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The development of rhizomania in two areas of the Netherlands and its effect on sugar-beet growth and quality

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Abstract

Since detection of beet necrotic yellow vein virus (BNYVV) by serological techniques was not possible 10 years ago, there is no reliable information about the occurrence of the disease in the Netherlands prior to 1983. By evaluating historical information on the sugar production of fields, which have been proved to be infested by rhizomania recently, the time of occurrence of the first infections could be estimated roughly.

Analysis of root samples from diseased fields and comparison with uninfected fields, revealed a correlation between sugar and sodium content and the occurrence of rhizomania. Therefore both quality parameters can be used as indicators for the disease under Dutch conditions.

Differences between infected and uninfected fields were detected from mid-June onwards. Only a weak correlation between sugar and α-amino N content could be established. At later stages of crop growth the α-amino N level of diseased fields was always lower than that of healthy ones. However sugar content remained at a low level and did not increase substantially.

Additional keywords: Polymyxa betae, beet necrotic yellow vein virus (BNYVV).

Introduction

During the last ten years rhizomania has disseminated from epicentres in France (Putz and Richard Molard, 1984) and the Federal Republic of Germany (Schäufele et al., 1983). In 1983 the presence of rhizomania was demonstrated for the first time in California (Duffus et al., 1984), Switzerland (Häni, 1983), Belgium (Van Steyvoort, 1985) and the Netherlands (Heijbroek, 1984). Reporting of a first positive identification does not necessarily mean that rhizomania was not present earlier. Since small infected areas cannot be recognized easily, most symptoms are not specific and reliable detection techniques were not available (Walter et al., 1979), infested fields may have been overlooked. Already in 1976 rhizomania-like symptoms were found in the Netherlands, but virus tests carried out in the Federal Republic of Germany on trap plants, grown in soil samples originating from two suspected fields, were negative. Applying ELISA in 1983 these fields were undoubtedly positive, although no sugar-beets had grown since. This experience initiated an investigation into the history of infested farms in two different areas, based on the production data and information concerning crop rotation.

Secondly investigations into the effect of rhizomania infection on sugar-beet growth and quality were carried out to provide information on the seriousness of the disease in the Netherlands. According to Wieninger and Rössner (1983), rhizomania affects the sodium, potassium and α-amino N concentrations. If the ratio between sodium and potassium on the one hand and α-amino N on the other exceeds 4.2, the beets should be infested by rhizomania. Pollach (1984) modified this equation and included sucrose, i.e. (Na $\times$ K $\times$ 1000)/(% sucrose $\times$ N); where Na, K and N are concentrations of sodium, potasium and α-amino nitrogen-containing compounds in mmol per g of fresh beet tissue, and sucrose is expressed as weight percentage of fresh beet tissue. He did not establish a threshold value, but used the quotient as a rhizomania signal. For Austrian conditions Müller (1983) detected differences in the contents of sugar, mark, dry matter, sodium, potassium and α-amino N from July onwards, related to the increase in severity of the rhizomania infestation. However, there are considerable doubts whether all these parameters can be used as indicators for rhizomania in a series of years and under different conditions. Therefore it was tried to establish correlations between sugar content and sodium, potassium and α-amino N concentrations in a number of diseased and rhizomania-free fields under Dutch conditions, during the course of the growing season.

Materials and methods

BNYVV was detected in beets by collecting sap from the root tips with a hand press and analyzing this by ELISA (Clark and Adams, 1977; Walter et al., 1979), using antiserum produced by the Institut National de Recherche Agronomique at Colmar (France). Samples were regarded positive if the extinction value at 405 nm exceeded three times the healthy standard with a minimum of $A_{405\ nm} = 0.060$. From infested fields samples were not taken randomly, but plants were chosen showing a whitish yellow discolouration of the leaves, combined with root proliferation and/or necrosis of vascular tissues. Samples of 20 beets from plots in rhizomania-infested and healthy fields were collected every two weeks and analysed for root weight, sugar content, sodium, potassium and α-amino N contents (De Nie and Van der Poel, 1986). Diseased fields were selected on the basis of a history of low sugar content and bio-assays of soil by growing sugarbeets as trap plants on soil samples and analysing roots for BNYVV by means of ELISA after six weeks at 25 °C.

