatly dependent on soil treatment. The effect of the earthworm population on the stability of the structure should be studied in further detail as the vegetation itself may also have a soil-improving effect.
The consequences for soil productivity can only be assessed over a longer period.

1. Introduction

It is generally accepted at the present day that it is not only the physical and chemical factors that play an important part in soil economy but the biological ones as well. This is shown by the increasing amount of systematic research into the role of soil organisms in the processes that take place in the soil. The contribution of earthworms is a section of this subject to which great attention has been paid in recent years.
Of the earlier research workers in this field it was DARWIN (1881) among others who stressed the importance of earthworms and drew conclusions which still have their value today. He was one of the first to realise that these animals turn over the soil, thereby increasing its porosity. This effect is enhanced when the earthworms are of a species which does not eject its castings in its burrows or soil crevices but mostly on the surface of the ground. Another very important aspect mentioned by DARWIN was the formation of more or less rounded clay-humus aggregates in the wormcasts which

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he attributed to the intimate commingling of organic matter and clay minerals in the alimentary tracts.

Although the incidence of earthworm burrows (also known as the degree of perforation) is also a factor determining the soil structure, it is, in fact, this formation of aggregates on which attention is at present focussed. The reason is that these aggregates which are formed by earthworms are not only porous but also have a certain stability. It is becoming increasingly probable that the stabilisation of the soil structure is chiefly due to this fact (EVANS, 1948; HOEKSEMA, JONGERIUS and VAN DER MEER, 1956).

It is obvious that this aspect is receiving particular attention now that an increasing number of complaints are being heard about the structural degradation of agricultural soils. In fact it is clear that with intensification of agricultural methods, and possibly also as a result of the increasing use of chemical agents for fertilisation and the control of pests and diseases, earthworm populations are being adversely affected. Consequently worm activity may decline to such an extent as to be of no further importance to the formation and maintenance of a soil structure desirable for agriculture. It need hardly be said that this will begin to have a harmful effect on soil productivity.

The Itbon has recently been conducting research in this field. In the first instance it was ascertained what effect certain methods of soil management have on the number of worms. Since no clear idea of the pedological significance of these organisms can be obtained as yet from the literature of the subject, an attempt was also made to answer the question as to what extent there is a connection between worm numbers and the stability of the structure of the soil. It should be expressly stated that no attempt was made to define this relationship in exact terms. This question will be reverted to at a later date.

Owing to the importance of a good soil structure (possibly caused by a dense worm population) for good root development of fruit trees (HULSHOF, VAN DER KLOES and SCHELLEKENS, 1960) it was considered useful to begin investigations in this sector of agriculture. For the sake of completeness attention was also paid to the connection between yield and worm activity and that between yield and soil nitrogen supply. For this purpose use was made of experimental fields in apple orchards which had already been utilised in soil management experiments for several years, viz. an experimental field at Nieuw and St. Joosland (Province of Zeeland), one at Heiningen (W.Brabant) and one at Beuningen (Province of Gelderland). On the experimental fields at Nieuwland and Heiningen a comparison was made between soil covers of grass and green manures. The problem at Beuningen was to compare clean cultivated plots with a soil cover of grass. On the three experimental fields it was also examined how the adverse effects of a grass sward on the fruit trees could be overcome by controlling the frequency of mowing and supplying nitrogen and water.

2. Methods

On these experimental sites the worm populations were estimated as follows: Four samples were taken per trial plot under conditions favourable to earthworms. At Nieuwland and Heiningen the time of sampling was the beginning of winter 1959 and the early spring of 1960, and at Beuningen the summer and autumn of 1960. For each sample the soil was dug up in 50 $\times$ 50 cm sections to a depth of 40 cm. The earthworms found in this material were counted and weighed by species.

In addition to these earthworm counts, the stability of the structure was evaluated by means of the wet sieving technique. We aimed at using a method which was easy to put into practice and would yield comparable results. 50 g of air-dried soil was soaked in water for an hour and then transferred to a 1 mm-mesh sieve and screened while wet. This consisted in continually immersing the sieve in water by hand an equal number of times (viz. 10). The aggregates retained in the sieve were then dried at 105 °C and weighed. In order to calculate the stability of the soil structure the weight of these aggregates was expressed as a percentage of the likewise oven-dry initial weight of the sample. These estimates were based on soil samples which had been previously crumbled to aggregates of a diameter of about 1 cm. The method described above gives reproducible figures and is therefore suitable for comparative investigations.

