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Formation of canker lesions on stems and black scurf on tubers in experimentally inoculated potato plants by isolates of AG2-1, AG3 and AG5 of *Rhizoctonia solani:* a pilot study and literature review

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Development of black scurf on potato tubers (cv. Nicola) was compared in plants inoculated with isolates of *Rhizoctonia solani* of three anastomosis groups (AG2-1, AG3 and AG5) which occur in potato crops in Finland. All isolates induced stem canker lesions but only isolates of AG3 formed efficiently black scurf on progeny tubers. Among the AG2-1 and AG5 isolates tested, only one AG2-1 isolate formed a few sclerotia on 13.5 % of the progeny tubers in one experiment. The data indicate that isolates of AG3 differ from those of AG2-1 and AG5 in having a higher ability to form sclerotia on tubers. Therefore, while AG2-1 and AG5 isolates have a broader host range, AG3 is more efficient in producing black scurf, which provides this anastomosis group with more efficient means of dissemination on seed potatoes. These differences probably explain the predominance of AG3 (98.9 % of isolates) in potato crops in Finland and other northern potato production areas.

Key-words: *Rhizoctonia solani*, anastomosis group, black scurf, sclerotia, AG2-1, AG3, AG5

Introduction

Infection with *Rhizoctonia solani* Kühn [teleomorph *Thanatephorus cucumeris* (Frank) Donk] causes a severe disease complex on potato. Initially, tips of sprouts may be killed (Richards 1921, Sanford 1938). Subsequently, brown and sunken lesions develop on the sprouts, underground parts of the stem and the stolons (Dana 1925, Glendenning 1965, Baker 1970). These symptoms are collectively called stem and stolon canker. Fol-

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lowing emergence and infection-induced defence (Lehtonen et al. 2008b), the underground part, the underground part of the stem becomes more resistant (van Emden 1965) and symptom development ceases, whereas the damage on stolons continues (Glendenning 1965, Hide and Cayley 1982). At the end of the growing season during tuber maturation, dark hyphal clumps (sclerotia) called black scurf forms on the surface of the progeny tubers (Kühn 1858, Edson and Shapovalov 1918, Sanford 1938, 1941, Chand and Logan 1984, Banville 1989).

R. solani consists of at least 13 genetically defined populations or 'anastomosis groups' (AG) (Carling et al. 2002) defined by anastomosis of hyphae between isolates belonging to the same AG (Carling 1996). The genetic differences of isolates belonging to different AGs are sufficiently large to use molecular genetic criteria such as phylogenetic analysis of the internal transcribed sequences (ITS1 and ITS2) of ribosomal genes as a means to identify the AG of an unknown isolate (Lehtonen et al. 2008a and refs. therein). The secondary structures of ITS2 RNA sequences provide also additional evolutionary information in terms of compensatory base changes (CBC) occurring in the paired regions of a primary RNA transcript, which has revealed that strains of AG3 are a distinct species (Ahvenniemi et al. 2009). This AG was originally described as *R. solani* by Kühn (1858) and in light of CBC analysis other AGs should be designated to new species different from *R. solani* (Ahvenniemi et al. 2009).

AG3 is the main pathogen on potato. It causes most severe symptoms typically under cool growing conditions (Carling and Leiner 1990a). In Denmark, only isolates of AG3 have been reported from potato (Justesen et al. 2003). In the United Kingdom and France, 93 % and 94 % of the isolates of *R. solani* characterized from potato belonged to AG3, respectively. The remaining isolates were of AG2-1 or AG5 (Campion et al. 2003, Woodhall et al. 2007). Similar results indicating predominance of AG3 and occasional occurrence of other AGs have been reported from many other countries including Ireland (Chand and Logan 1983), Alaska (Carling et al. 1986), Canada (Bains and Bisth 1995), USA (Bandy et al. 1984, 1988), Peru (Anquiz and Martin 1989), South Africa (Truter and Wehner 2004), China (Chang and Tu 1980), Japan (Abe and Tsuboki 1978), and Australia (Balali et al. 1995).