The history of the disease on a farm was evaluated by using sugar yield figures of the whole farm, as provided by the sugar factory tare house. Since very often quantities of beets originating from different fields are delivered in one load, production figures for individual fields could not be obtained. Accordingly, where only one or two fields on a farm were infested, considerable fluctuations in yield from year to year could be expected.

The correlations between production losses caused by rhizomania and quality parameters involved, were determined by comparing a series of healthy and diseased fields, with different degrees of severity, on the same sampling date. Consequently correlations and regression coefficients were determined with sugar content as the common denominator.

The course of root weight, sugar content and the level of Na and α-amino N during the second part of the growing season was determined by comparing severely and moderately infested fields with healthy standards. During the trial period root samples of all fields were analysed for the presence of BNYVV and the development of leaf and root symptoms was checked.

Results

Rhizomania development in two different areas. In 1976 rhizomania-like symptoms were discovered in a field on the island of Tholen. In a trial fumigation with dichloropropene improved the root yield and sucrose content of the sugar beets, but did not compensate wholly the damage. Trap plants were grown on soil samples of this field and root press sap was tested on *Chenopodium quinoa* (ELISA was not yet available), but no BNYVV could be demonstrated. Irrespective of regular dichloropropene treatment, the farmer had to give up sugar-beet growing after 1976.

No host crops were grown until 1983 when sugar-beets on the same field produced rhizomania-like symptoms. Again trap plants were grown in soil samples and now ELISA was carried out on root press sap, producing the very high score of $A_{405\ nm} = 0.950$ (Hess, 1984). Long before 1976 this field and others gave bad yields, as shown in Fig. 1A. The sugar production of this farm is compared to average yield figures obtained in the Netherlands. These records suggest that 1967 was the first year in which crop losses were suffered due to rhizomania. In 1970 and 1971, years in which yields were relatively high, sugar-beets were grown on fields which were not or only slightly infested.

Information concerning the first damage caused by rhizomania in the Noordoostpolder was obtained by comparing the yields of 7 completely or partially infested farms

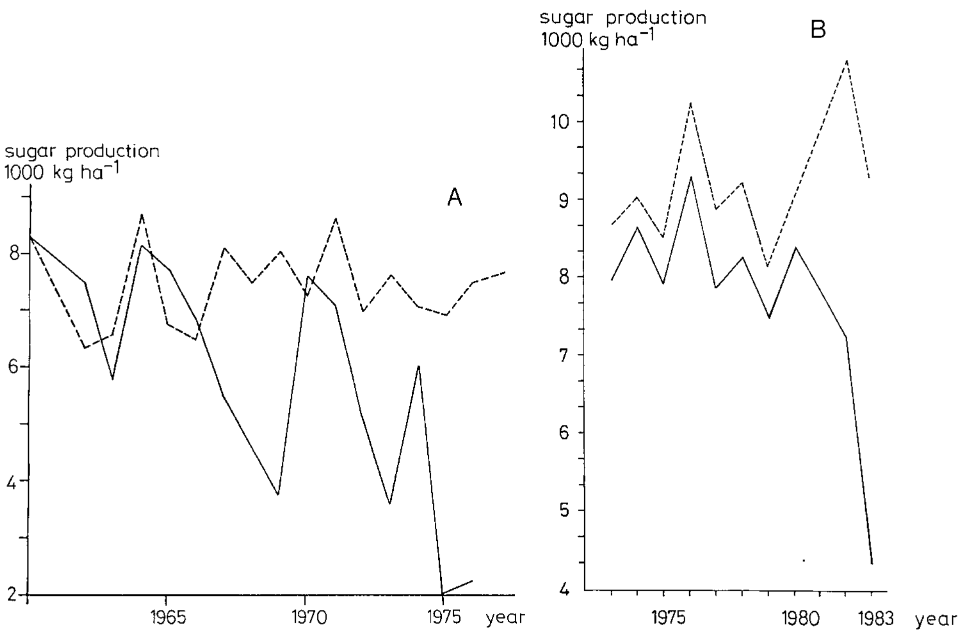

Fig. 1A. Annual sugar production (in 1000 kg ha^{-1}) of a farm (Tholen) compared to the average in the Netherlands. This farm was severely infested in 1983.
——— average sugar production per ha of infested farm; ------- average sugar production per ha for the Netherlands.

