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Current perspectives on integrated control of the some soil-borne diseases and pests of potato in the Netherlands

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Abstract

This paper evaluates the current status and prospects of biological methods and the application of certain crop varieties and cultural methods to prevent and control yield depressions and some soil-borne diseases and pests of potato in the Netherlands.

It is recommended that future research be directed towards combination of these methods in integrated control.

Introduction

In the Netherlands potato growers are confronted with three unsolved problèms associated with soil organisms. The first is the phenomenon of yield depressions on clay soil attributed to soil microbes that are harmful to plant growth although they are non-parasitic. The second is damage by *Rhizoctonia solani*. This fungal pathogen causes reduced yields, especially on sandy soils reclaimed from cut-over peat where potatoes are grown every other year for the starch industry. An even more important aspect of *Rhizoctonia* is the presence of sclerotia (black scurf) on seed tubers; infested tubers are downgraded upon visual inspection. Especially seed tubers from marine loams and clays are susceptible. The third is damage by potato cyst nematodes (*Globodera* spp.), particularly in narrow crop rotations on sandy soils reclaimed from cut-over peat in the starch potato area.

A common feature of current research to overcome these problems is the emphasis on prevention and biological or integrated control rather than chemical control.

This paper evaluates the current status and prospects of this research and results in a plea for using compatible prevention and control measures in farming systems.

Harmful microorganisms

Current status

Crop rotation experiments on a marine clay soil have been carried out in one of the recently reclaimed polders on the experimental farm De Schreef (since 1963) and at the Research Station for Arable Farming and Field Production of Vegetables (since 1973). Yield depressions of 10-15 % were common if potatoes were grown every third year as compared with growing them every sixth year. Another 20-30 % yield depression resulted from continuous cropping as compared with potatoes every third year (Hoekstra, 1981). Physical and chemical soil factors were shown not to be responsible for these yield depressions (Hoekstra, 1981; Lamers, 1981). Although notorious pathogens or pests were not observed to the extent that they could have caused the yield depressions, the causal agent was eliminated by soil sterilization (in pot experiments) and it was surmised that yet unknown harmful microorganisms were largely responsible for the yield reduction in narrow rotations (Schippers et al., 1986).

Elimination or reduction of the yield depressions was also achieved in pot experiments after seed tuber treatment with siderophore-producing fluorescent pseudomonads ('bacterization') (Geels & Schippers, 1983). Such an effect was also obtained in some plots of a field experiment in 1981 (Table 1) and in 1985 (Bakker & Schippers, personal communication, 1986). These experiences confirm results obtained in the USA (Schroth & Hancock, 1982).

The main mechanism by which *Pseudomonas* suppressed harmful microorganisms appeared to be efficient competition for Fe^{3+} by iron-chelating siderophores, while antibiosis may also have been effective against members of the root microflora.

Both in pot experiments and in field experiments (Bakker & Schippers, personal communication, 1986) the important role of siderophores was demonstrated with mutants which had lost their ability to produce siderophores and, concomitantly, their growth-promoting properties (Schippers et al., 1986).

Research efforts are now aimed at manipulation of *Pseudomonas* strains by transposon mutagenesis so as to enhance disease-suppressing and growth-promoting effects of bacterization. It is expected that in the Netherlands the first application of manipulated bacteria in the field will be with such strains of *Pseudomonas*.

Although growth promotion early in the season was usually observed after seed tuber treatment, bacterization was not always effective in the field to the extent that yield depressions were significantly reduced. In a different context (greenhouse experiments with wheat) the specific nature of microbial antagonism towards

Table 1. Effect of seed tuber treatments with strains of fluorescent pseudomonads on yields of potato in the field (1981) (from Schippers et al., 1985). The soil type was heavy sandy clay from 'De Schreef'.

Frequency of potato cropping (%)	Yield (tonnes per ha)	Relative yield (%)			
		control	strain WCS 358	strain WCS 365	strain WCS 374
67	60	100	104	91	98
33	50	100	111*	104	103
33	51	100	109*	102	100

*$P < 0.05$.

each of a number of pathogens causing foot- and root-rot was well established. However, the antagonism towards one pathogen was partly eliminated by the presence of another pathogen (Zogg & Amiet, 1980). Hitherto unknown interactions of this type may likewise contribute to the inconsistent results of bacterization of potatoes in the field. Another reason may well be that the conditions required for colonization by *Pseudomonas* and its sustained activity and maintenance on the root or tuber are poorly understood.

Prospects
These considerations call for thorough studies on interactions between *Pseudomonas* and the other root-colonizing microflora and between *Pseudomonas* and the root surface itself. Studies on the mechanism of root colonization with techniques as immunofluorescence and electrophoresis profiles of cell surface proteins and lipopolysaccharides have recently been started (Schippers et al., 1986). Together with results of ecological studies on interactions between growth-promoting *Pseudomonas* and other rhizosphere organisms, such studies will provide the basis of a successful introduction of genetically manipulated *Pseudomonas* strains.

Rhizoctonia solani

Current status
Besides competition and antibiosis, which are important antagonistic mechanisms of the *Pseudomonas* spp. mentioned above, there is another mechanism of microbial control exterior to the host: hyperparasitism. With the exception of *Trichoderma harzianum* and *T. hamatum* (Chet & Henis, 1985), very few examples of hyperparasites controlling fungal pathogens in the field are known (Ayers & Adams, 1981; Rahe & Utkhede, 1985). Therefore, mycoparasitism of the sclerotia of *Rhizoctonia solani* by *Verticillium biguttatum* in Dutch potato fields constitutes an interesting case.

Some slightly acid sandy soils in the northern Netherlands appeared to be suppressive against *R. solani*. Screening for effective antagonists yielded *V. biguttatum* as a potentially powerful mycoparasite (Velvis & Jager, 1983; Jager & Velvis, 1984). In a field experiment in 1981 with seed tubers inoculated with various hyperparasites separately or in combination, *V. biguttatum* was the only one that significantly reduced the amount of sclerotia on harvested tubers as compared with the untreated control. The efficacy was of the same level as that reached by treatment of seed tubers with diluted formaldehyde (Table 2).

On slightly acid sandy soils and neutral loamy soils inoculation of seed tubers in 1981 and 1982 was also effective in further field tests ($P < 0.05$) (Jager, unpublished). On average, it was more effective than chemical disinfection, probably because spores of *V. biguttatum* are passively transported on the surface of growing sprouts, stems and stolons, and hyphae of the antagonist grow on and in *R. solani* hyphae occurring on these plant parts (van den Boogert, personal communication, 1986). The effectiveness of *V. biguttatum* was lowered, however, when the germinating tuber could be colonized from heavily infected soil (Jager & Velvis, 1985).

Table 2. Sclerotium index of harvested seed and ware potatoes of 15 plants grown in the field from seed potatoes naturally infected with *Rhizoctonia solani* and inoculated with hyperparasites (from van den Boogert & Jager, 1984).

Hyperparasite applied	Seed potatoes[1] Sclerotium index	Ware potatoes[1] Sclerotium index
None (disinfected clean potatoes)	9.3 ± 9.8**	10.5 ± 4.3**
None (*Rhizoctonia solani* control)	28.8 ± 9.0	32.0 ± 11.0
Gliocladium roseum	31.8 ± 15.0	30.8 ± 16.3
Verticillium biguttatum	9.3 ± 6.3**	14.0 ± 8.9**
Trichoderma hamatum	21.3 ± 12.0	27.3 ± 12.8
Hormiactis fimicola	29.0 ± 7.8	30.0 ± 12.5
Mixture of the four hyperparasites	9.3 ± 6.7**	15.5 ± 10.7*

[1] Harvest dates of seed and ware potatoes 9 September and 3 October respectively.
** and * = Significantly different at $P < 0.01$ and $P < 0.05$ from '*Rhizoctonia solani* control' as determined by the Student's t-test.

Important reasons for the reduced effectiveness of *V. biguttatum* under such conditions are a less rapid growth than *R. solani* and a higher temperature required for growth (approximately 15 °C for *V. biguttatum*, approximately 5 °C for *R. solani*; Velvis & Jager, 1983).

The feasibility of compensating for the late start of growth of *V. biguttatum* during the cool spring period by applying a low dose of a fungicide (pencycuron) or by treating seed tubers with a different antagonist in order to retard the outgrowth of *R. solani* from sclerotia or its colonization from the soil is now being studied by Jager and co-workers.

Prospects

Isolates of *V. biguttatum* are considerably different in their effectiveness (Velvis & Jager, 1983). This raises the question whether the biological control of *R. solani* may be improved by enhancing the effectiveness of strains of *V. biguttatum*. Until recently no such efforts with mycoparasites had been undertaken but, especially in a pathosystem such as potato-*R. solani*-*V. biguttatum* in which biological or integrated control is close to introduction for commercial application, there appear to be prospects for induction of strains of *V. biguttatum* with, for instance, a higher growth rate and/or resistance to certain biocides. Induction of such strains could be achieved by chemical mutagens or UV radiation following Papavizas & Lewis (1981) or by genetic manipulation by plasma fusion.

Here again, application of results of such research depends on basic ecological knowledge about the pathosystem. Such knowledge is particularly needed on three aspects:

- the survival of both pathogen and hyperparasite in the soil;
- the colonization of the subterranean parts of the potato plant by *R. solani* from the soil and the production of sclerotia on new tubers;
- the detection of *R. solani* by *V. biguttatum* from the soil.

Potato cyst nematodes

Current status

On sandy soils reclaimed from cut-over peat in the northern Netherlands potatoes for the starch industry are usually grown every second year, alternated with winter wheat or sugar beet. In such cropping systems potato cyst nematodes (*Globodera* spp.) constitute a serious problem. Fig. 1 shows that the introduction of potato cultivars resistant to cyst nematodes has only been temporarily successful. One reason is the occurrence of *two* species of potato cyst nematodes, viz. *G. rostochiensis* and *G. pallida*. The population level of the latter, which grows and multiplies slower than the former, passes the damage threshold if the population of the former is suppressed by growing cultivars which were bred for resistance against the former only. Another important reason is that the resistance of successively planted varieties is repeatedly broken by the cyst nematodes which rapidly turn up with so-called pathotypes.

To reduce damage by the nematodes the farmers in the starch potato area have adopted the practice of frequent soil fumigation.

Prospects

It has been established that *G. pallida* does not reach pest levels when *G. rostochiensis* is *not* suppressed completely but kept at a low level. This can be achieved by alternately growing a resistant and a susceptible potato cultivar in combination with soil fumigation at a reduced dose (Mulder, personal communicatin, 1986). This would result in the following crop rotation scheme (with the theoretical effect on *G. rostochiensis* in brackets): cereal (–30 %) followed by soil fumigation (–80 %) – potato, resistant cultivar (–80 %) – sugar-beet (–30 %) – potato, susceptible cultivar (×30).

Favourable effects of such a practice would be:

– resistance is less rapidly broken which gives plant breeders more time to come up with new varieties;

– if reduction rather than extermination of *G. rostrochiensis* is aimed at considerably less fumigant is needed.

Moreover, crop sequence can probably be improved by not growing potatoes every other year but in two successive years, followed by two years with non-host crops. Additional advantages of such a practice are:

– volunteer growth of potato has to be controlled only after the second potato crop;

– following winter wheat a green manure can be grown, which is important, e.g. to reduce the blowing away of fertile topsoil and cysts and to reduce leaching of nutrients during the otherwise fallow winter season.