3. Results

To enable us to evaluate the relationship between soil managements and earthworm population, in FIG. 1 the plots were classified according to decreasing numbers of worms. The total weight of worms and the numbers of the various species were also included.

It was found that both on the plots with green manures and the clean cultivated ones the earthworm numbers were much lower than on the grass plots. Both the total number of worms and also the composition of the earthworm fauna is important in evaluating the connection between population and soil management. On all plots the small species (*Allolobophora caliginosa, rosea* and *chlorotica*) were much more numerous than the large ones (*Lumbricus terrestris* and *Allolobophora longa*). This was especially true of the grass plots. In FIG. 1 it can therefore be inferred from a comparison of the total numbers of earthworms with their weights that on these plots the worms are on an average the lightest.

As regards the frequency of mowing, the graphs in FIG. 1 show that short grass is conducive to the development of earthworm population. The Beuningen experimental field was unable to provide any information on this subject as during the last year in the short-grass plots a management with clean-cultivation strips in the fruit-trees rows had been applied and the counts had partly been made in the strips.

It was only on the Heiningen experimental field that sprinkling was less favourable to the worms. Here in practically all plots the not sprinkled ones were rather more densely populated than the sprinkled ones.

The evaluation of the stability of the structure is shown in FIG. 2 in which the number of worms and the yield and nitrate content figures are also included. (The latter relate to the 0—80 cm profile).

FIG. 2 clearly shows a correlation between the percentage of water-stable aggregates and the earthworm population, although none of the three diagrams shows any relationship between yield on the one hand and earthworm population and stability on the other; the same is true of the yield and the nitrate content of the soil, despite the fact that the clean cultivated plots and plots with green manures gave higher yields during the first years of the experiment.

