Rhizoctonia Disease of Potato: Effect on Yield and Control by Seed Tuber Treatment

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ABSTRACT

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Based on an individual plant sampling procedure, Rhizoctonia stem and stolon canker influenced the production of both marketable and cull tubers of *Solanum tuberosum*. As disease severity increased, there was a decrease in the percentage, by weight, of marketable tubers and a corresponding increase in the percentage of cull tubers. The disease was effectively controlled in commercial fields in Kern County, CA, by dipping seed tubers in a 2% solution of formaldehyde. The increase in percentage of marketable tubers that resulted from controlling stem and stolon canker by seed tuber treatment was consistent with predictions based on individual plant sampling data. The seed tuber treatment also resulted in a marked improvement in the appearance of progeny tubers. Disease control by seed tuber treatment and soil assay data provided evidence that the pathogen was not present in these soils and that lesions on plants from nontreated tubers developed from tuberborne inoculum. The pathogen was present in the soil in the Tulelake area, and seed tuber treatment did not control Rhizoctonia stem and stolon canker.

Stem and stolon canker of potato (*Solanum tuberosum* L.), caused by *Rhizoctonia solani* Kühn anastomosis group (AG) 3 (12), has been extensively investigated over a period of many years. This research has focused on several aspects of the disease, including the relationship between severity of stem and stolon canker and tuber yield, relative importance of tuberborne inoculum, seed tuber treatment for control of stem and stolon canker and of black scurf on progeny tubers, and variation in virulence among strains of the pathogen.

Although several workers have reported an increase in yield as a result of reducing stem and stolon canker, this effect was not consistently observed (1,3,7–10, 15,16). Others (5,11), however, have reported that there is no relationship between stem and stolon canker severity and yield. Also, there are some reports that the disease has an influence on the size distribution of progeny tubers (5,10).

The question of relative importance of tuberborne vs. soilborne inoculum has been addressed by several workers, particularly those investigating control by seed tuber treatment. There is good evidence for the importance of tuberborne inoculum (1–4,6,8,10,13–16), although some stem and stolon canker can result from infection from soilborne inoculum (2,6,8). It is clearly recognized that the virulence of *R. solani* isolates is highly variable and that strains that form sclerotia on tubers do not necessarily attack stem and stolon tissue (4).

The above-mentioned aspects of Rhizoctonia disease of potato are interrelated and cannot effectively be investigated separately. The impact of the disease on tuber production is a very important consideration in reaching decisions regarding disease management. To obtain information on this critical question, we initiated a study with the following objectives: a) determine the relationship between severity of stem and stolon canker and tuber yield, b) investigate the occurrence of the pathogen in field soils, and c) evaluate the effectiveness of seed tuber treatment for disease control. A brief summary of this work has been published (15).

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MATERIALS AND METHODS

Single-plant sampling to evaluate disease severity and tuber yield. This work was done in commercial fields of potato cultivar White Rose growing in Kern County, CA. At about 1–2 wk before harvest, sites were selected at random in fields with a history of Rhizoctonia stem and stolon canker. Fifteen to 25 plants were sampled from each site. During the 1975 and 1976 growing seasons, a total of 563 plants was evaluated from eight separate fields. Each individual plant, originating from a single seed piece, was hand dug, and all tubers produced by the plant were recovered. Each plant was assessed for disease severity.

Disease severity was expressed as the Rhizoctonia stem lesion index (RSI). Stolon damage was not considered because previous work (*unpublished*) had shown a positive correlation between RSI and percentage of stolons with *Rhizoctonia* lesions ($r = 0.99$, significant at $P = 0.01$). To obtain the RSI, each stem (average of 2.57 per plant) was evaluated separately and placed in one of the following classes: 0, trace to 5, 6–25, 26–50, 51–75, and more than 75% of belowground stem surface area covered by lesions. Assignment to a class was based on visual estimation. The number of stems in each class was multiplied by the midpoint of the class, and the sum of all values thus obtained was divided by the total number of stems to give the RSI for that plant.