Studies on genetic variability of *R. solani* infecting potatoes in Finland have been carried out only recently. In the survey that covered all main potato production areas of the country, a total of 503 isolates of *R. solani* were characterized and 497 of them (98.9 %) were found to belong to AG3. These isolates were collected from 281 potato fields and 31 cultivars (Ahvenniemi et al. 2006, 2009, Lehtonen et al. 2008a). Only three isolates belonged to AG2-1 and one each to AG4, AG5 and an unknown binucleate *Rhizoctonia* sp. These results from Finland and those from other countries quoted above raised a question as to why other anastomosis groups than AG3 are so rare in potato.

R. solani survives to the next growing season as sclerotia (black scurf) that form on tubers and provide also the most efficient means for dispersal of the fungus to new areas on infested seed potatoes (van Emden et al. 1966, Carling et al. 1989). Black scurf is commonly observed on tubers of plants infected with AG3 and was also originally the "symptom" leading to isolation and description of the fungal species, *R. solani* (Kühn 1858). However, isolates of other AGs can also form sclerotia on tubers in the field. Black scurf caused by AG2-1 has been detected in Alaska (Carling and Leiner 1986), Northern Ireland (Chand and Logan 1983) and the United Kingdom (Woodhall et al. 2007). Black scurf caused by AG4 has been detected under warm conditions in Peru (Anquiz and Martin 1989). Isolates of AG5 cause black scurf in Australia (Balali et al. 1995), South Africa (Truter and Wehner 2004), the United Kingdom (Woodhall et al. 2007) and also in Japan where the sclerotia of AG5 form on tubers later than those of AG3 (Abe and Tsuboki 1978). One isolate of AG7 has been found to damage potato sprouts and form black scurf on tubers under cool condition in Mexico (Carling and Brainard 1998). Isolates of AG8 may cause mild symptoms of stem canker (Carling and Leiner 1990a), severe root cankers (Balali et al. 1995) and reduce plant biomass in

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infected potato plants (Hide and Firmager 1990) in southern Australia and the United Kingdom but formation of black scurf has not been reported. Isolates of AG9 can produce hymenia on potato stems and cause mild stem canker symptoms but they do not seem to cause black scurf (Carling et al. 1986, 1987).

One explanation for the very common occurrence of AG3 in potato, as compared to other AGs, could be differences in the ability to form sclerotia on tubers, which in turn would influence survival and dispersal of the fungus. However, only few studies have focused on this topic under controlled conditions where the risk of plants getting infected with more than the single inoculated isolate can be avoided. In Australia, isolates of AG3, AG4 and AG5 were detected from potato plants but only isolates of AG3 and AG5 formed black scurf on tubers of the experimentally inoculated plants in the greenhouse (Balali et al. 1995). In similar experiments carried out in France on isolates of AG2-1, AG3 and AG5 only isolates of AG3 formed sclerotia on tubers (Campion et al. 2003). Other studies carried out under controlled conditions have not compared different AGs but used AG3 to determine the time needed for black scurf formation after haulm killing (Dijst 1985) or the role of source of inoculum in black scurf formation (Tsror and Perezt-Alon 2005). On the other hand, many studies have compared isolates of different AGs for induction of stem and/or stolon canker symptoms (e.g., Bandy et al. 1984, 1988, Carling et al. 1986, Carling and Leiner 1986, Lehtonen et al. 2008a).

The aim of this study was to test under controlled conditions whether the isolates of *R. solani* obtained from potato plants in Finland and belonging to AG2-1, AG3 and AG5 might differ in their ability to produce black scurf on potato tubers. In addition, the ability of these isolates to cause stem canker and affect yield was compared. Finland is one of the northernmost countries with intensive potato production in the world and these questions were therefore considered to be of particular interest to study using local isolates of *R. solani*.

