Nematodes in relation to plant growth IV. Pratylenchus penetrans (COBB) on orchard trees

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Summary

This paper brings together relevant data on damage by *Pratylenchus penetrans* in orchards in the Netherlands. The nematode was already known to be a cause of poor growth of seedling apples and other woody plants. A strong regression of growth on the preplanting nematode density is demonstrated for two different experimental fields and four varieties of apple; heavy nematode infestation reduces shoot growth by more than 50 %. It is probable that considerable damage occurs even at infestation levels below 100 nematodes per 300 ml of soil. It is demonstrated that seven *Malling* rootstocks are heavily infested and suffer damage. Rootstock *M VII* may be somewhat less susceptible to damage than the others, but is an efficient host.

The process of infestation and the appearance of damage are illustrated under field and experimental conditions. Both demonstrate the introduction of *P. penetrans* into uninfested soil by means of rooted plants, the build-up and persistence of a population on arable crops and the appearance of symptoms in woody crops. The non-specific character of such nematode damage to woody plants is shown by the fact that damage may occur on arable land where woody crops have never been grown before.

In clean-cultivated orchards on light sandy soils high populations in the roots often are accompanied by barely detectable populations in the soil. In heavier soils the populations in infested orchards are usually higher in the soil but lower in the roots than in sandy soils.

Cover crops under orchard trees have a special influence on the nematode population in and around the tree roots.

The data leave no doubt that *P. penetrans* is an important cause of the replant problem, distinct from the so-called "specific sickness". Control measures include soil sampling before planting, avoidance of efficient host plants prior to planting, choice of an appropriate cover crop and soil disinfection with a nematicide. It should be realised, however, that such control measures have their limitations, as the "specific sickness", which also occurs in many orchards, will not be controlled.

1. Introduction

Earlier work indicated the significance of at least two independent causes of soil sickness in seedling woody crops in the Netherlands, *viz.* damage by root-infesting nematodes and the so-called "specific sickness" due to other causes (OOSTENBRINK and HOESTRA, 1961). The nematode damage was not host-specific, owing to polyphagy of the prevailing parasitic species (*Pratylenchus penetrans*), and could be cured by soil treatment with nematicides such as dichloropropene (DD). The "specific sickness"

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appeared only with monoculture of certain plant species and could not be cured with DD; it was attributed to two fungi in *Rosa* and in *Laburnum* seedlings, but its cause remained uncertain in *Malus* seedlings. The authors indicated that both kinds of sickness were believed to play a role in the replant problem of orchards. This has been substantiated by field observations and by soil treatment experiments with different kinds of fumigants (HOESTRA, 1961 a, b) as well as by survey work in replanted orchards (VAN MARLE, 1961, 1962). It is also supported by the result of field trials with DD, which was found to be effective in some of the fields only; good results were correlated with nematode infestation (Anonymus, 1957, 1960).

The present paper deals with the non-specific part of the replant problem caused by nematodes and describes the characteristics of this kind of infestation. A number of phytophagous root-infesting nematodes are associated with orchards in the Netherlands, some of these reproduce well on fruit tree roots and reach high population densities and may therefore be of significance as growth factors. *P. penetrans*, however, is the only one of these species at present proven to be pathogenic to young apple and other orchard plants and to be sufficiently widespread to be of general significance. The following data deal with damage to fruit trees by this species.

Data on pathogenicity and occurrence of this nematode and results of experiments with seedlings of apple and other woody crops have been presented in part III of this series (OOSTENBRINK, 1961 a). Inoculations by workers from different countries have shown that *P. penetrans* is the primary cause or incitant of serious growth stagnation in seedlings of apple, cherry and several other woody plants. Information about the influence of the nematode on older trees is less conclusive. There is, however, little doubt that one- or two-year old rootstocks or trees as used for planting orchards are damaged in the same way as seedlings, because they show the same type of injury and poor growth on infested soil. The nematode was recorded from 30 % of all cultivated fields on sand, silt and loam soils in this country. Orchards, however, appear to be a favoured biotope, since 74 % of the samples from 271 orchards were infested; 24 % contained more than 50 specimens per 100 ml of soil, which is well above the critical density of 35 per 100 ml of soil which is used in advisory work. In a more recent survey of orchards of the river clay areas VAN MARLE (1962) found about the same percentages. He also found that 60 % of all recently replanted orchards showed visible growth stagnation and, therefore, that the replant problem is of great practical significance.

2. Results and observations

2.1. Influence of *P. penetrans* on the growth of apple trees

Two sets of experimental results are available to judge the influence of nematode density on young apple trees and on the susceptibility to damage of different rootstocks under our conditions. Results of representative trials, briefly recorded earlier in general reviews, are given here as a basis for discussion.

a. Shoot growth of young apple trees was found to be related to the density of *P. penetrans* in rotation experiments on two fields, W and N (OOSTENBRINK, 1956).

The published data were the mean results of four varieties of apple trees.

FIG. 1 gives separate regression lines and statistical data for each apple scion/rootstock combination on each of the trial fields. The slope and position of the regression lines can be read from the sample regression equations of TABLE 1.

TABLE 1. Sample regression equations, separately for four apple varieties on two trial fields

Variety of apple tree	Sample regression equations	
	Trial field W	Trial field N
JG/IV	y = —270 x +1089	y = —259 x + 900
GD/IV	y = —505 x +2062	y = —386 x +1459
J/I	y = —508 x +2406	y = —918 x +3116
GD/XI	y = —686 x +3337	y = —305 x +1790

For explanation of symbols see *fig.* 1.

b. OOSTENBRINK, S'JACOB and KUIPER (1957) compared 182 plant species with respect to resistance (*P. penetrans* density in roots) and susceptibility to injury (growth deficit in comparison to disinfested soil). The results on apple rootstocks in a representative trial, situated on soil N as recorded under a, are given in TABLE 2 in more detail than could be recorded in the 1957 paper.

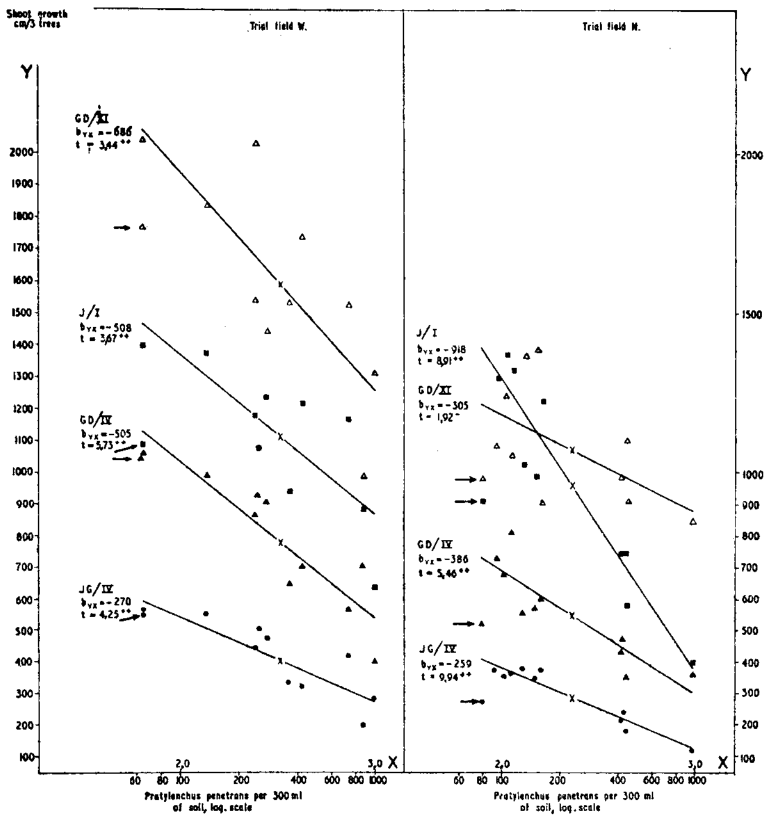
Discussion: Fig. 1 demonstrates a very significant negative correlation between *P. penetrans* density and shoot growth of all four apple varieties in trial W and of three of four varieties in trial N. The influence of the nematode density evidently dominates other rotational effects of the preceding crops; only the variety *Golden Delicious* on rootstock *M XI* in trial N gave results too variable to reach statistical significance. The fact that higher nematode numbers correspond with heavier damage to the trees clearly illustrates the primary importance of the nematode, whether it is the sole cause or the incitant of the damage. This is also of interest in view of the work of PITCHER, PATRICK and MOUNTAIN (1960) who did not find significant growth reduction of apple seedlings after inoculation with surface-sterilized *P. penetrans*.