Fig. 1B. The course of the average sugar production in 7 rhizomania-infested farms (———), as compared to 12 standard healthy farms (-------) in the same area (Noordoostpolder).

with those of 12 healthy reference fields (Fig. 1B). From these data it is obvious that in 1981 for the first time serious damage was suffered. At that time the farms were infested completely, since afterwards the groups deviated progressively.

The value of quality parameters as indicators of rhizomania. Under Dutch conditions quite often there is no impact of rhizomania on root weight. The tap roots develop normally, but in the second part of the vegetative period large numbers of lateral roots are formed in dense clusters (Fig. 2). However, sugar content is nearly always affected. Both the level of infestation and weather conditions influence the effect of rhizomania on root weight. For two years, groups of diseased fields in the Noordoostpolder were compared to reference groups of healthy fields. In 1984 root weight of both groups was approximately equal, but the following year significant differences were detected. However, in both years sugar contents differed by approximately the same amount. This led to the conclusion that sugar content is a highly reliable indicator for rhizomania.

Apart from this, a diseased crop often shows relatively high sodium and potassium contents, combined with low α-amino N. Therefore the correlation between these parameters and sugar content was examined, based on regular analyses covering the

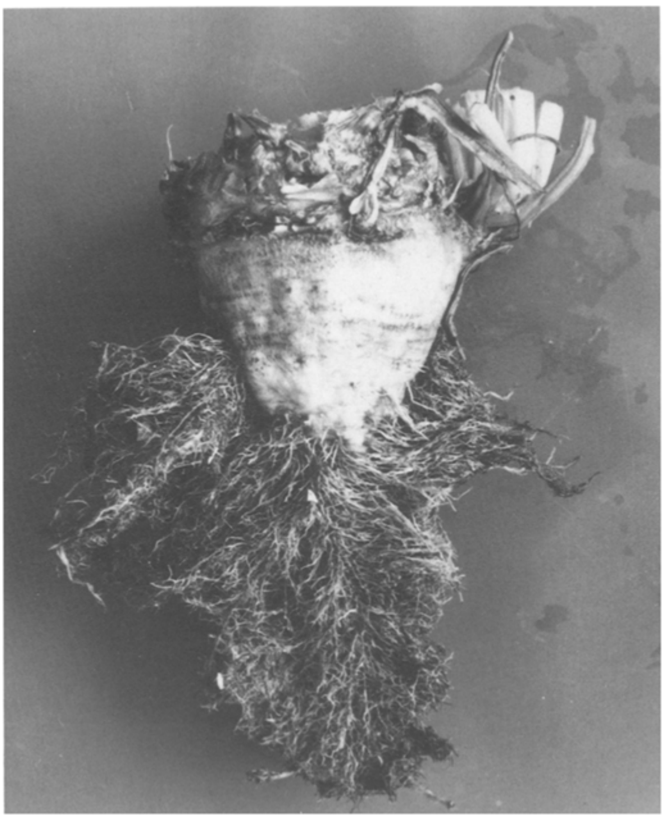

Fig. 2. Symptoms of rhizomania frequently occurring in Dutch rhizomania-infested fields. The tap root has developed more or less normally; numerous lateral roots were formed.