Materials and methods

Fungal isolates

Five Finnish isolates and three control isolates of *R. solani* from other countries were included in the study. The AG2-1 isolate 1734 was obtained from a teleomorph stage on potato stem in Liminka (northern Ostrobothnia). The AG2-1 isolate R114 was obtained from a potato stem canker lesion in Virtasalmi (central Finland). The AG5 isolate R96 was obtained from a stem canker lesion in Urjala (south-western Finland). The AG3 isolates 25 and R11 were obtained from potato stem canker lesions in Hankasalmi (central Finland) and Lammi (southern Finland), respectively, whereas the AG3 isolate R98 was obtained from a teleomorph stage on potato stem in Pyhäjoki (northern Ostrobothnia). Additionally, the Japanese anastomosis group tester isolates of *R. solani* representing AG2-1 (isolate PS-4) isolated from pea (Sneh et al. 1991) and AG5 (isolate Rh184) isolated from sugar beet (Carling and Leiner 1990a) were included in the experiments. They were kindly provided by Prof. S. Naito (University of Hokkaido, Sapporo, Japan). A single isolate of AG4 was detected on potato in Finland (Ahvenniemi et al. 2006, 2009) but could not be maintained and was not available for experiments. One isolate of AG2-1 was not virulent on potato as tested in our previous study (Lehtonen et al. 2008a) and was therefore excluded from experiments of this study.

The Finnish isolates were identified for their anastomosis groups by determining the ITS1 and ITS2 sequences and comparing them to previously described isolates of different AGs by phylogenetic analysis (see Lehtonen et al. 2008a). The sequences of most of the isolates have been deposited to the NCBI sequence database [accession numbers DQ913037 (AG2-1 1734), DQ913034 (AG5-R96), DQ913014 (AG3-R11), DQ913026 (AG3-R98), EF532828 (AG2-1 PS-4) and EF532827 (AG5 Rh184)]. In addition, the anastomosis reactions of the Finnish isolates were determined using the tester isolates for comparison as reported previously (Lehtonen et al. 2008a, Ahvenniemi et al. 2009).

Preparation of inoculum

Isolates of *R. solani* were maintained on potato dextrose agar (PDA, Difco, France) at +4 °C. Inoculum was prepared by adding 20 g of quinoa seeds (*Chenopodium quinoa* L.), 40 g of coarse quartz sand (grain size 0.5−1.2 mm; Optiroc Oy, Helsinki, Finland) and 22 ml of reverse osmosis water into a 400-ml bottle and autoclaved twice at 121 °C for 1 h, with a 24-h interval. Seven mycelial plugs (each 7 mm in diameter) of a 4-day old actively-growing mycelium of *R. solani* on PDA were added into the bottle. The fungus was allowed to colonize the seed-sand mixture for 14 days at room temperature in the dark. The contents of the bottle were mixed at 2-day intervals by shaking so to enhance even colonization of the seed-sand mixture. Sterile seed-sand mix was used as a control for inoculation.

Experimental set-up

The experiment was carried out twice. Pathogen-free minitubers of 'Nicola' were obtained from the Finnish Seed Potato Centre Ltd, Tyrnävä, Finland. Tubers were sprouted in the dark at room temperature until the sprouts were approximately 30 mm long. A single tuber was planted in a plastic pot of 10 l (diameter 280 mm, height 230 mm) to a depth of 10 cm in washed quartz sand moistened with 0.2 % Vihannes-Superex fertiliser (N:P:K=9:5:31) (Kekkilä, Tuusula, Finland). Fertilizer solution was added at a rate of 100 ml/kg. The tuber was covered with 1 cm of sand. The inoculum (10 g) was spread on the sand layer above the tuber and the pot filled with moist sand.