Growing potatoes in two successive years may also facilitate biological control of potato cyst nematodes. Although data on its use in potato are not available as yet, some support for this claim comes from an experiment with 18 years of continuous cropping of sugar-beet. In this trial the decline of the beet cyst nematode *Heterodera schachtii* coincided with an increase in the degree of parasitism of eggs in the cysts, predominantly caused by fungi (Heijbroek, 1983).

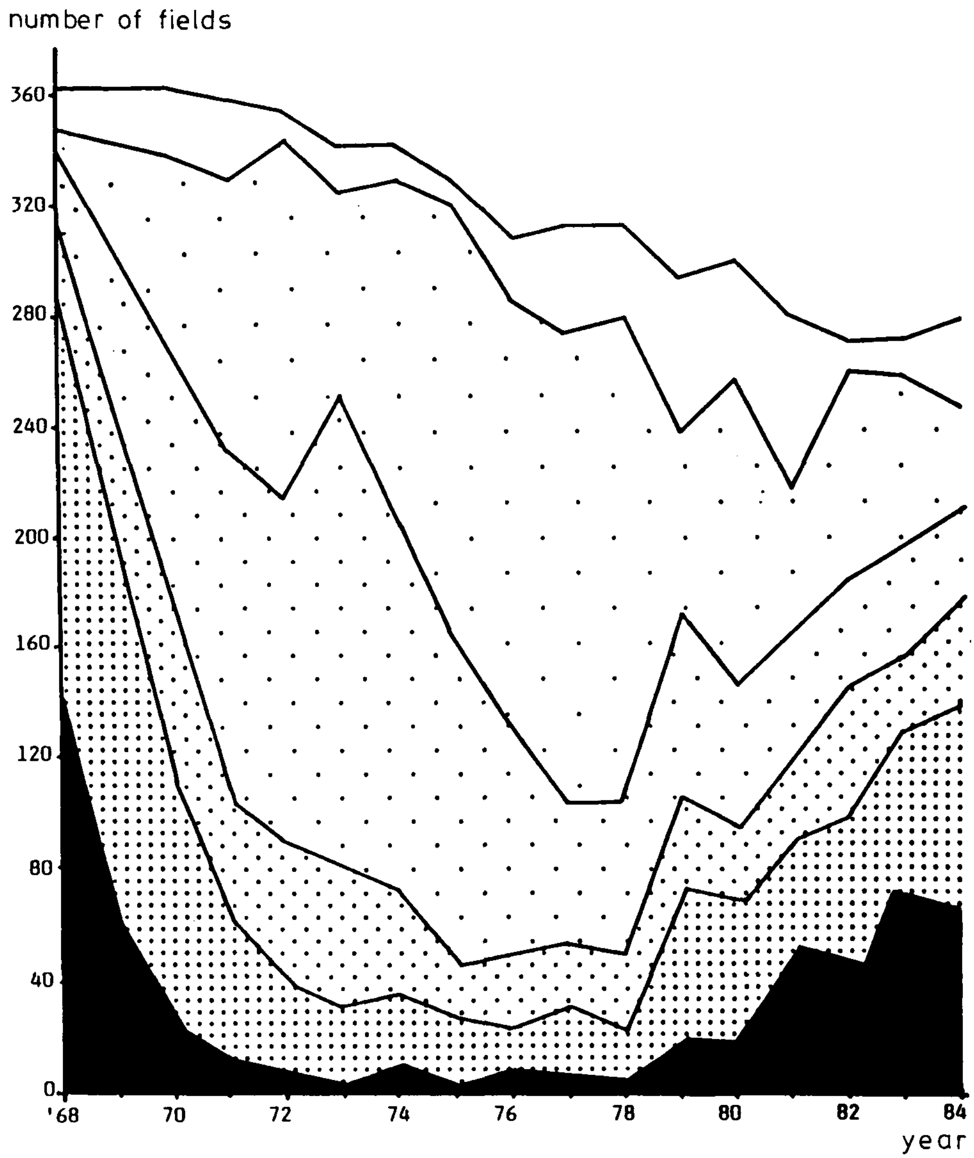

Fig. 1. Levels of infestation with potato cyst nematodes on fields on sandy soils reclaimed from cut-over peat. Black area: very heavily infested; white area: non-infested; dotted areas: intermediate levels. (Courtesy of A. Mulder, Assen.)

