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Management of the yellow beet cyst nematode with crop rotation, soil fumigation and granular nematicides

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Abstract

A trail field was managed for six years to test effects of short crop rotations, soil fumigation and granular nematicides on the population dynamics of the yellow beet cyst nematode (*Heterodera trifolii* f.sp. *beta*) and sugar-beet yields.

In the two-year rotation, the cyst nematode population before planting varied from about the tolerance level (5 eggs per millilitre of soil) to 25 eggs per millitlitre of soil, leading to losses of sugar yield. Soil fumigation with metam-sodium effectively reduced the nematode density before planting, resulting in a 15 and 25% increase in sugar yield in the first two crops, respectively, but was insufficient to protect the third sugar-beet crop from yield-reducing nematode attack. This was attributed to the wet soil at the time of application and accelerated disappearance of the chemical in the soil through biological adaptation to repeated fumigation. Oxamyl or aldicarb granular nematicides applied as a side-dressing to the rows had insufficient effect to protect the sugar-beet from yield-reducing nematode attack. An overall treatment with aldicarb rotavated into the soil, alone and in addition to soil fumigation, increased sugar yield significantly. However in the two-year rotation, yield of the third sugar-beet crop treated with soil fumigation and granular nematicide was still lower than that of the untreated second crop in the three-year rotation.

In the three-year rotation, the cyst nematode population before sugar-beet varied from hardly detectable to about the tolerance level. Here sugar-beet could be protected from yield-reducing nematode attack by soil fumigation or an overall treatment with granular nematicide. In the three-year rotation with soil fumigation an increase of *Rhizoctonia* crown rot was observed in the second sugar-beet crop.

Additional keywords: aldicarb, biological adaptation, *Heterodera trifolii* f.sp. *beta*, metam-sodium, oxamyl, pest control, *Rhizoctonia solani*, sugar-beet.

Introduction

In 1975, dense populations of *Heterodera trifolii* Goffart, 1932 were found in some fields where sugar-beet had been grown on sandy soils in the southern part of the Netherlands (Maas et al., 1976). From morphological and host range studies, Maas

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et al. (1982) distinguished this nematode from other *H. trifolii* population and *H. schachtii* Schmidt, 1871 as a host race (forma specialis, f.sp.) of *H. trifolii*, commonly called yellow beat cyst nematode.

In addition to the southern sandy part of the Netherlands, where the yellow beet cyst nematode is commonly found, its occurrence has been reported from Sweden (Andersson, 1984) and Switzerland (Vallotton, 1985).

Maas and Heijbroek (1982) revealed that the yellow beet cyst nematode is highly pathogenic to sugar beet. They found the threshold nematode density for damage (tolerance level) to be about 5 eggs per millilitre of soil and the yield to be reduced by about 35% at 50 eggs per millilitre. In spring when soil temperature exceeds 15 °C, they found 70% of the juvenile nematodes to hatch from the cysts in tap-water after 14 days and the nematode population to decrease by 80% in the field in one year when non-host crops were grown.

Taking this relative fast decrease in the yellow beet cyst nematode under non-host crop in account, a trial field was managed for six years to test effects of short crop rotations, soil fumigation and granular nematicides on the yellow beet cyst nematode and on sugar-beet yields.

Materials and methods

At Vredepeel experimental farm, on sandy soil, a two-year and a three-year sugar-beet rotation were designed on a field where sugar-beet was heavily infested by the yellow beet cyst nematode in 1979. In each of the two rotations, four treatments were applied in six replicates (only four replicates in 1985): (1) untreated; (2) soil fumigation with 300 litre of metam-sodium (380 g l^{-1}) per hectare injected into the soil at a depth of 15 cm in autumn; (3) granular nematicide applied at sowing (25 kg oxamyl 10% per hectare in 1981 and 1982; 25 kg aldicarb 10% per hectare in 1983) as a (row) side-dressing to a depth of 5 cm or just before sowing sugar-beet (25 kg aldicarb 10% per hectare in 1985) as an overall treatment, rotavated through the soil to a depth of 10 cm; (4) soil fumigation plus granular nematicide. Plot size was 108 m^2.

Population densities of yellow beet cyst nematode were estimated by analysing one soil sample per plot, taken each year just before sowing or planting. Field samples consisted of 50 cores of soil taken in a regular pattern with an auger 1 cm diameter to a depth of 20 cm. The nematode cysts were washed with an Oostenbrink elutriator model II from 200 ml subsamples taken from the field samples after thorough mixing. Cysts, together with organic debris were placed on nylon sieves of mesh 125 μm in Petri dishes with picric acid (2 mmol l^{-1}) at a temperature of 22 °C. Hatched juvenile nematodes were counted after incubation for 14 days.