Four pots were inoculated with each isolate of *R. solani*. An additional pot was inoculated with isolates AG3-25, AG3-R11, AG5-R96 and AG2-1 1734 to observe the severity of stem and stolon canker symptoms at 48 days post planting (dpp). Four control pots were inoculated with the sterile sand-seed mixture (mock-inoculation). Pots were placed on greenhouse tables in a completely randomised design and covered with plastic bags to maintain high humidity for the optimal growth of the fungus. After emergence, a hole was pierced to the plastic to allow unrestricted growth of the stems. In the beginning of the experiment, pots were watered with 0.2 % Vihannes-Superex fertiliser twice a week (250 ml per pot at each time). Two weeks after planting automatic watering system was installed and plants obtained 50 ml of water daily for 30 min. Additionally, 250 ml of the fertilizer was given by hand once a week. Temperatures were constant (17 ± 2 °C) controlled by a cooling system. Photoperiod was 16 h. Additional light was supplied with 400 W high pressure sodium lamps (Osram Plantastar, Osram GmbH, Munich, Germany). Soil temperature in the pots was monitored weekly with thermometers inserted in 10 pots and ranged from 16 to 20 °C. At 106 dpp stems were cut to enhance tuber maturation and black scurf formation (Djist 1985). For the last two weeks of the experiment pots were not watered (soil temperatures 17–20 °C). Tubers were lifted and examined for black scurf at 120 dpp.

Assessment of disease symptoms

Lesions (canker symptoms) were observed on stems and stolons and the proportion of surface area covered by lesions estimated according to Weinhold et al. (1982) at 48 dpp. Two plants (one plant per experiment) inoculated with isolates AG2-1 1734, AG3-25, AG3-R11 and AG5-R96 were analyzed. All stems and stolons of the plant were evaluated and placed in one of the symptom severity classes: 0 %, 1−5 %, 6−25 %, 26−50 %, 51−75 % or 75−100 % surface area covered by lesions. The midpoint value of the class was used for further calculations. The Rhizoctonia disease severity index (RSI, 0-88) for each plant was obtained as a mean of the midpoint severity values of all stems and stolons of the plant.

Assessment of stem number was done at 106 dpp a the time of haulm removal. Black scurf severity was estimated and tuber number and tuber weight (yield) measured at termination of the experiments at 120 dpp. Sand was removed carefully from tubers and the incidence of black scurf on

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progeny tubers evaluated. Each tuber was placed in one of the five black scurf severity classes according to the coverage of surface by black scurf using the illustrated key (reference pictures) of Dijst (1985): 0, no symptoms; 1, very light infestation; 2, light infestation; 3, moderate infestation; and 4, heavy infestation. The mean of the tuber-specific values was used to indicate 'black scurf severity' for each plant.

Recovery and identification of the pathogen from inoculated plants

Fungal isolation was done to 2 % (w/v) water agar supplemented with 50 µg/ml streptomycin (Sigma, USA) from two canker lesions per each plant examined at 48 dpp. Furthermore, isolation was made from two sclerotia per plant at 48 dpp if any sclerotia were observed on tubers of the plant at that time. Hyphal tips were transferred to and grown on PDA and the typical characteristics of hyphae and growth of *R. solani* observed. DNA was extracted from the hyphae using the cetyl trimethylammonium bromide extraction buffer method, amplified by polymerase chain reaction using the ITS1 and ITS4 primers, and the amplification products sequenced directly without cloning, as described (Lehtonen et al. 2008a). Sequences were compared to the previously determined sequences to confirm the AG of the isolate.

Analysis of data

The numbers of stems and tubers, total yield, marketable yield (tubers size 40-60 mm), and the severity of black scurf on progeny tubers were tested by the analysis of variance (ANOVA) using the GLM procedure of the SPSS statistical software package (SPSS Inc., Chicago, USA). Least significant differences were used to separate the means at $p = 0.05$. Dunnett's t-test was used to identify the treatments (isolates) that differed significantly from the control treatment (mock-inoculation).