In all cases apple seedling (indicated by ——> on the graphs) was a poorer preceding crop than could be expected from the nematode figures, thus demonstrating the influence of "specific sickness" in addition to nematode damage. This influence is less evident in trial field W, but it is striking with all apple varieties in field N.

The relationship between the logarithm of the nematode figures and shoot growth are approximated here by straight lines; heavy nematode infestation evidently reduces shoot growth by far more than 50 %. It is also probable that considerable damage can occur at population densities below 100 *P. penetrans* per 300 ml of soil, the lowest level of infestation which is at present taken into account in advisory work. If we accept that this relationship is truly rectilinear and that the lines may be extrapolated to zero infestation (which may be true, but is questionable), then 100 *P. penetrans* per 300 ml of soil (x = 2 in *table* 1) would correspond with shoot growth reductions between 41 and 50 % on trial W and between 34 and 58 % on trial N, giving a mean value of 48 %, whereas 1000 *P. penetrans* (x = 3) would correspond with shoot growth reductions which are 1½ times as high. Each doubling of the nematode density would correspond with a percentage shoot growth reduction between 6 and 7 on trial W and between 5 and 9 on trial N (overall mean 7 %). These percentages are much higher, and perhaps appear more realistic, if reductions are compared to the shoot growth at 100 nematodes per 300 ml of soil, about the lightest infestation in the experiments. The loss in this case is between 11 and 15 % on trial W and between 8 and 22 % on trial N for each doubling of the nematode density (overall mean 15 %).

Normal, wellknown differences in shoot growth between rootstock/scion combinations are clearly demonstrated. The marked difference in growth between *Golden Delicious* and *James Grieve* on the same rootstock, *M IV*, is in agreement with existing knowledge on the development of these varieties. Shoot growth of *Golden Delicious* is much better on *M XI* than on *M IV* on lightly as well as on heavily infested soil; the percentage reduction in shoot growth between 100 and 1000 nematodes per 300 ml of soil, i.e. the susceptibility to injury, was less in the first-mentioned combination than in the last (respectively 35 and 48 % in trial W, 26 and 56 % in trial N).

Table 2 indicates that all seven rootstocks are heavily infested; i.e. none is resistant to *P. penetrans* infestation and shoot growth is decreased in all cases. Although it is open to question whether shoot growth of the rootstocks themselves is definitely related to shoot growth of scions on these rootstocks, it is interesting to note that *M VII* showed the smallest reduction or deficit of top growth on infested soil, whereas *M IV* was heavily affected. In fruit-growing regions in the Netherlands it is often found that, in replanted areas, trees on *M IV* suffer much more than trees on *M VII*. If, indeed, *M VII* is less affected, this is certainly not due to reduced nematode infestation, but to tolerance, for the nematode density in the roots of *M VII* is not low, but high.