Sugar-beet was sown as early as possible with respect to temperature and humidity in spring. About two weeks after emergence, seedling density was determined and the further development of the sugar-beet plants was monitored regularly. In June, ten young sugar-beet plants regularly distributed per plot were carefully dug out and the number of juvenile cyst nematodes was counted after extraction from subsamples of 5 g of roots by the mixer-centrifugal-flotation method (Coolen, 1979). In October, sugar-beet plant density and yield were estimated per plot.

Results

Population of yellow beet cyst nematode. In the two year rotation, in the untreated plots, the population of cyst nematodes before sugar-beet ('initial population', Pi) increased from about the tolerance level (5 eggs per millilitre) in 1981 to 10 in 1983 and to 25 in 1985 (Fig. 1). By soil fumigation, Pi was kept below the tolerance level for sugar-beet in 1981 and 1983, but not for the crop in 1985. In the untreated plots, the post-harvest population ('final population', Pf) increased to about 100 eggs per millilitre after the third sugar-beet crop in 1983 and decreased to 50 after the fourth crop in 1985. There was no significant effect of soil fumigation on Pf.

In the three-year rotation, Pi increased in the untreated plots, from hardly detectable (0.4 egg per millilitre) before sugar-beet in 1982 to about the tolerance level before the next sugar-beet crop in 1985 (Fig. 2). By soil fumigation Pi was kept low (1 egg per millilitre). In the untreated plots, Pf increased to 70 eggs per millilitre after the second sugar-beet crop in 1982 and decreased again to 35 after the third crop in 1985. Again there was no significant effect of soil fumigation on Pf.

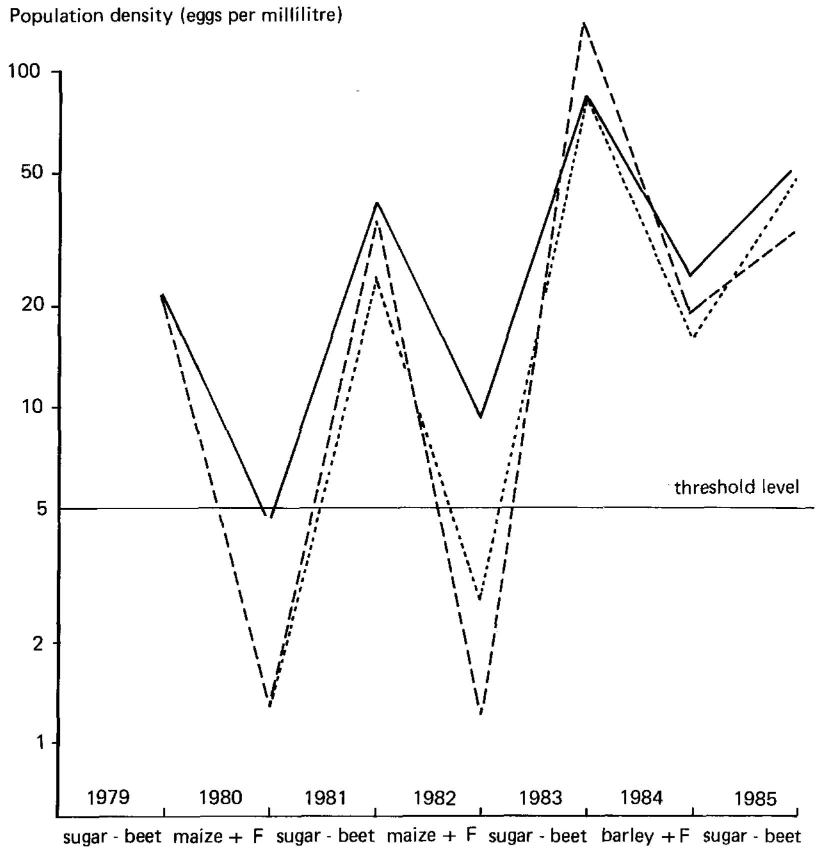

Fig. 1. Population density in soil of yellow beet cyst nematode in a two-year sugar-beet rotation. Solid line, untreated; broken line, soil fumigation (F); dotted line, soil fumigation and granular nematicide.