The incidence of black scurf and the proportion of marketable tubers in the yield were analysed by logit models. Logit models were preferred to the use of ANOVA because the response variables were of a quantal nature (i.e., presence or absence, for which the results are reported as percentages or proportions), whereas ANOVA assumes a continuous response variable and homoscedasticity of the residuals. ANOVA could have been applied using the arcsin-transformation of data, but the logit models do not require such transformations and thus the results of the analyses using logit models are more straightforward to understand (no back-transformations required). In logit models, the effects of explanatory variables are described using the concept of odds ratio, which is a relative measure of difference between the two probabilities compared: $[P_2/(1\text{-}P_2)]/[P_1/(1\text{-}P_1)]$ (Collett 1991, Lindén et al. 1996, Hiltunen et al. 2005). Significance tests and confidence intervals for the single parameters were based on Wald statistics. The logit analysis was carried out by the logistic regression procedure of the SPSS statistical software package.

Results and discussion

Canker symptoms were observed as discolouration and necrotic lesions on the underground parts of the young stems and on stolons, and also as death of sprout and stolon tips, in the potato plants inoculated with isolates of *R. solani*. These symptoms were studied in detail 48 dpp in two experiments with four of the eight isolates included in the study. Symptoms were mild in plants inoculated with isolate AG2-1 1734 (RSI 7.2±6.5), whereas the AG3 isolates 25 and R11 and the AG5 isolate R96 caused more severe symptoms (RSIs 20.5±9.9, 21.4±16.5, and 29.0±12.3, respectively). The fungi were re-isolated from two stem canker lesions and characterized for the ITS sequences, which confirmed their identity as the inoculated isolates.

The total number of tubers per plant (means 14 and 15 tubers, respectively, in two experiments) was similar in plants infected with the different

isolates of *R. solani* and the uninoculated plants. Infection did not significantly affect the proportion of the marketable-sized tubers in the yield as compared to uninoculated control plants in the two experiments (Table 1). However, plants infected with the AG3 isolate R11 produced significantly lower yields (327 g per plant) than the uninoculated control plants (519 g) in the second experiment (p=0.009; df=8) (Table 1). Furthermore, black scurf was detected on progeny tubers of all plants infected with the three AG3 isolates in both experiments. Isolate 25 formed black scurf already at a young growth stage of tubers at 48 dpp. At this time no sclerotia were observed on tubers in the plants infected with other isolates. At 120 dpp, the incidence (84.5−97.8 %) and severity (index 1.82-2.51) of black scurf were similar on tubers of the plants infected with the three isolates of AG3 (Table 1, Fig. 1).

Black scurf formation with the isolates of AG2-1 and AG5 differed clearly from AG3. The progeny tubers of plants inoculated with isolate 1734 of AG2-1 contained mild black scurf symptoms (Fig. 1) and even then just a few tubers contained black scurf (incidence 13.5 %) which was very mild (index 0.2) (Table 1). No black scurf was observed on tubers of plants inoculated with the two other AG2-1 isolates and the two isolates of AG5 tested.

The results showed that all Finnish isolates of *R. solani* tested were pathogenic on potato in terms of the damage they caused on sprouts and underground parts of the stem. However, only isolates of AG3 formed black scurf efficiently. These results are congruent with the previous reports showing that AG3 isolates are specialized to potato and AG3 is the most severe pathogen of potato among the different AGs (Weinhold et al. 1982, Banville 1989, Banville et al. 1996). Other studies have indicated that AG2-1 isolates from potato are generally not very virulent on potato plants (Carling and Leiner 1990a, Woodhall et al. 2007), which was found also in this study. The black scurf symptoms caused by one Finnish AG2-1 isolate in one experiment were very mild, consistent with previous reports in which AG2-1 has been occasionally recovered from black scurf on tubers grown in the field in Alaska (Carling and Leiner 1986, Carling et al. 1986), Northern Ireland (Chand and Logan 1983) and the United Kingdom (Woodhall et al. 2007).

