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Effects of soil disinfection and potato harvesting methods on stem infection by *Rhizoctonia solani* Kühn in the following year

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Summary

A two year field experiment was conducted twice to assess effects of chemical soil disinfection at planting and methods of harvesting potatoes on stem infection with *Rhizoctonia solani* in the subsequent year. In the first year of the experiments seven methods, including one with soil disinfection at planting, were applied in August. In the following year, *R. solani* stem and stolon infection (disease severity) on potato plants were assessed in June.
Soil treatment at planting with pencycuron resulted in lowest disease severity in the following year. Compared with chemical haulm killing and haulm pulling, immature-crop-harvesting also resulted in a lower disease severity, but only when black scurf was scarce on tubers at harvest in the preceding year.

Introduction

Rhizoctonia solani (AG-3) is a soil-borne plant pathogen that causes canker on potato stems and stolons and black scurf on tubers. Severe canker results in delayed emergence, fewer emerged stems, lower tuber yield, a high proportion of small, partly green and misshapen tubers with a lower dry matter content and also an increased proportion of very large tubers (Van Emden, 1958; Hide et al., 1985, 1989; Scholte, 1989).

The infection of potato plants in early spring can arise from tuber-borne or soil-borne inoculum. Especially in crop rotations with a high frequency of potato (Hide & Read, 1991; Scholte, 1987), soil-borne *Rhizoctonia* can significantly reduce the yield and quality of potato tubers (Frank, 1975; Scholte, 1989; Simons, 1990). *R. solani* AG-3 has a small host range (Carling et al., 1986), but potato is a good host and therefore the build-up of soil inoculum by growing potatoes may play an important role in its population dynamics. Controlling this build-up of soil inoculum can contribute to the non-chemical control of soil-borne stem canker. Boosalis & Scharen (1959) and Van den Boogert & Velvis (1992) found that surviving structures of *R. solani* are found mainly on and in plant debris.

Sclerotia (black scurf) form on progeny tubers and other underground plant parts mostly at the end of the growing season. The level of black scurf on tubers can be decreased by soil disinfection with fungicides. For example, soil treatment with pency- curon or tolclofos-methyl at the recommended doses at planting is very effective (Mulder & Roosjen, 1982; Jager et al., 1991). Also harvesting methods that are used in potato seed production in the Netherlands can affect the level of black scurf. Chemical haulm destruction enhances black scurf more than haulm pulling (Reestman & Scheepers, 1955; Van Emden et al., 1966; Mulder & Roosjen, 1982; Bouman et al., 1983; Dijst, 1985). Green-crop-harvesting (harvesting the immature crop by machinery and replacing the tubers into the soil for curing and final harvesting 2–4 weeks later) often results in low levels of black scurf (Mulder et al., 1992). This is especially the case with immature-crop-harvesting (pulling haulm and collecting the tubers by hand) (Van Emden et al., 1966). However, whether these haulm destruction methods and soil disinfection also affect the amounts of soil inoculum and disease severity in the subsequent years has not been investigated. Therefore, experiments were conducted to study the effects of such treatments on stem and stolon canker in the following season.

Materials and methods

Experimental set up. Two-year field experiments were carried out in 1991–1992 (Experiment 1) and in 1993–1994 (Experiment 2). The experiments were sited in Achterberg, close to Wageningen, on a sandy soil with a pH-KCl of 5.2 and an organic matter content of 3.9%. In Experiment 1 the preceding crops were potato in 1989 and sugar beet in 1990 and in Experiment 2 potato in 1991 and maize in 1992. In both experiments potatoes were grown in two consecutive years.

N, P, K and Mg fertilizers were applied each year at standard recommended quantities. Ridges were prepared directly after planting in both experiments. Weeds and late blight were controlled chemically. When necessary, fields were irrigated during the growing season.

In April of Year 1 pre-sprouted seed tubers of cv. Santé (Experiment 1) or Spunta (Experiment 2), severely infested with black scurf, were mechanically planted 30 cm apart at a row distance of 75 cm. Plots were 6x6 m^2, containing 8 rows of potatoes. The four inner rows were used for observations. The experiments were laid out as randomized complete block designs with seven treatments and six replications.

The treatments (Table 1) were applied in August of Year 1 except the soil disinfection in Treatment 1. In Treatment 1, soil disinfection with pencycuron (Monceren, 25% a.i., Bayer Nederland bv, 25 kg/ha of the trade product), applied one day before planting in April, was combined with chemical haulm destruction. For chemical haulm destruction in Treatments 1 and 2, DNOC (Luxan DNOC-oil, 200 g a.i./l, 25 l/ha) was applied four weeks before harvesting. Haulm pulling (Treatment 3) was done by hand four weeks before harvesting the tubers. Potato tubers of Treatment 4 were harvested after complete natural plant senescence. Immature-crop-harvesting was performed by lifting the potato plants by hand on the same dates as chemical haulm killing and haulm pulling in Treatments 1 to 3. The remaining plant debris was removed from the field (Treatment 5), left on the field (Treatment 6) or chopped into pieces of about 30 cm length and incorporated into

Table 1. Treatments in Experiments 1 and 2.