4. Discussion

The considerable difference between the numbers of earthworms on plots bearing a

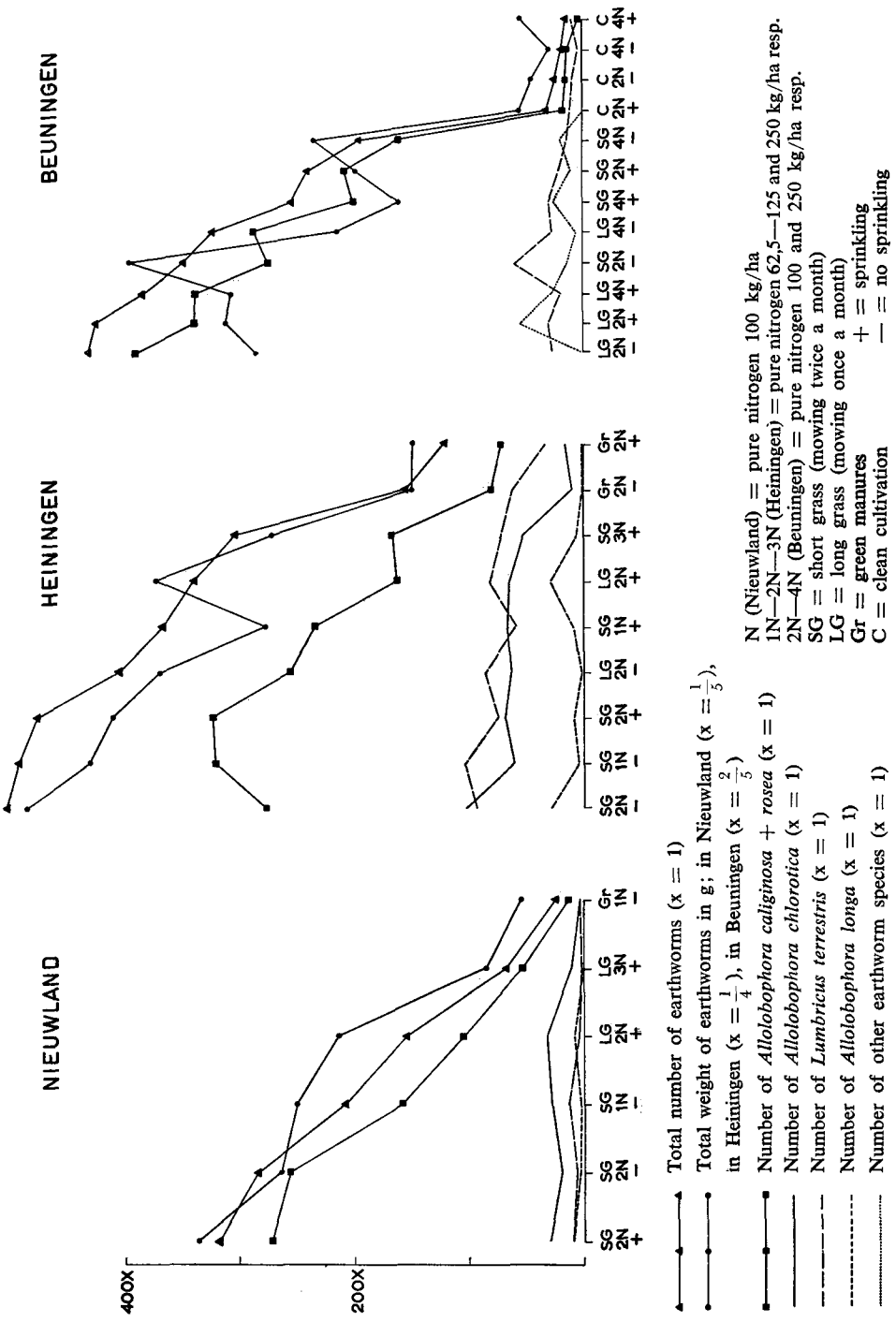
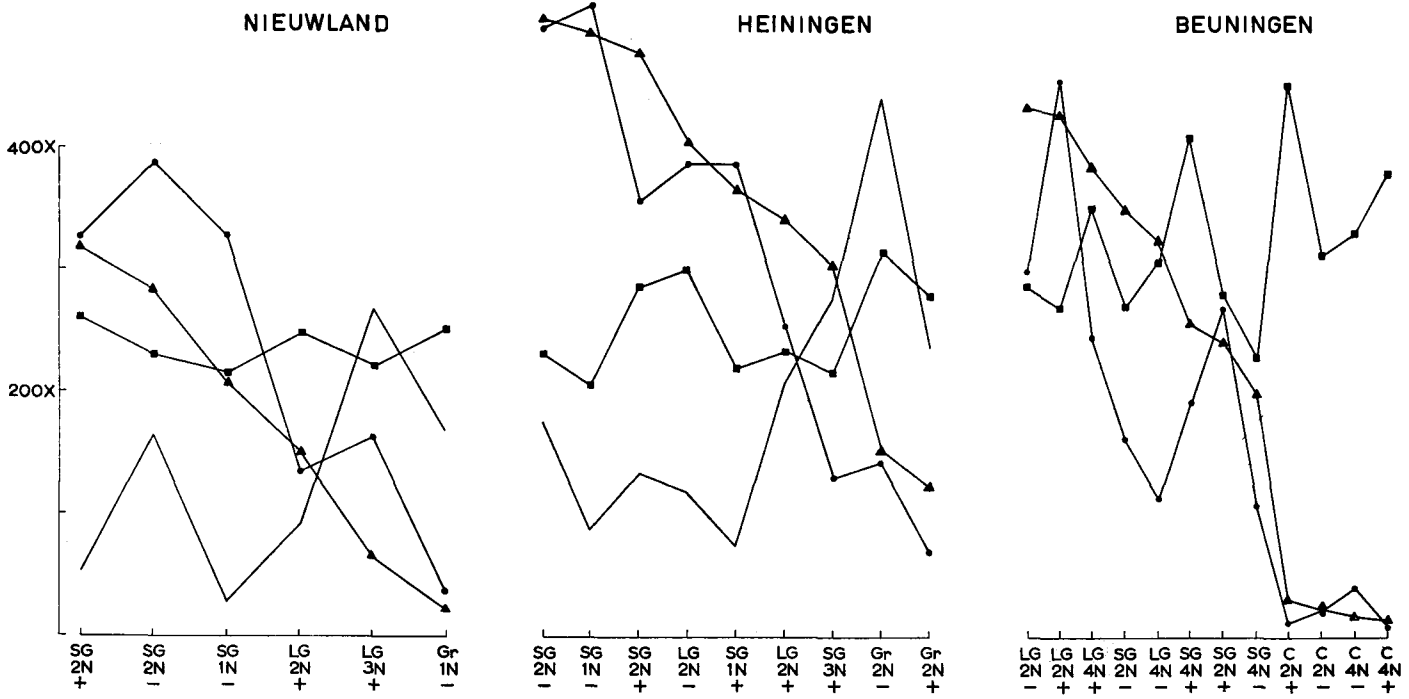


FIG. 1. Earthworm population on fields with different systems of soil treatment (number and weight per m²)

FIG. 2. Total number of earthworms per m^2, percentage of water-stable aggregates, yield and N (nitrate)-percentage of the soil with the same systems of soil treatment as mentioned in FIG. 1



permanent soil cover (grass) and those with a temporary cover (green manures) or without vegetation (bare orchard soil) confirms the impression that a permanent dense soil cover has a good effect on the development of earthworm populations (EVANS, 1948; HOEKSEMA, JONGERIUS and VAN DER MEER, 1956).