In this study, the AG5 isolate from potato caused severe stem canker symptoms on inoculated potato plants, which has been observed with AG5 isolates also in the United Kingdom (Woodhall et

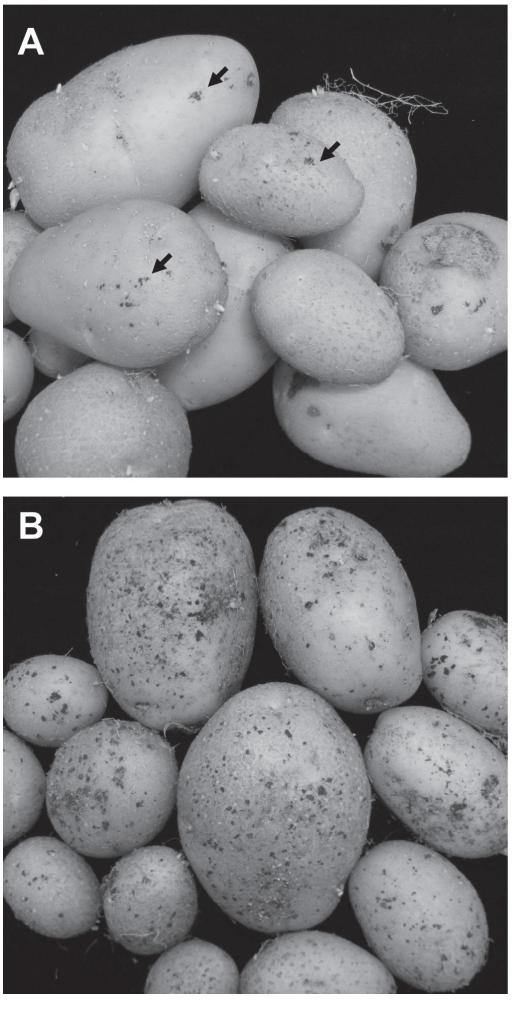

Fig. 1. Black scurf on tubers of cv. Nicola infected with *Rhizoctonia solani* in the greenhouse. **A**, Sclerotia formed by the AG2-1 isolate 1734 (arrows). **B**, Moderately severe black scurf of class 3 according to the severity classification of Dijst (1985) caused by the AG3 isolate 25. Tubers of both plants were harvested 120 days post-planting.

Table 1. The yield and proportion of marketable-sized tubers (40–60 mm in diameter) per plant, and the incidence and severity of black scurf 120 days after planting. Two experiments including four plants (pots) inoculated with each isolate of *Rhizoctonia solani* were carried out in the greenhouse.

Isolate	Anastomosis group	Marketable yield (g) per plant				Proportion of marketable tubers (%)[b]		Incidence of tubers with black scurf (%)[b]		Severity of black scurf (SD)[c]	
		Exp. 1		Exp. 2		Exp. 1	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2
		Mean	(SD)[a]	Mean	(SD)						
1734	AG2-1	459	(66)	573	(101)	50.9	65.4	0	13.5[e]	0	0.19 (0.23)[f]
R114	AG2-1	408	(115)	457	(84)	56.4	50.0	0	0	0	0
PS-4	AG2-1	470	(43)	525	(21)	49.2	55.8	0	0	0	0
R96	AG5	503	(34)	518	(35)	56.1	50.0	0	0	0	0
Rh184	AG5	416	(42)	485	(64)	46.4	59.2	0	0	0	0
25	AG3	387	(133)	426	(83)	33.3	58.3	97.1	91.7	2.33 (1.22)	2.51 (0.86)
R11	AG3	281	(68)	327	(82)[d]	36.2	37.0	84.5	96.3	1.82 (0.48)	2.35 (0.29)
R98	AG3	415	(171)	411	(149)	44.6	53.3	90.8	97.8	1.82 (0.48)	1.96 (0.37)
Control	-	464	(59)	519	(39)	48.3	50.0	0	0	0	0
$P_{isolate}$ (df)		NS	(8)	0.009	(8)	NS (8)	NS (8)	NS (2)	<0.001 (3)	NS (2)	0.031 (3)

[a] SD, standard deviation of the mean (n = 4).