The tubers from each plant were graded as follows: tubers larger than 4.8 cm in diameter and of commercially acceptable type (US #1 and #2 grades) = marketable, tubers less than 4.8 cm in diameter = small, and tubers that were misshapen or exhibited growth cracks = cull.

The RSI data for all plants sampled were subjected to regression analysis using the product moment method (*classified data*). The points on Figure 1 are the mean values for the plants in each RSI class. The regression lines were calculated using the following formulas: marketable tuber, $y = 82.7 - 0.236x$; culls, $y = 11.4 + 0.191x$; small, $y = 8.6 + 0.032x$.

Seed piece treatment. Preliminary work involved laboratory testing of available disinfestants to determine their efficacy in killing *Rhizoctonia* sclerotia on tubers. Of the materials tested, including sodium hypochlorite and several quaternary ammonium compounds, only formaldehyde was effective. Dipping tubers in 1 or 2% a.i. solutions of formaldehyde for 5 min killed all of the sclerotia. With a 0.5% solution, large sclerotia occasionally survived the treatment. For field trials, whole tubers were dipped in 2% a.i. formaldehyde for 5 min and allowed to dry under ambient conditions. In preliminary trials, check tubers were dipped in water, but this had no effect and was discontinued. Temperature did not influence the effectiveness of the treatment, within the range of 15–22 C.

To avoid damage, it was critical that the treatment be applied to whole tubers that are dormant. Cut seed pieces were damaged by formaldehyde, resulting in delayed and erratic emergence. We also evaluated other materials, including captan [*N*-(trichloromethyl thio)-4-cyclohexene-1,2-dicarboximide] and benomyl [methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate].

Trials in Kern County were done in commercial potato fields and those at Tulelake were done at the University of California Field Station. In Kern County, treated tubers were planted in blocks ranging from 4 to 16 rows and adjacent to nontreated seed at several locations in each field. At intervals during the growing season, plants were sampled and the RSI was determined. Yield data were obtained by the individual plant sampling procedure or by collecting all tubers from 2.5-m portions of two adjacent rows at harvest. These samples were graded into marketable, small, and cull tubers. In one field trial, one 1.0-ha block planted with treated tubers and another with nontreated tubers were compared by commercial harvesting and grading. The Tulelake plots were arranged in a randomized block design. Each block ranged from one to four rows 16.5–33 m in length. RSI was determined during the growing season, and tubers were harvested and graded.

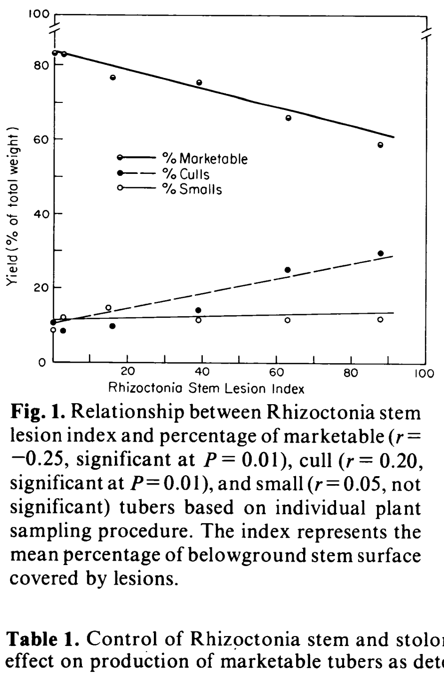

Fig. 1. Relationship between Rhizoctonia stem lesion index and percentage of marketable ($r = -0.25$, significant at $P = 0.01$), cull ($r = 0.20$, significant at $P = 0.01$), and small ($r = 0.05$, not significant) tubers based on individual plant sampling procedure. The index represents the mean percentage of belowground stem surface covered by lesions.

Source of *R. solani* AG 3 inoculum: Soil vs. tubers. A soil-sieving procedure (14) developed for *R. solani* AG 4 was used to assay soils for the presence of *R. solani* AG 3. The method is less satisfactory for AG 3 than for AG 4, but the *Rhizoctonia* affecting potato can be isolated by the procedure, and this provides some information on whether or not the pathogen is present in a soil. Soil samples from a total of 44 fields in five potato-growing areas in California were assayed. Twenty-three fields were located in Kern County, the major potato-growing area in the state; 12 in the Tulelake area; 4 in the Stockton Delta; 3 in the Santa Maria area; and 2 in the Salinas Valley.