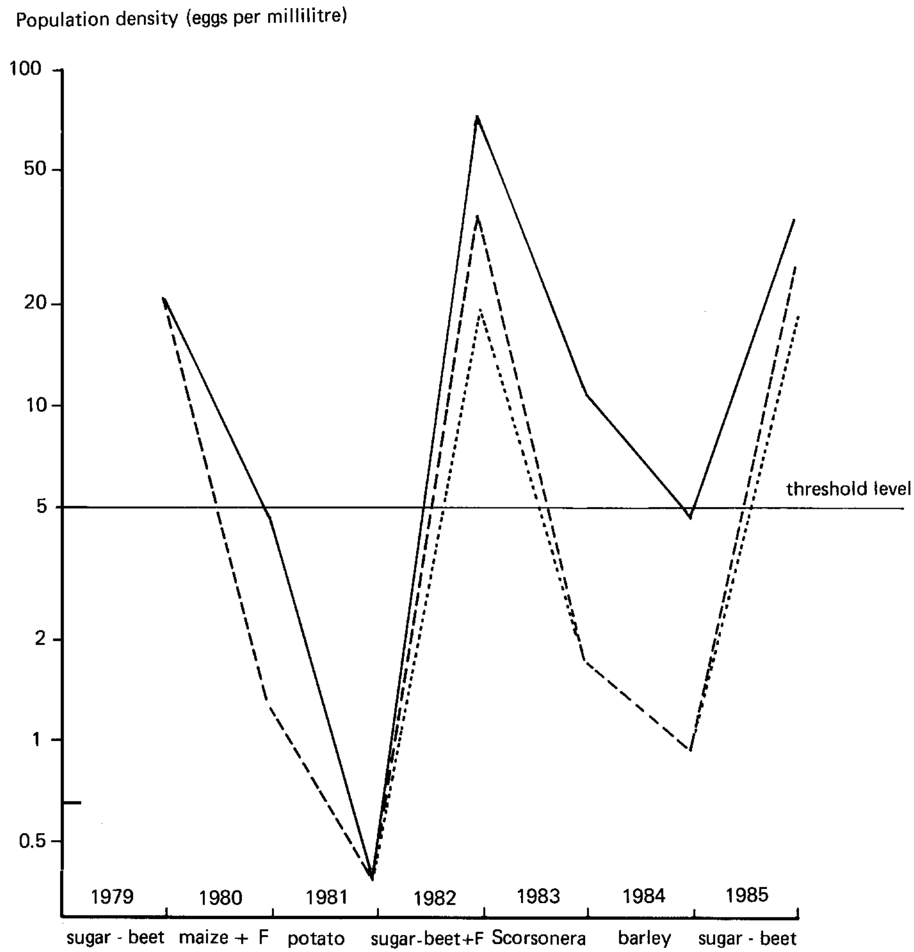

Fig. 2. Population density in soil of yellow beet cyst nematode in a three-year sugar-beet rotation. Solid line, untreated; broken line, soil fumigation (F); dotted line, soil fumigation and granular nematicide.

In none of the two rotations were granular nematicide applications effective to control the population of the yellow beet cyst nemtode (Fig. 1 and 2). However, in the two-year rotation in June 1981 and 1985, significantly fewer nematodes were found in sugar-beet roots from granular nematicide treated than untreated plots (Table 1) and in the three-year rotation, Pf was significantly lower in fumigated and granular nematicide treated plots than in untreated plots in 1983 and 1985 (Fig. 2).

Sugar-beet crops. Two weeks after emergence, there were no significant differences in seedling density between the treatments. In 1985, the root-rot fungus *Aphanomyces cochlioides* Drechsler lowered plant density. Germination tests with sugar beet seedlings in the laboratory revealed no diffeences in disease incidence between soil smaples from the two-year and the three-year rotations. At harvest, plant density was higher

Table 1. Numbers of young cyst nematodes per gram of roots in June from sugar-beet in a two-year and a three-year rotation without (O) and with granular nematicide (N) and soil fumigation (F).

Treatment	Two-year rotation			Three-year rotation
	1981	1983	1985	1985
O	128a[1]	193a	286a	76c
N	22b	148a	171b	46cd
F	165a	74b	137bc	27d
NF	2c	82b	92c	18d

[1] Different letters in the same year mean significantly different (P = 0.05).

in fumigated than in untreated plots in the two-year rotation, but not in the three-year rotation. At harvest in 1985, plant density was even lower in the fumigated than in the untreated plots in the three-year rotation, which was attributed to severe infestation of the beets by the crown-rot fungus *Rhizoctonia solani* Kühn. Untreated plots had about 5000 plants per hectare with crown-rot symptoms and fumigated plots about 26 000 plants (Fig. 3). A positive effect of granular nematicide treatment on plant density at harvest occurred only in the two-year rotation in 1985.