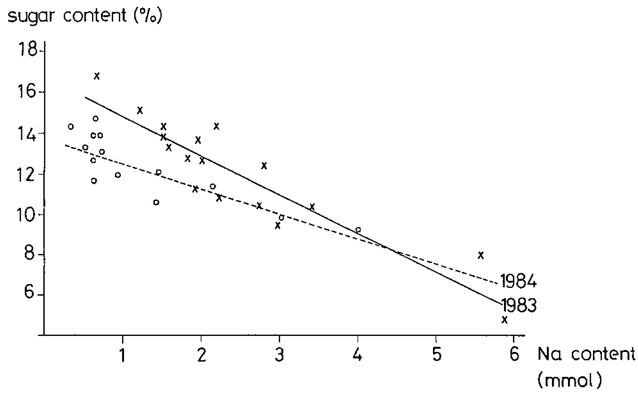

Fig. 3. Correlation between sugar content (%) and Na content (mmol . 100 g^{-1} of beet) of beets from a series of rhizomania-infested fields in 1983 (x——x) and 1984 (o-----o). Regression coefficients: Rc_{1983} = 0.87 (x); Rc_{1984} = 0.92 (o).

period from June to August in 1983, 1984 and 1985. No correlation between potassium and sugar content has been detected in any of these three years. Although in 1983 a rather good correlation between sugar and α-amino N content (Fig. 4) could be established (Rc = 0.72), this was far less for 1984 (Rc = 0.45) and completely absent in 1985. The correlation between sugar content and sodium, expressed as mmol per kg of beets, proved to be the best (Fig. 3). The regression coefficients for 1983-1985 were 0.87, 0.92 and 0.81 respectively. Therefore the quotient Na mmol per kg of beet/sucrose % was chosen as indicator; if this exceeded 0.5, rhizomania infestation was always present. Roots collected from all fields gave positive ELISA reactions, but the severity of rhizomania disease symptoms differed from some extra proliferation at the end of the tap root to complete rotting and desintegration, accompanied by discolouration and malformation of leaves.

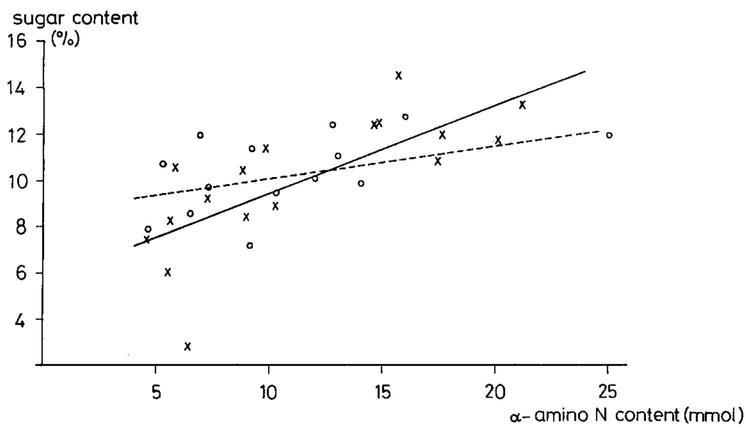

Fig. 4. Correlation between sugar content (%) and α-amino N content (mmol kg^{-1} of beet) of beets in a series of rhizomania-infested fields in 1983 (x——x) and 1984 (o-----o). Regression coefficient: Rc_{1983} = 0.72 (x); Rc_{1984} = 0.45 (o).

Table 1. The development of sugar production in kg ha^{-1} during the summer in moderately and severely infested fields, compared to healthy standards (Noordoostpolder, 1984 and 1985).

Sampling date		Healthy standard		Moderately infested		Severely infested	
1984	1985	1984	1985	1984	1985	1984	1985
June 6		31		54 (174)*		15 (48)	
June 25	June 24	125	66	103 (82)	59 (89)	37 (30)	19 (29)
July 2	July 1	350	186	277 (79)	186 (100)	59 (17)	40 (22)
July 16	July 8	960	462	1058 (110)	488 (106)	604 (63)	120 (26)
July 30	July 29	2378	2250	2098 (88)	2115 (94)	1032 (43)	623 (28)
August 13	August 12	4441	3768	3320 (75)	3167 (84)	1380 (31)	1242 (33)

* Percentage related to healthy.