In addition, soils from Kern County and Tulelake were bioassayed for the presence of *R. solani* AG 3 by growing potatoes in them in the greenhouse. Four 20-cm pots with three seed pieces per pot were planted for each soil.

To evaluate the relationship between the amount of sclerotia on seed tubers and subsequent development of stem and stolon canker, a procedure to assess sclerotial inoculum was required. A template divided into 1-cm^2 grids was used to estimate the number of square centimeters of tuber surface that contained one or more sclerotia. Twenty-five tubers from each seed source were evaluated. The sclerotial index (SI) is the average percentage of square centimeters containing visible sclerotia.

In 1978 and 1979, a number of seed lots were sampled and the SI was determined. The tubers were planted at various locations in Kern County, and during the growing season plants were sampled and the RSI was determined. In 1979, a portion of each seed lot was treated with 2% a.i. formaldehyde so that a comparison could be made between treated and nontreated tubers.

RESULTS

Relationship between stem and stolon canker and tuber yield. There was a relationship between Rhizoctonia stem lesion index and both marketable and cull tubers (Fig. 1). As disease severity increased, the percentage by weight of marketable tubers decreased ($r = -0.25$, significant at $P = 0.01$). For example, the mean percentage of marketable tubers from plants in RSI class interval 0–6 was 81, compared with 65% from plants with an RSI ranging from 66 to 88. There was a corresponding increase in the percentage of cull tubers as disease increased ($r = 0.20$, significant at $P = 0.01$). *R. solani* did not affect the yield of small tubers.

Seed tuber treatment to control *R. solani* and its effect on tuber yield and appearance. In Kern County, treating seed tubers with formaldehyde resulted in almost complete elimination of stem and stolon lesions (Tables 1–3). The data presented in the tables were obtained over a period of 5 yr and involved six field trials. When the data were combined, the mean RSI for plants grown from treated seed tubers was 1.3 compared with 15.0 for plants grown from untreated tubers. In one trial (Table 3), benomyl appreciably reduced stem and stolon lesions, but captan was ineffective in controlling the disease. In Tulelake, seed tuber treatment had little effect on the incidence of stem and stolon lesions. In two tests, the RSI values for plants from treated tubers were 15 and 14, compared with 24 and 20 for plants from nontreated tubers. This

Table 1. Control of Rhizoctonia stem and stolon canker on White Rose cultivar in commercial fields in Kern County by seed tuber treatment and effect on production of marketable tubers as determined by individual plant sampling prior to harvest

Treatment	Rate	Mean Rhizoctonia stem lesion index[a]: Early April	Mid-April	Early June	Yield: Total (mean kg/ 25 plants)	Percentage of total: Marketable	Small	Cull
				1976[b]				
Formaldehyde	2% a.i., 5 min dip	···	0.4 ± 0.2	0.3 ± 0.2	30.0 ± 1.6	85 ± 0.04	4 ± 0.01	11 ± 0.05
None	···	···	6.0 ± 2.0	19.0 ± 1.7	30.7 ± 1.4	83 ± 0.1	5 ± 0.1	12 ± 0.1
				1977[c]				
Formaldehyde	2% a.i., 5 min dip	2.2 ± 0.7	1.0 ± 0.6	6.0 ± 0.7	34.1 ± 1.6	89 ± 1.8	6 ± 0.9	5 ± 1.7
None	···	1.5 ± 0.7	21.5 ± 3.0	25.1 ± 4	33.5 ± 2.3	84 ± 3.5	6 ± 0.7	10 ± 3.8

[a] Mean percentage of stem surface covered by lesions.

[b] Tubers treated 10 January. Field planted 26 February and harvested 16 June. Each value is the mean of three 20-plant samples. Standard error is indicated.

[c] