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Causes of root rot in maize on sandy soil

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Abstract

In an outdoor pot trial the causes of root rot in maize were studied with a nematicide (oxamyl) and fungicides (captafol and metalaxyl). Root rot is particularly severe with continuous cropping of maize on sandy soil.

There was clear evidence of *Pythium* spp. being the main cause of it. *Fusarium* spp. may contribute to root rot at a later stage in the growth of the crop.

The parasitic root nematodes *Pratylenchus crenatus* and *Tylenchorhynchus dubius* were harmless in the present trial. Application of metalaxyl significantly increased the population of *T. dubius.*

No interaction was found between fungicides and a nematicide.

Additional keywords: Captafol, *Fusarium,* metalaxyl, oxamyl, *Pratylenchus, Pythium, rotation, Tylenchorhynchus.*

Introduction

The development of the precision drill and the maize chopper (Boonman, 1974) and the introduction of new varieties better adapted to temperate climate have caused a marked increase in area under forage maize in the Netherlands, viz. from 6 400 ha in 1970 to 147 000 ha in 1982 (Anonymus, 1983). Especially on sandy soil, many stockfarmers grow forage maize, because of its high yield on such soils. In grassland areas maize is able to withstand large amounts of slurry.

Dairy farmers grow the crop in fields further away from farm buildings, because those fields are less suited for the cattle. For maize, the distance is no problem since the crop requires little care during the growing season. This situation had led to frequent cultivation of forage maize on the same plot. Continuous cropping is no exception on sandy soil.

Williams and Schmitthenner (1963) reported a loss in yield with root rot after continuous cropping. Scholte and s'Jacob (1983) reported that continuous cropping of forage maize resulted in browning of the root system (root rot), probably caused by soil organisms. They also found that nematodes did not play an important role and presumed that parasitic soil fungi accounted for it. We attempted to measure the effect of soil fungi in an outdoor pot trial.

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Material and methods

In November 1979 soil was taken from two fields with different crop sequences. At field R (rotation) maize, sugar beet, barley and sugar beet were grown in 1976-1979, respectively. At field C maize was grown continuously from 1972. At 22 April 1980, soil of both fields was placed in white enamelled pots of 5.5 l and maize was sown.

Untreated soils derived from both crop sequences (henceforth these soils will be referred to as R-soil and C-soil) were compared with the same soils that had been treated with the nematicide oxamyl (N) and/or with the fungicide(s) metalaxyl (F1) or metalaxyl + captafol (F2). The timing and doses of the applications are given in Table 1.

Table 1. Timing and rates of application of pesticides.

Days with respect to sowing date	Oxamyl (N) (mg/pot)	Metalaxyl (F1) (mg/pot)	Metalaxyl + captafol (F2) (mg/pot)
−14	25	180	180 + 0.48
0	25	75	75 + 0.24
+14	0	0	0 + 0.24
+20	0	75	75 + 0
+27	0	0	0 + 0.24
+35	0	75	75 + 0
+48	0	75	75 + 0
	50	480	480 + 1.20

Tabel 1. Tijdstippen van toediening en dosering van bestrijdingsmiddelen.

Oxamyl (Vydate L) was applied because of its broad spectrum against all free-living root nematodes, metalaxyl (Ridomil 25 WP) because of its selective activity against Oomycetes including *Pythium* spp., and captafol (Ortho-Difolatan 80) for its broad spectrum against fungi including *Fusarium* spp.

The following amounts of nutrients were applied per pot, apportioned over eight applications: 4704 mg N, 992 mg P, 5616 mg K, 784 mg Mg and trace elements (Cu, Mn, Zn, B and Mo).

Two plants of maize cultivar LG 11 were grown per pot. Each treatment included 6 pots. The effects of the treatments were assessed 30, 60, 90 and 120 days after sowing date and the final harvest was on 15 September (140 days after sowing date).

The presence of *Pythium* and *Fusarium* spp. on and in the roots was investigated. At each date of assessment, 36 pieces of roots (about 0.5 cm long) from each treatment were cleaned with sterile water and immediately plated out on a medium selective for *Pythium* (Schmitthenner, 1974). For the examination of *Fusarium* spp. also 36 pieces were used, but these were disinfected for 1 min in a NaClO solution (33 g/l). After being rinsed in sterile water, the root pieces were placed on a selective medium (Nash and Snijder, 1962). After incubation at 25 °C for 5 days, the pieces were examined for the presence of fungi.

Nematodes were examined in the soil as well as in the roots. Extraction of endoparasitic nematodes from the roots was done by the funnelspray method (extraction time 6 days) (Oostenbrink, 1960). Determination of densities in soil was done by extracting the nematodes from the soil with the Oostenbrink elutriator (Oostenbrink, 1954, 1960).

The quality of the roots was estimated for incidence of root rot by using a scale from 0 to 4: where 0 is < 10%, 1 is 10-25%, 2 is 25-50%, 3 is 50-75% and 4 is > 75% of roots affected.

Weight of roots and shoots per pot was assessed after drying overnight at 105 °C.

Results

Fungi. Table 2 shows that at 90 days after sowing date, *Pythium* spp. were appreciably more frequently isolated from plants on soil where maize had been grown continuously (C-soil) than from those on soil where crop rotation was practized (R-soil). Oxamyl (N) had no effect on the rate of *Pythium* colonization, whereas the fungicides together (F2) controlled the fungus completely. The effect of the fungicide metalaxyl (F1) alone on the rate of *Pythium* colonization is not examined.

Pythium colonized the maize roots in an earlier stage than *Fusarium* (Table 2). For *Fusarium,* the differences between the two systems of cropping were less obvious.

Table 2. Proportion (%) of roots infected with *Pythium* spp. and *Fusarium* spp.

Soil treatment[1]	*Pythium* spp.: days after sowing date			*Fusarium* spp.: days after sowing date		
	60	90	120	60	90	120
R	44	27	100	0	0	66
C	28	83	100	6	45	72
RN	33	17	89	17	27	44
CN	42	72	94	0	33	44
RF2	0	0	0	0	6	22
CF2	0	0	0	6	0	17
RNF2	0	0	0	0	6	17
CNF2	0	0	17	0	6	11

[1] For explanation of symbols: see 'Materials and methods'.

Tabel 2. Het percentage wortelstukjes met Pythium spp. en Fusarium spp.

Nematodes. At sowing date, the numbers of Tylenchidae in the R-soil and C-soil were 650 and 1080 per 100 ml, respectively. By far the most common nematodes were *Pratylenchus crenatus* and *Tylenchorhynchus dubius.*

At 30 days after sowing date when the plants had only primary roots, the numbers of *P. crenatus* in fresh roots were considerably higher than later in the growing season for both untreated soil and soil treated with fungicides (Table 3). During the entire growing season, larger numbers of *P. crenatus* were found in the roots of plants in C-

Table 3. Numbers of *Pratylenchus crenatus* per 10 g of fresh roots.

Soil treatment[1]	Days after sowing date				
	30	60	90	120	140
R	608	206	69	556	1056
C	3959	532	825	817	1551
RN	56	7	29	37	93
CN	5	46	70	53	188
RF1	–	–	–	–	1395
CF1	–	–	–	–	2118
RF2	726	241	143	307	547
CF2	3431	523	435	728	1505
RNF2	0	60	36	60	182
CNF2	10	82	10	47	201

[1] For explanation of symbols: 'Materials and methods'.

Tabel 3. Aantal Pratylenchus crenatus per 10 g verse wortels.

soil than in R-soil (P <0.01). Fungicides had no effect on the numbers of *P. crenatus* in the roots. The nematicide reduced the number of *P. crenatus* in the roots by 90-95% (P <0.001).

Table 4 shows that, except for the final harvest, the numbers of *T. dubius* in the soil were always higher in C-soil than in R-soil (P <0.01). Fungicides had initially no effect on numbers. However, towards the end of the growing season, there was a strongly positive effect (P <0.01).

Table 4. Numbers of *Tylenchorhynchus dubius* per 100 ml of soil.

Soil treatment[1]	Days after sowing date				
	30	60	90	120	140
R	65	57	126	530	1163
C	725	–	573	1153	793
RN	20	3	134	20	113
CN	40	43	30	77	110
RF1	–	–	–	–	2200
CF1	–	–	–	–	4116
RF2	47	96	160	1303	2223
CF2	547	470	817	4572	3533
RNF2	10	7	10	16	90
CNF2	20	13	20	77	257

[1] For explanation of symbols: 'Materials and methods'.

Tabel 4. Aantal Tylenchorhynchus dubius per 100 ml grond.

The nematicide strongly reduced number in both cropping systems during the whole growing season (P <0.001).

Root rot. Root rot occurred earlier and more severely in maize grown in C-soil than in R-soil (Table 5). Oxamyl had no effect on severity of the disease. Fungicides delayed root rot strongly. Metalaxyl (F1) alone was as effective as its combination with captafol (F2).

Table 5. Incidence of root rot[2].

Soil treatment[1]	Days after sowing date			
	60	90	120	140
R	0	0	1.0	2.5
C	0	3.7	4.0	4.0
RN	0	0	2.0	1.5
CN	0	3.5	4.0	4.0
RF1	–	–	–	0
CF1	–	–	–	3.5
RF2	0	0	0	0
CF2	0	0	1.5	3.0
RNF2	0	0	0	0.5
CNF2	0	1.0	2.0	4.0

[1] For explanation of symbols: 'Materials and methods'.
[2] Scale 0-4, where 0 is <10%, 1 is 10-25%, 2 is 25-50%, 3 is 50-75% and 4 is >75% of roots affected. Each figure represents the mean of 6 replicates.

Tabel 5. Het optreden van wortelrot.

Dry weight of roots. For the first three months, no significant differences were observed between C-soil and R-soil (Table 6). However, in the second half of the growing season, differences were very large. The root mass increased in R-soil till the end of the season, whereas it decreased in C-soil.

Oxamyl did not influence dry weight of the roots. However, fungicides did. The dry weight of roots from the treated R-soil was lower than from the untreated R-soil, which shows that the applied dose of the used fungicides were toxic to the maize. From Tables 6 and 7 can be concluded that metalaxyl was responsible for this toxic effect, because no differences in negative effects was found between F1 (metalaxyl) and F2 (metalaxyl + captafol). Treating the C-soil with fungicides shows a decrease in dry matter weight in the first half of the season. However, later on there is a positive effect.

The differences between the two soils were levelled out entirely, except in the last weeks of the season when there was some decrease in dry weight with continuous cropping.

Metalaxyl alone had the same effect as in combination with captafol.

Table 6. Mass of dried roots per pot (g).

Soil treatment[1]	Days after sowing date			
	60	90	120	140
R	8.2	17.8	34.7	50.2
C	11.6	14.5	25.0	17.8
RN	11.8	16.1	39.7	43.0
CN	10.1	14.6	28.7	16.0
RF1	–	–	–	32.5
CF1	–	–	–	25.7
RF2	2.0	11.4	27.7	29.7
CF2	3.8	13.7	30.8	26.3
RNF2	3.0	16.4	30.7	30.3
CNF2	3.4	16.5	32.2	26.8
LSD[2]	3.5	5.8	7.5	21.5

[1] For explanation of symbols: 'Materials and methods'.
[2] According to the Studentized range test of Tukey at P = 0.05.

Tabel 6. Het drogestofgewicht van de wortelmassa (g).

Table 7. Mass of dried shoots per pot (g)

Soil treatment[1]	Days after sowing date				
	30	60	90	120	140
R	0.5	20	80	213	225
C	0.5	21	74	159	146
RN	0.5	21	78	198	230
CN	0.7	23	76	166	135
RF1	–	–	–	–	206
CF1	–	–	–	–	205
RF2	0.5	9	53	169	208
CF2	0.5	13	66	194	204
RNF2	0.4	10	55	179	204
CNF2	0.5	13	70	195	202
LSD[2]	0.2	4	16	31	41

[1] For explanation of symbols: 'Materials and methods'.
[2] According to the Studentized range test of Tukey at P = 0.05.

Tabel 7. Het drogestofgewicht van de bovengrondse massa per pot (g).

Dry weight of shoots. In the first two months of the growing season, there was no difference in dry weight of shoots between C-soil and R-soil (Table 7). Afterwards the growth rate of the plants in C-soil fell further and further behind.

The plants on the soil treated with nematicide reacted in almost the same way, whereas the plants on the soil treated with fungicides behaved quite differently. As for roots, maize treated with fungicides did not perform as well as untreated plants. At 60 and 90 days after sowing growth of the plants from both the R-soil and the C-soil was inhibited by the fungicides. At 120 and 140 days after sowing, however, only the plants on the R-soil were inhibited, whereas the plants on the C-soil gave a sharp increase in yield in comparison with those on untreated soil. Metalaxyl alone had the same effect as its combination with captafol.

Treating the soil with a nematicide and fungicides (NF2) gave no extra effect on the yield of the plants, so there is no interaction between application of a nematicide and fungicides.

Discussion

Continuous cropping of maize gave a lower yield than maize in a crop rotation. The difference in yield found in this trial (35%) was much higher than has been observed in field trials (Scholte and s'Jacob, 1983). In the middle of the growing season (July), there was so much rain that the pots were regularly flooded, undoubtedly encouraging degeneration of the root system with continuous cropping. The difference in yield between continuously cropped maize and rotated cropping was therefore higher than under normal conditions. Nevertheless, this trial gives an indication of the loss in yield of maize with continuous cropping.

Notwithstanding the excellent control of the nematodes *P. crenatus* and *T. dubius* by oxamyl, the difference in yield between the two cropping systems was not diminished by its application. Nor had the nematicide any positive effect on the health of the root system.

However, the fungicides eliminated completely the difference in yield between the two cropping systems. Metalaxyl alone was as effective as its combination with captafol (Tables 6 and 7).

The fungicides markedly improved the quality of the root system of the plants under continuous cropping. In particular the time of attack was postponed. Continuing the application till later in the growing season might have further improved root quality. However, because of toxicity to the crop their application was stopped 48 days after sowing.

At 90 days after sowing, *Pythium* spp. were isolated more often from roots with continuous cropping than from roots with rotational cropping. The influence of the nematicide on *Pythium* spp. was relatively slight. *Pythium* was not isolated from roots from the fungicide-treated soil. Fungicides severely affected incidence of *Pythium*.

Fusarium spp. were isolated less frequently from the roots and also appeared later in the season than *Pythium* spp. For *Fusarium* spp., the differences between the two cropping systems were less marked, although *Fusarium* tended to be more common on roots of plants under continuous cropping than under rotation cropping. Application of fungicides considerably reduced the number of root pieces from which *Fusarium* spp. were isolated.

These experiences agree with those of Rao et al. (1978), who found that in the United States *Pythium* spp. and *Fusarium* spp. were the most important causes of root rot in maize. In their trials, *Pythium* spp., particularly *P. graminicola,* proved to be the most common root pathogen in the early stage of growth; *Fusarium* spp. spread only later in the growing season.

The great difference in yield between continuous cropping and crop rotation on untreated soil disappeared entirely after application of the selective fungicide metalaxyl, whose antifungal activity is restricted to species of the order Peronosporales, to which *Pythium* spp. belong. So *Pythium* spp. were considered to be the main cause of decrease in yield with continuous cropping of maize.

Metalaxyl more than doubled the population of the ectoparasite *T. dubius.* The better developed root system could account for such a phenomenon. Otherwise the fungicide may inhibit fungal antagonists of the nematode.

Conclusions

a. In outdoor pot trials, continuous cropping of maize is associated with earlier and more severe root rot than crop rotation. It causes loss in yield.
b. Root rot seems to be caused primarily by *Pythium* spp.
c. *Fusarium* spp. may contribute to root rot at a later stage of growth.
d. Application of metalaxyl to the soil may increase the population density of the nematode *T. dubius.*
e. In no way an interaction was found between application to the soil of the nematicide oxamyl and the fungicides metalaxyl and/or captafol.

Samenvatting

Oorzaken van wortelrot bij mais op zandgrond

Bij de teelt van mais op zandgrond treedt in nauwe rotaties, vooral bij continuteelt, in hevige mate wortelrot op. In een potproef is met behulp van een nematicide (oxamyl) en fungiciden (metalaxyl) en captafol) gezocht naar de oorzaken ervan. Er werden duidelijke aanwijzingen gevonden dat *Pythium* spp. de belangrijkste verwekkers zijn van dit wortelrot. *Fusarium* spp. bleken tevens van betekenis te zijn, maar dan op een later tijdstip in het groeiseizoen.

De parasitaire wortelnematoden *Pratylenchus crenatus* en *Tylenchorhynchus dubius* bleken bij de in deze proef aanwezige dichtheden niet schadelijk te zijn.

Er werd geen interactie gevonden tussen de toepassing van de fungiciden en het nematicide.

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Book reviews

L. Bos, 1983. Introduction to plant virology. Pudoc (Wageningen), in conjunction with Longman (London and New York). Vinyl cover, 160 pages, 63 illustrations and 22 colour plates. ISBN 90-220-0739-6. Price Dfl. 35/£6.95.

With a frequency of about once in 2 to 3 years voluminous, expensive textbooks on plant virology are published. Dr. Bos, feeling that the need for smaller works which give fundamentals rather than details is largely neglected, wrote the present book. It stresses the role of plant viruses as disease incitants, with a slight emphasis on ecological aspects.

There are nine regular chapters of c. 15 pages each, giving key references for further reading on the subject at the end of each chapter. In the first chapter the history of plant virus research is outlined and viruses are defined and compared with other submicroscopic disease agents such as mycoplasmas and viroids. The second chapter (somewhat evading its title Viruses as disease incitants) elaborates on disease symptoms, which are actually reactions of the host plant metabolism. The third chapter surveys the various ways in which plant viruses are transmitted. Virus purification and laboratory methods to characterize plant viruses physicochemically are the subject of the fourth chapter. The fifth chapter is dedicated to two of the most important methodologies of plant virus research: serology and electron microscopy. Chemical composition, architecture and molecular biology of plant viruses are dealt with in the sixth chapter. The seventh chapter discusses classification and nomenclature of viruses and diagnosis (in the etiological sense) and detection of plant virus infections. Then there is a chapter on the ecology of plant viruses, based on the five determinants of disease spread: viruses, infection sources, vectors, crops and environmental conditions. Much attention is given to the importance of these factors for epidemiology and forecasting. The last chapter is on human involvement with plant virus diseases, viz. losses and control measures, the latter being mainly sanitary.

There are two appendices. The first one is a survey of the taxonomic division of plant viruses into groups, characterizing each group and listing member viruses. The second in-