Sugar yield and quality parameters during crop growth. From an infested area of the Noordoostpolder in 1984 and 1985 13 and 18 diseased fields were selected respectively, of which 2 and 4 fields showed severe damage in these two consecutive years. Sampling was done every two weeks, together with a reference group of twelve healthy fields. At the beginning of the sampling differences in the average sugar yield between the severely infested fields and the healthy standards could be detected already (Table 1). In both years the first statistically significant (P = 0.05) sugar losses in the severely infested fields were recorded at the end of June. The group of moderately infested fields deviated from the healthy standards in a later stage, statistically significant differences not being detected until mid-August (Fig. 5A). Yield differences between moderately infested and healthy fields at the end of the season were mainly the result of lower sugar concentrations in the former group, rather than a reduced root weight.

In the severely infested fields sugar content and root weight development were equally retarded. However during the course of the summer sugar content stabilized at 10-11%, while root weight continued to increase.

In moderately infested fields the course of sugar content followed the same pattern, although at a different level, stabilizing at 13-14% sugar.

In contrast sodium content of sugar-beets from diseased fields did not show a regular pattern (Fig. 5B), although the averages were always higher than those in the healthy standards. In 1984 there were marked differences between severely infested fields and healthy standards, even at the beginning of the sampling. At the same time the correlation coefficients between low sucrose and high sodium content of all infested fields proved to be better in 1984 than in 1985. The values of α-amino N content proved to be variable, but in both years the contents were lower in the rhizomania infested fields during September and October.

Discussion

Rhizomania could easily spread from epicentres in France and southern Germany into northern Europe, since in most of the fields the vector *P. betae* was already present. Although in the Netherlands rhizomania was identified for the first time in 1983, the

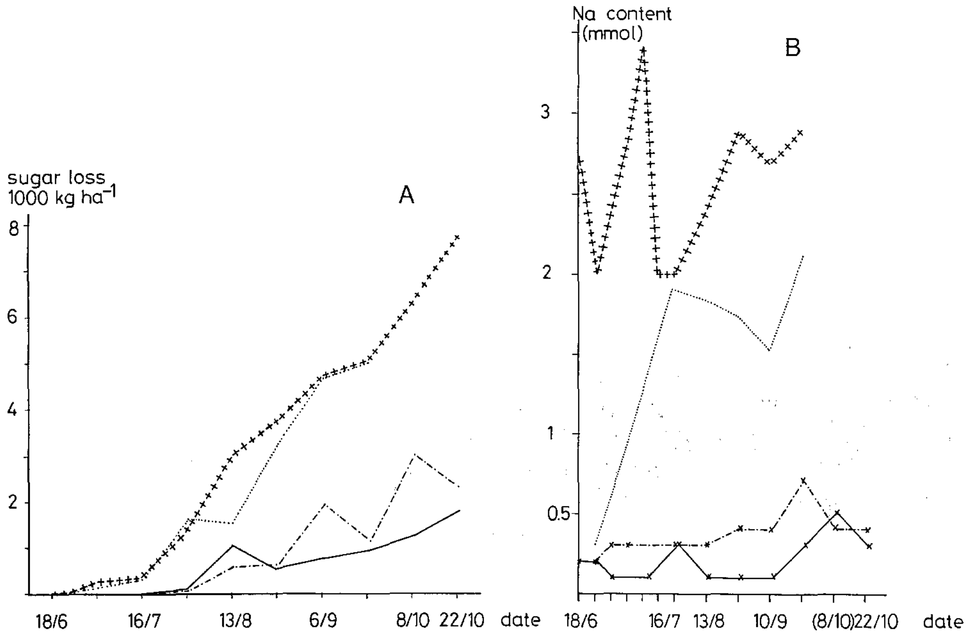

Fig. 5A. The losses of sugar yield (1000 kg . ha^{-1}) in rhizomania-infested fields as compared to 12 healthy standards during the second half of the growing season (Noordoostpolder). + + + + severely infested fields 1984; ········ severely infested fields 1985; ———— moderately infested fields 1984; ·—·—· moderately infested fields 1985.

Fig. 5B. The difference in Na content (mmol . kg^{-1} of beet) of beets from rhizomania-infested fields as compared to 12 healthy standards during the second half of the growing season (Noordoostpolder). + + + + severely infested fields 1984; ········ severely infested fields 1985; ———— moderately infested fields 1984; ·—·—· moderately infested fields 1985.

disease probably occurred earlier. Investigations of the farm and industrial records of sugar-beet crops suggest that in one case sugar losses caused by rhizomania occurred already some 20 years ago. This means that the first infections may have entered at least 10 years earlier, since crop rotation on this farm was 1/4 to 1/5 and it probably requires about three sugar-beet crops for rhizomania to spread sufficiently through a field to cause measurable crop damage.