[b] Logit analysis was used to compare the proportions.

[c] Black scurf severity using the scale 0−4 according to Dijst (1985) in tubers harvested 14 days after haulm killing. Comparison was only carried out between the isolates that caused black scurf on progeny tubers.

[d] The yield of plants inoculated with this isolate was significantly lower than in the uninoculated control according to Dunnett's t-test.

[e] The incidence of black scurf with this isolate was significantly lower than other isolates that caused black scurf on progeny tubers. Comparison was only carried out between the isolates that caused black scurf on progeny tubers.

[f] The severity of black scurf with this isolate was significantly lower than other isolates that caused black scurf on progeny tubers.

al. 2007). However, no black scurf was observed on the progeny tubers of plants inoculated with the Finnish AG5 isolate. In Japan, isolates of AG5 were found to form sclerotia on tubers later than AG3 (Abe and Tsuboki 1978). It is possible that the Finnish AG5 isolate R96 tested in this study could have formed sclerotia on tubers after an extended time in soil. However, all tubers were harvest 14 days after haulm removal because it is sufficient for tuber maturation and potatoes are usually lifted latest at this time after haulm killing in Finland.

Dijst (1990) has proposed that volatiles produced by immature potato tubers prevent but do not totally inhibit AG3 isolates from forming sclerotia on tubers, and that the inhibitory effect disappears rapidly when tubers mature. It is also possible that maturation of tubers induces black scurf formation. In the present study, the AG3 isolate 25 formed sclerotia abundantly on young tubers of vigorously growing potato plants already at 48 dpp. Spencer and Fox (1979) have concluded that problems with the health of the root and stolon system may allow induction of black scurf formation prior to senescence of the potato plant. However, this is not likely to explain the results obtained with isolate 25 in the present study because disease symptoms in stems and stolons were not more severe than with the other AG3 isolates. It is hypothesized that isolate 25 may be more tolerant to the inhibitory substances postulated by Dijst (1990) or more sensitive to putative compounds that induce formation of sclerotia. Another possibility is that the heavy infestation of the artificially inoculated soil leads to unspecific aggregation of the hypha (Sanford 1941), which is more pronounced with isolate 25 due to its putative high growth rate and colonization.

AG3 causes most severe symptoms under cool temperatures (Carling and Leiner 1990a), whereas the temperature in the cooled greenhouse used in this study (17 °C) was somewhat higher than soil temperatures (<15 °C) at the time of black scurf development on tubers in the field in Finland. Hence, the temperature did not favour AG3 over AG2-1 and AG5 and could not explain the differences in black scurf formation. Many abiotic and biotic factors including soil texture, temperature, water potential, pH, oxidative stress, antagonistic organisms and plant compounds affect mycelial growth and sclerotia formation, survival and germination of *R. solani* (Jager and Velvis 1983, Grosch et al. 2007, Kai et al. 2007, Patsoukis and Georgiou 2007, Ritchie et al. 2006, Yulianti et al. 2006, Wilson et al. 2008a, 2008b). Populations of AG3 increase rapidly in field soils during potato cultivation but also decline quickly after the last potato crop. Two intercrops between potato crops are sufficient in most cases to significantly reduce the soil-borne inoculum and disease caused by AG3 (Carling et al. 1986, Peters et al. 2003) but some AG3 isolates may survive longer periods of time in cool soils (Carling and Leiner 1990b). These findings are consistent with higher host species-specificity or host-dependency on potato exhibited by AG3 and a putatively lower ability of AG3 to survive as a saprophyte than other AGs (Carling et al. 1986, Sumner 1996). For example, AG5 and AG2-1 isolates occur in a broader range of crops and are important pathogens in legumes and turfgrass, and brassicas, respectively (Carling et al. 1986, Sneh et al. 1991, 1996, Valkonen et al. 1993). However, black scurf on seed potatoes AG3 is considered as the most important dispersal and survival mechanism of AG3 (van Emden et al. 1966, Cubeta and Vilgalys 1997, Ceresini et al. 2002, 2003) relatively short-living soilborne inoculum. However, black scurf on seed potatoes is considered as the most important dispersal and survival mechanism of AG3 (van Emden et al. 1966, Cubeta and Vilgalys 1997) as compared to its relatively short-living soilborne inoculum (Tsror and Perezt-Alon 2005). Hence, it seems that efficient formation of sclerotia on tubers and high host-specialization makes AG3 isolates superior on potato, a crop which is vegetatively propagated using tubers, whereas the isolates of other less-specialized anastomosis groups of *R. solani* infect potato as an alternative host and have not developed specialized strategies for this host.