In 1953 and 1954 eleven preceding crops were grown in each of two infested fields W and N. Replication was threefold. In 1955 four varieties of apple were grown across all plots, viz. *James Grieve* on *M IV = JG/IV, Golden Delicious* on *M IV = GD/IV, Jonathan* on *M I = J/I* and *Golden Delicious* on *M XI = GD/XI*. One tree of each variety per plot, i.e. three per preceding crop on each trial field.
Total shoot growth of these three trees per preceding crop (y) is plotted against the logarithm of the corresponding *Pratylenchus* infestation per 300 ml of soil, i.e. against the sum of the *Pratylenchus* figures per 100 ml of soil of three replicate plots (x). Regression coefficients (b_{yx}) and significance data (t — values) are calculated, separately for each apple variety and each trial field; ++ = probabilities more than 99 % (cf. SNEDECOR, 1956). Apple seedlings as a preceding crop, indicated by ——➤ on the graphs, were purposely excluded in the calculation because it was known, that this crop may cause "specific sickness" in apple.

FIG. 1. Regression of growth of young apple trees (one year's inoculations on different *Malling* rootstocks) on density of *P. penetrans* (logarithmic scale) in 1955

TABLE 2. Susceptibility trial with seven Malling (M) rootstocks of apple, *Malus pumila* MILL., on sandy peat soil with 84 *Pratylenchus penetrans* per 100 ml of soil, year 1954. Average top growth of each rootstock on infested soil (three replicate plots) is compared to average top growth on soil disinfested with the nematicide dichloropropene (five replicate plots). *Pratylenchus* figures determined in root samples of infested soil taken on 16. July 1954 by uprooting plants of two replicate plots

Apple rootstock	Top growth deficits of injured plants (on infested soil) as percentages of healthy plants (on disinfested soil) %	Average *Pratylenchus* infestation per 10 g of roots in injured plants on infested soil
M I	68	6.100
II	36	8.000
IV	51	6.600
VII	11	13.400
IX	41	6.300
XI	36	9.800
XVI	36	12.000

2.2. The character of the nematode damage

The following observations illustrate the introduction of *P. penetrans* into arable soil by means of rooted plants, the build-up and persistence of its population on arable crops, the occurrence of poor growth in newly-planted orchards on soil where such plants have not been grown before and the nature of the symptoms.

a. A three-year-old apple orchard on sandy soil in Beugen showed good growth except on a square of about 1 ha where a nursery of woody crops had been maintained in the years 1949—1951. From 1952 to 1957 arable crops, among which were clover and rye, had been grown on the whole field and in 1958 it was planted with two varieties of apple: *Stark Earliest* and *Close,* both on *M IX*.
Both varieties showed a markedly reduced growth on much of the former nursery soil. The situation in 1962 and the symptoms are illustrated in FIG. 2. Sampling revealed a dense population of *P. penetrans* in the apple roots in the poor-growing part of the nursery and a light infestation in the rest of the field (TABLE 3).

b. Soil from an arable field at Beilen, supporting a population of *P. crenatus,* but not of *P. penetrans,* was fumigated with DD in the spring of 1955. The treatment reduced the *Pratylenchus* population from 235 to zero per 100 ml of soil (although a few specimens were found in a larger sample). The soil was thoroughly mixed and placed in twelve 8-litre pots. Series of three pots were maintained for

TABLE 3. *Pratylenchus penetrans* infestation in poorly growing and healthy parts of an apple orchard at Beugen (Cf. FIG. 2). Orchard planted in autumn 1958, nematode figures determined in autumn 1960. Sandy soil, clean-cultivated

	P. penetrans infestation	
	per 100 ml of soil	per 10 g of roots
Very poor growth in former nursery soil	35	5220
Moderately poor growth in former nursery soil	5	1720
Healthy growth outside former nursery	0	485

FIG. 3. Pear seedling, *Pyrus communis* L., on arable soil following apple - apple - rye (foreground, heavily infested with *P. penetrans*) and following grass - grass - rye (background, lightly infested). Cf. TABLE 4. Pear seedlings sown on 17th April, 1958, and photographed on 25th August, 1958.