Haulm treatment	Tuber harvest[a]	Plant debris
1 Pencycuron[b] + chemical haulm destruction	28	left on soil surface
2 Chemical haulm destruction	28	left on soil surface
3 Haulm pulling	28	left on soil surface
4 Natural senescence	63	left on soil surface
5 Immature-crop-harvest field	0	removed from the
6 Immature-crop-harvest	0	left on soil surface
7 Immature-crop-harvest	0	incorporated into the soil

[a]Days after immature-crop-harvest in August.
[b]Pencycuron incorporated into the soil one day before planting in April.

the soil one day after tuber harvesting using a rotary hoe at slow speed (Treatment 7). Black scurf severity on tubers was assessed after harvest.

Potatoes were also grown in Year 2 of the experiments. Before planting, seed tubers (size 35–40 mm) of cv. Element visibly free from black scurf were disinfected by immersing them in a solution of validamycine (Solacol, AAgrunol, 30 g/l a.i., 3% solution of the trade product). In April the seed tubers were planted by hand at a spacing of 20x75 cm to achieve a high stem density. Stem and stolon canker caused by *R. solani* were assessed in June.

Determination of black scurf on tubers in Year 1. At harvest in Year 1 of both experiments, samples of 100–150 tubers were taken from the four inner rows of each plot to assess the effect of treatments on black scurf. Disease severity on each tuber was recorded using 5 classes (Dijst, 1985) and converted to a black scurf-index (BI=0–100) using the following formula:

$$BI = 100x(0xn_0+1/4xn_1+2/4xn_2+3/4xn_3+n_4) / n_{total}$$

where n = the number of tubers in each category 0–4.

Determination of stem and stolon infection in Year 2. In both experiments, stem and stolon infection caused by *R. solani* were assessed on June 15. Forty plants with on average three main stems were harvested per plot. Stem infection was recorded on each stem and classified as follows:

0 = no lesions,
1 = some small lesions scattered over the stem,
2 = moderate number of small lesions not covering >25% of the stem,
3 = major lesions covering >25% of the stem, but no girdling of the stem,
4 = major lesion including girdling of the stem,
5 = severe lesions killing the stem.

Stolon infection was recorded per plant using a classification from 0–5 (analogous to the classes of stem canker). Stem and stolon infection were each converted into a disease index (DI=0–100), using the following formula:

$$DI = 100x(0xn_0+1/5xn_1+2/5xn_2+3/5xn_3+4/5xn_4+n_5) / n_{total}$$

where n = the number in each category 0–5.

Statistical analysis. Data of both experiments were combined in a split-plot analysis in time using ANOVA. Least significant differences between treatments were calculated using the LSD-test.

Results

Black scurf severity in Year 1. Black scurf severity was higher in Experiment 2 (1993) than in Experiment 1 (1991), except for the pencycuron treatment (Table 2). Effects of the various treatments on black scurf severity on tubers were pronounced and lowest severities were obtained with immature-crop-harvest or when the soil was treated with pencycuron at planting. Highest incidence of black scurf occurred with chemical haulm killing without soil disinfection, whereas haulm pulling and natural senescence showed intermediate levels.

Stem and stolon canker in Year 2. There was a close correlation between stem canker and stolon canker (Fig. 1). The regression coefficients (Exp. 1: 1.07, SE=0.08, 40 df; Exp. 2: 1.28, SE=0.10, 40 df) of both experiments did not differ significantly. Table 3 presents means of the stem and stolon canker indices. Stem and stolon canker were lower in Experiment 1 than in Experiment 2, except for the pencycuron treatment and haulm pulling. In both experiments, soil treatment with pencycuron in Year 1 resulted in relatively low infection levels in Year 2, and especially in Experiment 2. In Experiment 1, immature-crop-harvesting tended to give less disease than haulm pulling and chemical haulm destruction, especially when plant debris was incorporated into the soil, but this effect did not occur in Experiment 2.

Discussion

Black scurf in Year 1. In these experiments the effect of soil disinfection and various harvest methods on black scurf severity on progeny tubers are in agreement with

Table 2. Effect of soil disinfection with pencycuron at planting and harvest methods in Year 1 on black scurf index (0 - 100) on progeny tubers in Year 1.