Sugar yield was not positively influenced by soil fumigation and granular nematicide treatment in the three-year rotation (Table 2). On the contrary, yields in 1985 were lower from treated than untreated plots because of infestation by *R. solani.* In the two-year rotation, sugar yields were higher from the fumigated than the untreated plots in all three years. There was no significant effect of granular nematicide treatment on sugar

Table 2. Numbers of plants at harvest and yield of sugar-beet in a two-year and a three-year rotation without (O) and with granular nematicide (N) and soil fumigation (F).

Treatment	Two-year rotation			Three-year rotation	
	1981	1983	1985	1982	1985
	Plants per ha				
O	55 000a[1]	65 000a	33 000a	71 000a	64 000c
N	52 000a	68 000a	46 000b	65 000a	62 000c
F	77 000b	70 000a	40 000ab	73 000a	47 000b
NF	72 000b	75 000b	62 000c	69 000a	53 000bc
	kg sugar per ha				
O	9 100a	8 000a	2 600a	7 800a	6 800d
N	9 600a	8 500a	4 000b	8 000a	6 200cd
F	11 300b	9 800b	3 800b	8 900a	5 900cd
NF	11 000b	10 800b	6 000c	8 400a	6 200cd

[1] Different letters in the same year mean significantly different (P = 0.05).

Fig. 3. High incidence of crown rot of sugar-beet caused by *R. solani* in a fumigated plot of the three-year rotation in 1985.

yields in 1981 and 1983. But in 1985, granular nematicide treatment had a positive effect on yield in the two-year rotation.

In 1985, when sugar-beet was grown in both of the two rotations, a good estimate of the rotation effect on sugar yield was possible. In the two-year rotation, the plots fumigated and treated with granular nematicide yielded best. This yield, however, was still lower than the yield from untreated plots in the three-year rotation.

Discussion

Nematode population. In the two-year rotation, the initial population in the untreated plots increased from about the tolerance level to 25 eggs per millilitre (Fig. 1), leading

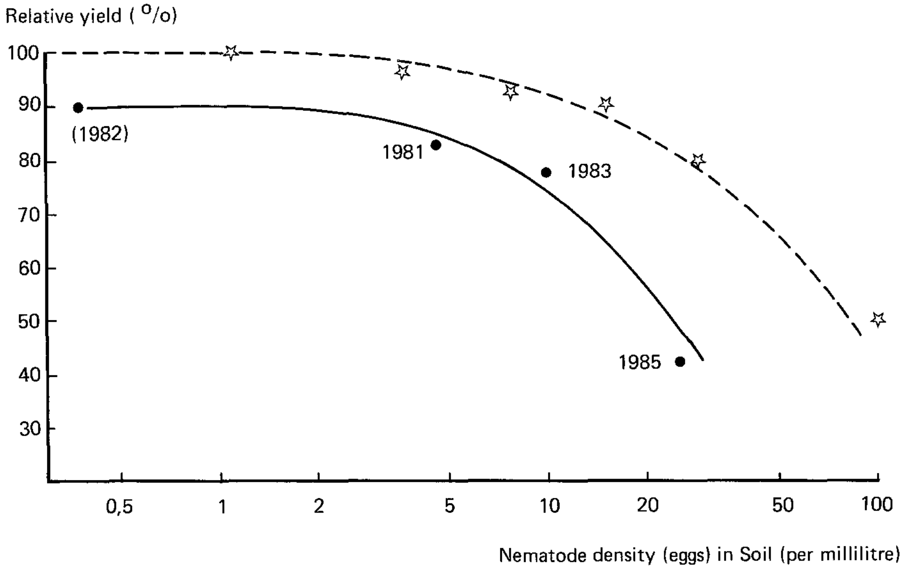

Fig. 4. Relation between initial yellow beet cyst nematode density and yield of sugar-beet. Solid line, yields of successive crops in untreated plots relative to plots treated with fumigant and granular nematicide in the two-year rotation; broken line, yields of different plots relative to uninfected plots reported earlier (Maas and Heijbroek, 1982).