FIG. 2. Apple orchard at Beugen. Good growth (left), except on former nursery soil (right) with heavy infestation of *P. penetrans*. Cf. TABLE 3. Apple trees planted in 1958 and photographed in 1962.

two years (1955 and 1956), planted with the following species: young apple trees (*James Grieve* on *M IV*), ryegrass (*Lolium multiflorum* LAM.), rye (*Secale cereale* L.), and red clover (*Trifolium pratense* L.). In the summer of 1957 rye was grown in all pots; it developed somewhat better following apple and red clover than following rye and ryegrass. In the spring of 1958 it appeared that the former apple pots contained the highest *Pratylenchus* population, consisting mainly of *P. penetrans* (1125 out of the total population of 1295 per 100 ml of soil). The former ryegrass pots contained 130 *P. penetrans* out of a total *Pratylenchus* population of 1290 per 100 ml of soil, whereas the *P. penetrans,* and also the total *Pratylenchus* numbers in the rye and red clover pots were lower. The *P. penetrans* population in the apple pots must have been due to infection by means of the young apple trees in the spring of 1955; the trees, obtained from a normal commercial stock, were known to have lightly-infested roots when they were planted. It cannot be due to selective reproduction on the apple roots, since red clover, rye and ryegrass are more efficient hosts of *P. penetrans* than apple. The presence of some *P. penetrans* in the red clover, rye and ryegrass pots is probably due to accidental infection originating from the apple pots in the course of the experiment, for all pots stood side by side, plunged into garden soil, for three years.

In 1958 five pear seedlings were planted in each of the former apple and ryegrass pots. Growth was much poorer in the former apple pots than in the others in 1958, cf. FIG. 3. This growth deficit was still marked at the end of 1960, when the plants were lifted, measured, weighed and examined. Density of the *P. penetrans* population in the pear roots was about 25 times as high in the former apple soil as in the former grass soil (TABLE 4).

c. In an arable field at Overloon on sandy loam a population of *P. penetrans* was built up by growing potatoes and cereals. The origin of this infestation is unknown, as tree crops have never been grown here. The population density of *Pratylenchus* spp., consisting mainly of *P. penetrans,* exceeded 185 per 100 ml of soil in the spring of 1955. In 1955 cherry seedling-rootstocks, *Prunus avium* L., grown here showed extremely poor growth; this was also true for rose, apple and several other plants susceptible to *P. penetrans,* but not for a number of unsusceptible Cruciferae and Chenopodiaceae.

The symptoms of poor growth in susceptible plants were absent on strips of this field which had been fumigated with DD. *Pratylenchus* density in *Prunus avium* roots was negligable on the fumigated soil, but reached 4460 per 10 grams of roots in

TABLE 4. Growth of pear seedlings on arable soil which had carried apples in preceding years, in comparison with soil under grass. Pots of 8 litres; five pear seedlings per pot planted on 17. April 1958. Average figures per three pots; between brackets, range of figures of individual pots

Preceding crops 1955/56/57	*Pratylenchus* per 100 ml of soil, spring 1958		Evaluation of pear development, autumn 1960				*Pratylenchus* per 10 g of roots, autumn 1960	
	penetrans	*crenatus*	Number of surviving plants	Plant height (cm)	Top weight (g)	Root weight (g)	*penetrans*	*crenatus*
Apple - Apple - Rye	1125	170	4,0	60 (58—61)	396 (311—467)	539 (484—625)	19.450	0
Grass - Grass - Rye	130	1160	4,7	89 (75—98)	760 (536—924)	968 (842—1183)	790	790

the untreated soil by 30. August 1955. The shoot growth (sum of all branches) of the *P. avium* plants was then 242 cm (range 141—363) on the fumigated and 24 cm (23—24) on the untreated soil. The mean shoot-growth deficit was thus 218 cm, or 90 % of the growth of the trees in fumigated soil. A large difference in vigour was maintained in the following season, as illustrated by FIG. 4.