Not only by selecting sugar-beets for leaf symptoms, but infested fields were also traced by searching the computer files of the sugar industry for beet deliveries exhibiting a low sugar content and other deviating quality parameters indicating rhizomania infestation. Therefore a rhizomania threshold value had to be established, comparable to the one described by Wieninger and Rössner (1983). However, under Dutch conditions, over a three-year period, a reliable correlation was only demonstrated between the infestation by rhizomania and sugar or sodium content of the beets. The quotient Na mmol per kg of beet/ sucrose % = 0.5 was chosen as a rhizomania threshold. However, a distinct number of moderately diseased fields show values lower than this and on the other hand some uninfested fields that received a surplus of liquid manure exceed this quotient. On the contrary in the latter case the α-amino N will be much higher than in the beets of infested fields.

Although under Dutch conditions clear symptoms of rhizomania appear relatively late in the season, the first differences in sugar yield and sodium content between beets from severely infested and healthy standard plots were recorded as early as mid-June. In moderately infested fields these differences appeared later and the pattern was irregular, probably due to variation among plants with respect to BNYVV content in the roots and the time of infection. If the inoculum level in the soil is low, or the conditions for penetration by the zoospores and multiplication of BNYVV are unfavourable, the influence on root yield will be minor. However, an effect on sugar and sodium content could always be observed. During the course of the growing season, in the infected fields root weight increased at a rate that was inversely proportional to the degree of infestation. However, sugar content stabilized at a certain level and did not increase further. The sodium content as a quality parameter was always higher in the roots from infested fields than in the healthy standards, but in the course of the season this did not show a regular pattern. Sometimes the sodium content of infested sugar beets was already very high by mid-June, being an early indicator for rhizomania.

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Samenvatting

De ontwikkeling van bieterhizomanie in twee gebieden in Nederland en de invloed op de groei en kwaliteit van suikerbieten

Aangezien tien jaar geleden geen serologische technieken beschikbaar waren, kon het voorkomen van bieterhizomanie in Nederland niet worden aangetoond. Door het beoordelen van de suikeropbrengsten van percelen die met bieterhizomanie besmet bleken te zijn, over een reeks voorafgaande jaren, kon een periode waarin de infectie vermoedelijk had plaatsgevonden worden vastgesteld.

Door analyse en vergelijking van bietmonsters van een reeks aangetaste proefplekken met een aantal gezonde referentiepercelen, kon worden aangetoond dat onder Nederlandse omstandigheden suiker- en Na-gehalten de meest betrouwbare indicatoren voor de aanwezigheid van bieterhizomanie zijn.

Afwijkingen in de gehalten van deze kwaliteitsparameters werden in de zwaar aangetaste percelen vanaf half juni gevonden. Er werd een zwakke relatie tussen de gehalten aan suiker en α-amino N aangetoond. Gedurende de tweede helft van de zomer was het gehalte aan α-amino N in de zieke percelen lager dan dat van bieten in de gezonde. Het suikergehalte bleef op een laag niveau en vertoonde geen of een geringe toename.

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Book review

B.C. Clifford & E. Lester (Eds), 1988. Control of plant diseases: costs and benefits. Blackwell Scientific Publications, Oxford, London, Edinburgh, Boston, Palo Alto, Melbourne. XIV + 263 pp. ISBN 0-632-01453-9. Price £ 49.50.

This multi-author book stems from a meeting of the British Society for Plant Pathology in 1984. The book is very British and the title ought to have the words 'in Britain'. However that omission is corrected by the picture on the cover of five-pound notes issued by the Bank of England. The book deals with a theme which is internationally indicated by the incorrect but widely used term 'crop loss'. The publication of this book (with a four-year delay) is nevertheless timely, as a renewed interest in costs and benefits of plant disease control is world-wide, for a variety of reasons.