to increasing losses of sugar yield of every next crop. Yield losses were caused by dying of plants and by small beets at harvest. In Fig. 4, the decreasing yields of these successive crops are compared with the relation between yield and nematode density reported earlier (Maas and Heijbroek, 1982). As the shape of both curves is similar, environmental conditions in the different years have a limited effect on this relation. Most probably, the lower position of the curve from the present trial was caused by an unexplained effect of soil fumigation on sugar yield alongside the effect on the yellow beet cyst nematode. In the three-year rotation in 1982, at a nematode density far below the tolerance level, the fumigated plots yielded about 10% more than the untreated plots. Although not significant, such an unexplained effect of soil fumigation indicates other soil-borne minor diseases, which would be more active in the two-year rotation. In 1985, the initially better growth of sugar-beet was followed by a heavy attack by *R. solani*, which resulted in a 10% lower yield from fumigated than untreated plots in the three-year rotation.

In the three-year rotation, the initial nematode population increased from hardly detectable to about the tolerance level in the untreated plots (Fig. 2). In 1982, which began with a very low nematode density, the nematode multiplied on sugar-beet by almost 200 times to a final population of 73 eggs per millilitre of soil. In one sugar-beet crop, this nematode appeared to be able to reach its maximum Pf, which varied from 20 (1979) to 135 (1983) eggs per millilitre in this field (Fig. 1). In the untreatd plots, annual breakdown factors of the cyst nematode population varied from 0.08 in 1981 to 0.52 in 1984. Both of these extreme factors, however, were calculated from relatively low nematode densities under the second non-host crops in the three-year rotation.

Sampling error at low nematode density diminishes the reliability of these figures. When these two extreme figures are excluded, the average breakdown factor was 0.26, varying from 0.14 to 0.43. This population course agrees well with previous results (Maas and Heijbroek, 1982).

Soil fumigation. In the two-year rotation in 1980 and 1982, soil fumigation reduced the initial population effectively (Fig. 1) resulting in 15 and 25% increase in sugar yield in 1981 and 1983, respectively (Fig. 4). In 1984, however, soil fumigation was almost ineffective. This failure may be attributed to the impossibility of finding suitable soil fumigation conditions in the extremely rainy autumn of that year. However, in incubation tests, metam-sodium also disappeared faster in soil from plots that had been fumigated for the third time (halving in 5 days) than in soil from untreated plots (where it halved in 25 days), indicating biological adaptation of soil repeatedly fumigated with metam-sodium (Smelt et al., 1987).

In the three-year rotation in 1982 and 1985, no losses of sugar yield were detected by controlling the nematodes effectively with soil fumigation because of initial populations below the tolerance level (Fig. 2). On the contrary, in 1985, a hitherto unexplained severe infestation by *R. solani* caused lower sugar yields from treated than untreated plots. These results do not agree with those of Schuster and Harris (1960), who found an increasing incidence of crown rot with a decreasing duration of the rotation cycle. Possibly black salsify (*Scorsenera*) in 1983 stimulated *R. solani* and soil fumigation controlled activity of antagonistic micro-organisms in the soil or predisposed the plants in a way that favoured crown rot.

The absence of an effect of soil fumigation on the nematode density after harvesting sugar-beet must be explained by the negative correlation between initial density and multiplication rate of the nematode (Maas and Heijbroek, 1982) compensating for nematode reduction after soil fumigation.

Granular nematicide. Granular nematicide reduced the number of nematodes in roots of every sugar-beet crop in June, except for the 1983 crop (Table 1). In the two-year rotation, yield was significantly higher from plots treated with granular nematicide than from untreated plots only in 1985 (Table 2), when aldicarb was rotavated into the soil as an overall treatment. Although granular nematicides applied as a side-dressing protected sugar-beet seedlings from nematode attack to some extent, they were not effective enough to save the yield of the crops. Similar results were obtained by Heijbroek et al. (1985).

In the three-year rotation at a relatively low nematode density, the nematode population decreased significantly when granular nematicides were applied in addition to soil fumigation (Fig. 2). In the two-year rotation in 1985, when the soil fumigation almost failed to control the nematodes, a significantly better nematode control and sugar yield was obtained by an additional overall treatment with aldicarb. But yield was then still 12% less than from the untreated plots of the three-year rotation, although both contained about the same nematode population in the roots in June (Table 1).

Conclusion

Damage by the yellow beet cyst nematode cannot be controlled with metam-sodium fumigation and oxamyl or aldicarb granular nematicides in a two-year rotation. In a three-year rotation, the pre-plant nematode population will remain just below the tolerance level if the average maximum post-harvest populations is 70 eggs per millilitre of soil and the average annual breakdown factor 0.26. Occasionally, higher pre-plant nematode populations can be controlled by metam-sodium fumigation or oxamyl or aldicarb granular nematicides applied as an overall treatment.