Discussion: *Fig.* 2 and *table* 3 show a situation which is quite common in commercial practice. Young orchards often show marked growth stagnation on former nursery soil, especially on sandy soils, which is not restricted to apples. A number of cases examined in recent years have shown that the poor growth was usually correlated with heavy infestations of *P. penetrans*. It appeared, therefore, that nurseries or former nurseries often contain populations of *P. penetrans* which are well above the critical level for young fruit trees (*fig.* 2). Six arable crops on the soil under 2.2 had been grown between former nursery crops and the apple crop showing severe nematode damage. The nursery crops, which were rooted plants, must have introduced the infection, but the arable crops have evidently not suppressed the population of *P. penetrans,* they may even have built it up, for several arable crops are known to be more efficient hosts than woody plants. Arable crops, however, normally show less marked symptoms than woody plants, or no symptoms at all. Thus plantings of fruit trees on arable land infested with *P. penetrans* will normally be threatened unless the nematode population is suppressed by choosing a suitable preceding crop or by treating the soil with a nematicide. The situation described above was reconstructed in the experiment under 2.2. b (*fig.* 3 and *table* 4). Here young apple trees grown in 1955 and 1956 introduced the infestation and summer rye must have maintained or multiplied the nematodes in 1957 to a level which was harmful to the pears grown in 1958—1960. Young fruit trees, therefore, may carry light infestations themselves, as do other rooted plants. This infection will not normally be harmful to the trees if planted in nematode-free soil, but it may cause damage to subsequent plantings of the same or other susceptible species (*table* 4, cf. also OOSTENBRINK, 1957 a).

The case described under 2.2. a concerned a former nursery, part of which had been planted with apple rootstocks. An apple orchard was planted later and therefore specific sickness might also be present in addition to an infestation of *P. penetrans*. The orchard, however, showed poor growth in areas where rootstocks other than apple had been grown. Moreover, in a less heavily infested part of the former nursery less damage occurred (*table* 3). These facts, together with the heavy nematode infestation, indicate the importance of *P. penetrans* in this case. The same holds good with respect to the experiment under 2.2. b. Pear may play a part in the "specific sickness" complex of apple, which may be a specificity to a plant genus rather than to a plant species, but pear is probably less susceptible to specific sickness than apple (THOMPSON, 1959). There is little doubt that a *P. penetrans* density of more than 19.000 per 10 g of roots, as indicated in *table* 4, does cause serious damage to pear. We therefore conclude that the damage described above must have been due mainly to the nematode infestation.

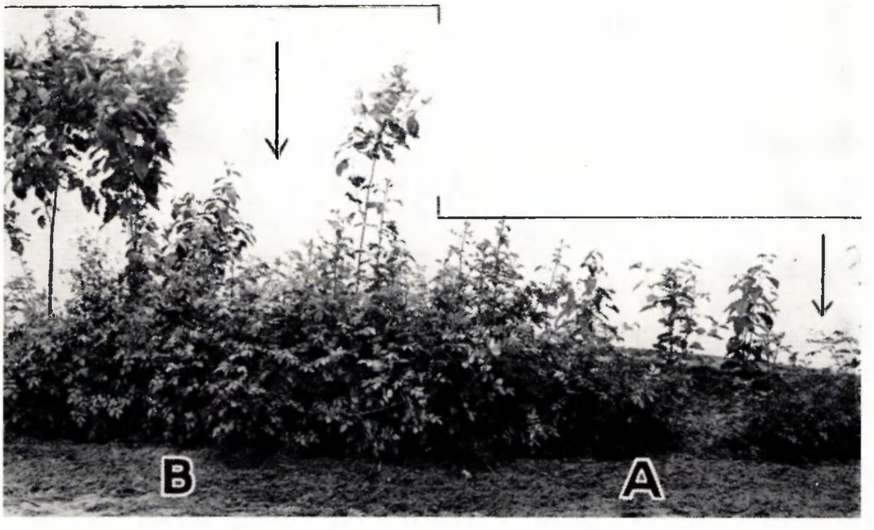
This was certainly true of the case described under 2.2. c. *Fig.* 4 illustrates that poor growth due to *P. penetrans* damage may also occur in *Prunus* and other susceptible crops on soil where woody plants have never been grown before and gives pertinent evidence of the non-specific character of such nematode injury.