At present it is still difficult to gain an accurate picture of the causal relation, but having regard to what is already known about the ecology of earthworms we can point to various factors which play a part in their life-history. It is generally assumed that recurrent annual cultivation, as occurs each spring when there is a temporary soil cover or the orchard is kept bare, must cause mechanical injury to earthworms. This theory is confirmed by the relatively low density of the small species mainly living in the topsoil of the fields with green manures and of the bare ones. It is also known that dry matter production is highest in a grass cover, and this ensures the earthworms a good supply of food. In the third place, a permanent grass cover creates a more favourable microclimate which particularly stimulates the development of the species living in the top-layer of the soil. On the fields which have no sward the soil cover is usually inadequate and during the autumn and winter the temperature fluctuations will be greatest here. According to HOPP's (1947) investigations we must in fact expect a higher mortality during the cold season on sites with insufficient vegetation. Finally, the fourth and most important factor is the moisture condition of the soil. It is known that in periods of drought the worms are hardly if at all active (DOEKSEN, 1957), but they are equally intolerant of excessive moisture (ROOTS, 1956). It is clear that as a result of all these factors the soil management must have an effect on earthworm activity, and this must be ultimately reflected in their population density.

The differences, albeit slight, between population density on well-mown (short) and little-mown (long) grass plots may possibly be explained by the better nutritive state of the soil with short grass (resulting in a greater amount of material which is more rapidly digestible and richer in nitrogen).

The differences in earthworm density shown in FIG. 1 between sprinkled and not sprinkled plots afford indications that, at Heiningen at least, sprinkling was less favourable to the earthworm population. However, little importance can be attached to this as this experimental field was occasionally sprinkled with fairly saline water.

The differences in earthworm density between the three experimental sites are rather due to their previous history than to the type of soil. Those at Heiningen and Nieuwland, for example, are silt-loam soils with not more than 23 % of silt, whereas the Beuningen site is a light stream-ridge soil (about 25 % of silt) with a high gravel content. But the experimental plots at Heiningen and Beuningen, which taken as a whole had a denser population than the Nieuwland plots, already had a sward for some time when they were laid down in 1957 and 1955 respectively. Against this is the Nieuwland orchard which had always been kept clean before the experiment started.

Although it is no longer possible to revert to the original state for both the earthworm population and soil structure, it seems very likely that at Heiningen and Beuningen a picture can be gained of the maintenance of the worm populations and the stability of the structure below a sward on the one hand, and of their decline on the other after the sward had been disced in or replaced by green manures. On the other hand at Nieuwland, where the original state was an orchard which had long been kept clean, the population density and the stability of the structure remained

on the low side when green manures were supplied, but increased when the orchard was laid down to grass.

The positive connection between earthworm density and the formation of stabler aggregates in the soil was already known (EVANS, 1948; HOEKSEMA, JONGERIUS and VAN DER MEER, 1956), but the fact that the soil treatments discussed here resulted in marked differences in earthworm density and soil structure in the fairly short period of 3 to 5 years shows that this development is a comparatively rapid one. This might indicate that the earthworms have a good effect on the structure of the soil.

However it should not be ignored that the vegetation itself has also a soil-improving effect. WEHRLI (1958), for example, has already been able to demonstrate that a sward forms a better soil structure than a vegetation of legumes. As regards this point the separate effect of earthworms and grass roots still has to be examined.

Despite the low nitrate content of the soil on most of the grass plots at Nieuwland and Heiningen the yields were no lower, or not much lower than those of the fields bearing green manures and the grass plots with a heavy nitrogen dressing. This may possibly be due to the better soil structure of the former plots. Probably, and this may also be true of the experimental field at Beuningen, the differences in fertility will not be significant and noticeable in productivity until both the development of earthworm activity below a sward (and hence also the soil structure) has advanced far enough and the nitrogen requirements at this point have been fully satisfied. But it is a question to what extent the use of chemical agents for the control of pests and diseases will be an inhibiting factor for the desired development of earthworms. This is another problem which is being investigated at the Itbon.

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