Biological control of cyst nematodes seems to work well in the region of origin of the potato, the Andes region of South America. In potato crops in that region cyst nematode populations may reach high levels without visible damage to the crop, followed by a sudden breakdown apparently after attack by natural enemies (Mulder, personal communication, 1986). It appears that over the centuries tolerance to cyst nematodes has accumulated in the local potato cultivars.

If supported by additional evidence it can be inferred that the successful use of natural enemies of potato cyst nematodes in the Netherlands will be favoured by growing *tolerant* rather than *resistant* varieties. Recently, Mulder and co-workers have started a screening and selection programme for promising fungal parasites of cysts. Use of bacterial pathogens such as *Bacillus penetrans* is also envisaged.

In addition, evaluation of predatory nematodes and predatory mites may also be worthwhile, because they search the whole depth where cyst nematodes occur (roughly speaking the upper 0.60 m of the soil), whereas the activities of microbial pathogens are mainly restricted to the upper 0.10-m zone (Van Gundy, 1985).

All in all, the current status of research on prevention and control of potato cyst nematodes in the Netherlands makes a strong case for aiming at a combination of tolerant varieties, cultural methods and biological control. Such an approach will probably draw attention from beyond the Dutch borders, because only recently Klassen (1981) stated: 'Nematode-resistant crop cultivars are in widespread use today. Also, crop rotation, field sanitation and cultural methods are extensively used to manage nematodes. Nevertheless, I was unable to find any publications in which an attempt was made to evaluate beneficial interactions of biological control agents of nematodes with resistant crop cultivars or cultural methods of nematode control.' Herzog & Funderburk (1985) likewise stated: 'Although we could locate no literature to support the hypothesis, possibly the greatest potential for compatibility of plant resistance and biological control is with the joint utilization of pest tolerant varieties and microbial pathogens.'

Conclusions

1. In potato production in the Netherlands considerable improvement of prevention and control of yield depressions and economic damage by microbial pathogens can be achieved if seed tubers are inoculated with fungal hyperparasites or antagonistic bacteria.
2. Genetic improvement of antagonists by mutagenesis (bacterial antagonists) or plasma fusion (mycoparasites) is worth-while pursuing.
3. There are good prospects for improved prevention and control of potato cyst nematodes by the combined utilization of tolerant rather than resistant varieties, cultural methods, moderate soil fumigation, and biological methods.
4. Research aiming at improved prevention and control, as mentioned in items 1-3, should include basic soil ecology studies, mainly directed at the interactions between crop, pathogen or pest and natural enemies.

Outlook

From the research on potato cyst nematodes in the Netherlands it may be inferred that the future of a carefully planned combination of certain crop cultivars with cultural measures and biological methods may well be brighter than a practice in which these methods are used separately or independently. This calls for integrated control research at the farming system level. As far as soil-borne diseases and pests of potatoes in the Netherlands are concerned, an excellent opportunity for integrated control research is offered by a newly established experimental farm for the development of farming systems in the area where potatoes for the starch industry are grown in narrow rotations.

In a wider context than just integrated control, interest in basic soil ecology research for the development of farming systems is growing in the Netherlands (Brussaard, 1986). Long-term objectives of such research, besides integrated control, are synchronization of crop demand for nutrients and supply by the soil ecosystem and optimization of the contribution of the fauna to the maintenance of soil structure. By connecting soil ecology research with the development of farming systems, an agricultural practice which is both ecologically and economically feasible will hopefully come within reach in the Netherlands.

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