Treatment		Experiment 1	Experiment 2
1	Pencycuron + chemical haulm killing	29	26
2	Chemical haulm killing	41	65
3	Haulm pulling	34	44
4	Natural senescence	31	58
5-7	Immature-crop-harvest	7	26

LSD for comparing means is 5.6 (P = 0.05).

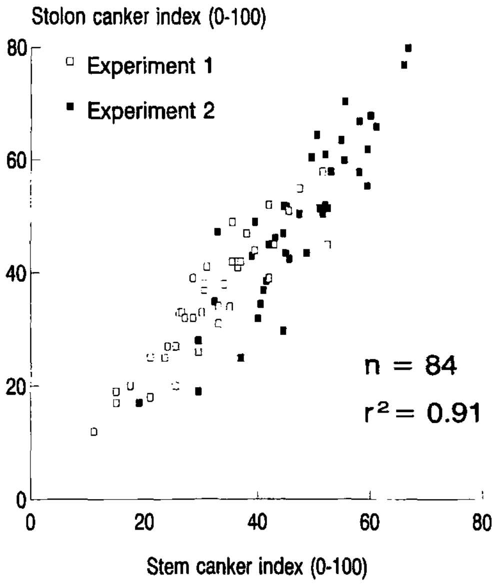

Fig. 1. Relation between stem and stolon canker index.

results from other researchers. Application of pencycuron resulted in equal levels of black-scurf in both experiments, although the mean level of black scurf was higher in Experiment 2 than in Experiment 1. Immature-crop-harvesting was less effective in Experiment 2 because formation of sclerotia had already started by the date of immature-crop-harvesting, probably because the seed tubers used were severely infested. Also the higher level in Experiment 2 could be attributed to lower temperatures and wetter conditions in the soil. For example, mean soil temperature at 10 cm depth and precipitation in the period 30 days before to 30 days after immature-crop-harvesting were 20.9 or 17.3 °C and 48 or 193 mm rainfall for Experiments 1 and 2 respectively.

Table 3. Effect of soil disinfection with pencycuron at planting and harvest methods in Year 1 on stem and stolon canker (disease-index 0 - 100) in Year 2.

Treatment		Experiment 1	Experiment 2
1	Pencycuron + chemical haulm killing	28	33
2	Chemical haulm killing	40	56
3	Haulm pulling	45	52
4	Natural senescence	39	48
	Immature-crop-harvest:		
5	- debris removed	32	51
6	- debris left on the soil	34	49
7	- debris incorporated into the soil	22	51

LSD for comparing means is 8.4 (P = 0.05).

Disease severity in Year 2. It may be supposed that differences in plant infection in Year 2 between treatments were caused by different levels of soil infestation with *R. solani* because the plant debris (which is the main source of soil inoculum) was returned to the field (except Treatment 5), and all other factors possibly interacting with the disease level, such as soil fertility, soil moisture and soil temperature did not differ between the treatments. Tuber-borne infection in Year 2 was excluded because visibly sclerotia-free seed tubers were disinfected with validamycine which had proved to be very effective in controlling *R. solani* in earlier experiments (Scholte, personal observations). Only the antagonistic soil flora and fauna could possibly interact with disease levels in Year 2.

Soil disinfection with pencycuron appeared to have a significant after-effect on the disease severity in the following year. Pencycuron is very effective in inhibiting the growth of *R. solani* (Kataria & Gisi, 1989; Kataria et al., 1989). Thus it may be expected that at the end of the growing season in Year 1, low levels of *Rhizoctonia* would be present in the soil, resulting in the formation of low levels of resting structures. This was demonstrated by the black scurf index in Year 1. Probably also low levels of survival structures are formed on plant debris remaining in the soil.

In Experiment 1 immature-crop-harvesting, especially when combined with incorporation of plant debris into the soil, resulted in a lower disease index in Year 2, compared with the other harvesting methods. This can have been caused by a lower soil infestation. Dijst (1990) showed that volatile and unstable exudates from underground plant parts stimulate the formation of resting structures. Sufficient aeration of the soil would reduce the accumulation of these components (Dijst et al., 1986). Use of the rotary hoe clearly resulted in a higher aeration of the soil. In Experiment 2 no reducing effect of immature-crop-harvesting was observed. Formation of black scurf had already reached a considerable level at immature-crop-harvesting date (Table 2), and this fact may have obscured effects. It may be expected that only at lower soil infestation levels there will be a (linear) relationship between level of soil infestation and disease severity.

It can be concluded that soil disinfection with pencycuron results in a low soil infestation level of *R. solani* in the subsequent year, but the effect of harvest methods seems to depend on soil infestation level at immature harvest time.

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