Taken together, there are no previous studies comparing formation of black scurf by isolates of *R. solani* that belong to different AGs and infect potatoes in the Nordic countries. The data of this study indicate that the Finnish AG3 isolates are superior to those of AG2-1 and AG5 in formation

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of black scurf and thus also more likely to be efficiently spread with seed tubers. This is consistent with the fact that the great majority (98.9 %) of *R. solani* isolates infecting potato belong to AG3 in Finland (Ahvenniemi et al. 2006, 2009, Lehtonen et al. 2008a) and in other northern potato production areas as discussed above. The other AGs infect many host species and would therefore be expected to be more common also in potato unless the differences in their abilities to form black scurf on potato tubers played an important role in dispersal, survival and prevalence in potato crops.

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SELOSTUS

Erot kolmen Suomessa perunalla esiintyvän *Rhizoctonia solani*-sienen anastomoosiryhmän kyvyssä muodostaa seittirupea

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Perunaseittiä, versolaikkua ja seittirupea aiheuttava *Rhizoctonia solani*-sieni (seittisieni) on haitallisimpia perunan taudinaiheuttajia. Sen merkitys mukuloiden epämuotoisuuden ja lukuisten erilaisten pintavikojen aiheuttajana, kasvin mukuloiden kokojakauman hajonnan lisääjänä sekä kauppakuntoisen sadon vähentäjänä jäänyt vähälle huomiolle. Näitä kysymyksiä sekä perunaseitin torjuntaa on tutkittu tarkemmin Suomessa vasta äskettäin. Tulosten perusteella laadittiin seitintorjuntaohjeet koko perunasektorin yhteisenä ponnistuksena. Myös seittisienen geneettistä monimuotoisuutta tutkittiin ensimmäistä kertaa Suomessa. Tulokset paljastivat, että 98.9 % seittisienen isolaateista kuului geneettisesti määriteltyyn anastomoosiryhmään AG3, joka on perunaan erikoistunut.

Tämän tutkimuksen päätarkoituksena oli verrata perunasta eristettyjen AG3-ryhmän isolaattien ja perunalla harvinaisina esiintyvien AG2-1 ja AG5 -ryhmien isolaattien kykyä muodostaa seittirupea mukuloiden pinnalla. Tulokset osoittivat, että AG3-ryhmän isolaatit ovat ylivertaisen tehokkaita seittiruven muodostajia. Seittirupi eli seittisienen rihmastopahkat mukulan pinnalla säilyttävät sienen kasvukaudesta toiseen ja tarjoavat tehokkaan tavan seittisienen leviämiselle siemenperunoiden mukana. AG2-1 ja AG5 -ryhmien isolaateilla on laajempi isäntäkasvilajisto kuin AG3-ryhmän isolaateilla, mutta AG3:n tehokas seittiruven muodostus perunalla lienee yksi tärkeimmistä syistä AG3:n yleisyydelle perunalla niin Suomessa kuin muillakin perunantuotantoalueilla. Seittiruvettoman siemenperunan käyttö, tai vähäisesti seittirupisen siemenperunan peittaus, ovatkin tärkeitä seitintorjunnassa. Lisäksi perunan viljely korkeintaan kolmen vuoden välein samalla lohkolla estää maalevintäisen seitin (rihmastopahkojen) aiheuttamat satotappiot.