2.3. The influence of soil type on injury

P. penetrans is more common in lighter soils, although it does occur on clay soils especially in orchards, as was mentioned in the introduction. Experimental data on the influence of soil type on this nematode is scanty, but our observations in apple orchards indicate that the populations behave differently on sandy and clay soils.

a. Clean-cultivated orchards on sandy soils apparently suffering from injury by *P. penetrans* often support 5000 or more nematodes per 10 g of fine roots, but nematode numbers in the soil are often very low; TABLE 3 illustrates a typical case.

FIG. 4. Growth stagnation in seedling cherry root stocks, *Prunus avium* L. (background), and of seedling rose, *Rosa canina* L. (foreground), in arable land which had not previously carried these crops



A *P. penetrans* population was built up by growing cereals and potatoes (A). Left on soil which was fumigated beforehand with the nematicide dichloropropene (B). Crops sown on 29th April, 1955, photograph taken on 22nd June 1956. Arrows indicate missing trees which were uprooted for root examination and nematode extraction.

b. In clean-cultivated orchards on medium- to heavy-texured soils (the most important for fruit-growing in the Netherlands), root infestation rarely exceeds 1000 nematodes per 10 g. Serious damage may, nevertheless, be associated with this number on these soils. In comparison to the numbers found in sandy soils the nematode density per 100 ml of soil may be rather high. Cf. TABLE 5.

TABLE 5. *Pratylenchus penetrans* density in roots and surrounding soil of an apple orchard at Winkel. Clay soil; clean-cultivated part compared to part with a grass cover crop

	P. penetrans density		
	per 100 ml of soil	per 10 g of apple roots	per 10 g of grass roots
Clean - cultivated part	130	675	
Grass - grown part	215	45	1580

Discussion: Extensive survey and field observations have convinced us, that the differences mentioned above hold good for clean-cultivated orchards. *P. penetrans* is a migratory endo-parasite and the occurrence of high numbers in roots and low numbers in soil suggest that a sandy soil is more favourable to the nematode than are heavier soils. The observed differences between light and heavy-textured soils may be due to an improved mobility of the nematode in a sandy soil.

2.4. Influence of cover crops on the infestation

The density of *P. penetrans* in the soil and/or the roots of fruit trees may be influenced by the cover crop grown beneath them. This is illustrated by the following data and observations from various sources.

a. *Tagetes* spp. are known to suppress *P. penetrans* populations in the soil around and in the roots of seedling woody crops and apple trees both when grown as a cover crop or as a preceding crop (OOSTENBRINK c.s., 1957, 1959, 1961 b; MEIJNEKE and OOSTENBRINK, 1958; Anonymus, 1959, 1960).

b. Young apple trees were planted on infested sandy peat soil and undersown with different cover crops in 1959. For each cover crop six one-tree plots were distributed at random over the field. The cover crops were *Tagetes patula,* red clover, apple seedlings and fallow. The *Pratylenchus* population, a mixture of *P. penetrans* and *P. crenatus,* was high on the red clover plots (av. 865/100 ml of soil), intermediate on the apple seedling and fallow plots (av. 320 and 300 respectively) and low on the *Tagetes* plots (av. 160). The differences between the three population densities were statistically significant.

c. Orchards undersown with arable crops, such as potato, cereals, red clover or grass/clover may support much denser soil populations than corresponding clean-cultivated areas. This is especially true soon after the crops have been lifted or ploughed under. Under such circumstances infestation levels of 1000—1650 *P. penetrans* per 100 ml of soil are sometimes found, especially on the lighter soils.

d. Most orchards in this country have permanent pasture as their cover crop; in such cases a low population density in the apple roots is often associated with high population densities in the grass roots and possibly also in the soil. TABLE 5 illustrates a typical case.

Discussion: Published data show that arable and green manure crops influence the population density of *P. penetrans* and, therefore, also the degree of damage to apple trees and other susceptible plants grown in following years; see also *fig.* 1. The data given under a, b, c indicate that a similar influence is exerted on the soil population density when these crops are grown in association with apple trees, i.e. as cover crops. The data under d, however, suggest that grass as a permanent cover crop may be a more efficient host than apple and thereby at least temporarily decrease the infestation of the apple roots. The dense grass root system may provide a better opportunity for the reproduction of the nematode population, the nematodes may prefer grass roots to apple roots, or an other nematode biotype may be present in grassland.
It is evident that the influence of cover crops on the nematode infestation of fruit trees may be complex and requires further study.

3. General discussion and conclusions

The data leave no doubt that *P. penetrans* is an important cause of the replant problem under our conditions and is independent of the so-called "specific sickness". The nematode is already known as a cause of poor growth of seedling apples and other woody plants. TABLES 1—3 and FIGS. 1—2 indicate that quite apart from "specific sickness" or other effects of preceding crops (FIG. 1), apple rootstocks and young trees suffer comparable injury closely related to the soil population density of *P. penetrans.* The data show that nematode damage can be very serious for all rootstocks and tree varieties tested, although perhaps rootstock *M VII* shows some tolerance. It is probable, from the slope of the lines in FIG. 1, that considerable injury can be caused by *P. penetrans* at densities below 100 per 300 ml of soil.
Injury by *P. penetrans* may occur in several woody and other crops. The symptoms are in all cases unusually poor growth, as illustrated in FIG. 2 for young apple trees, in FIG. 3 for two-year-old pear seedlings and in FIG. 4 for two-year-old seedlings of cherry rootstock and of rose. It is not yet possible to define reliable diagnostic differences between nematode damage and other symptoms of poor growth in orchard trees. The presence of a soil and/or root population density of *P. penetrans* well above the experimentally established critical level for the appropriate crop is the only sure basis for a diagnosis of nematode damage.
The data under 2.2. stress the role of infection and the polyphagy of the nematode; nursery stock and young fruit trees evidently act as carriers of the nematodes. It is clear, however, that infested trees do not themselves suffer obvious injury if they are planted in uninfested or lightly-infested soil. The importance of an original infestation of the planting material in relation to decline in the ageing orchard is not yet fully understood. The data in 2.2. also show that dense nematode populations can be present and fruit trees can be severely injured in arable soil which has not previously carried a woody crop. Most arable fields, however, are not infested with *P. penetrans* and will not show this phenomenon.
The above results suggest that recommandations for avoiding nematode injury to young fruit trees should be much the same as those for the control of injury by *P. penetrans* to annual crops (OOSTENBRINK, 1961a). They may be summarized as follows:

a. Soil sample examination as a basis for advisory work. 50 *P. penetrans* per 100 ml is considered a critical density for medium to heavy soils and, as shown under 2.3., this figure may be lower for lighter soils. In the case of fields with growing fruit trees or other host plants of *P. penetrans,* root-sample analysis may also be necessary to enable reliable forecasts of injury.

b. Efficient nematode host plants (potato, cereals, red clover, and perhaps grass/clover) should be avoided as the last crop prior to planting on infested soil.
c. The growth of *Tagetes* spp. or grass as cover crops may be important but requires further evaluation.
d. Soil treatments with nematicides prior to planting may be helpful.

The main weakness of the above control measures is that none can guarantee good results in fields where "specific sickness" is also present (OOSTENBRINK, 1957b). Because this is so in many old orchards (VAN MARLE, 1962) other measures and other soil treatments will often be needed to ensure good growth in re-establishing an orchard (HOESTRA and KLEIJBURG, 1960; HOESTRA, 1961a).

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