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Samenvatting

Beheersing van de gele bietecystenematode door vruchtwisseling, grondontsmetting en nematicide granulaten

Om de effecten na te gaan van korte rotaties, grondontsmetting en nematicide granulaten op het populatieverloop van de gele bietcystenematode (*Heterodera trifolii* f.sp. *beta*) en de opbrengsten van suikerbieten werd gedurende zes jaren een proef uitgevoerd op een natuurlijk besmet perceel van de proefboerderij Vredepeel.

In de tweejarige rotatie variëerde de cystenematodepopulatie vóór het bietegewas boven de schadedrempel, wat resulteerde in verlaging van de suikeropbrengst. Grondontsmetting met metam-natrium veroorzaakte een effectieve vermindering van de dichtheid van de nematoden vóór de bieten en een verhoging van de suikeropbrengst van respectievelijk 15 en 25% bij de eerste twee gewassen, maar was onvoldoende om het derde bietegewas te beschermen tegen een opbrengstverminderende aantasting door nematoden. Dit was een gevolg van natte bodemomstandigheden bij het injecteren en het versneld verdwijnen van het middel door biologische adaptatie van de grond na herhaalde ontsmetting. Nematicide granulaten (oxamyl of aldicarb) naast de rij toegepast hadden onvoldoende effect om de bieten te beschermen tegen een opbrengstverminderende aantasting door nematoden. Een volvelds toepassing van in de grond gefreesde aldicarb alleen en toegevoegd na grondontsmetting verhoogde de suikeropbrengst beduidend. De opbrengst van het derde suikerbietegewas in de tweejarige rotatie was echter na toepassing van grondontsmetting en nematicide granulaten nog beduidend lager dan die van het onbehandelde tweede suikerbietegewas in de driejarige rotatie.

In de driejarige rotatie variëerde de cystenematodepopulatie vóór het bietegewas van nauwelijks aantoonbaar tot nabij de tolerantiegrens. Hier kon het suikerbietegewas worden beschermd tegen een eventueel opbrengstverminderende nematodenaantasting door grondontsmetting of volveldstoepassing van nematicide granulaten.

References

Andersson, S., 1984. First record of a yellow beet cyst nematode (*Heterodera trifolii*) in Sweden. Växtskyddsnotiser 48: 93-95.

Coolen, W.A., 1979. Methods for the extraction of *Meloidogyne* spp. and other nematodes from roots and soil. In: Lamberti, F. & Taylor, C.E. (Eds), Root-knot nematodes (*Meloidogyne* species) systematics, biology and control. Academic Press, London, p. 317-329.

Heijbroek, W., Kerstens, M.J.M. & Wevers, J.D.A., 1985. The effects of different fumigants on nematodes and weeds in sugar beets grown on sandy soils, with special reference to the yellow beet cyst nematode (*Heterodera trifolii* f.sp. *beta*). Instituut voor Rationele Suikerproductie, Bergen op Zoom, Mededeling Nr. 12, 20 pp.

Maas, P.W.Th. & Heijbroek, W., 1982. Biology and pathogenicity of the yellow beet cyst nematode, a host race of *Heterodera trifolii* on sugar beet in the Netherlands. Nematologia 28: 77-93.

Maas, P.W.Th., Schoemaker, A. & Stemerding, S., 1976. Een cysteaaltje bij suikerbieten in Brabant. Gewasbescherming 7: 10-11.

Maas, P.W.Th, Du Bois, E. & Dede, J., 1982. Morphological and host range variation in the *Heterodera trifolii* complex. Nematologica 28: 263-270.

Schuster, M.L. & Harris, L., 1960. Incidence of *Rhizoctonia* crown rot of sugar beets in irrigated crop rotation. Journal of the American Society of Sugar Beet Technologists 9: 128-136.

Smelt, J.H., Teunissen, W. & Crum, S.J.H., 1987. Nieuwe gegevens over de omzetting van 1,3-dichloorpropeen, metam-natrium en methylisothiocyanaat in de bodem. Gewasbescherming 18: 7-8 (Abstr.).

Vallotton, R., 1985. Première observation en Suisse de la 'forme spécialisée Betterave' du nématode à kyste *Heterodera trifolii* Goffart. Revue Suisse d'Agriculture 17: 137-140.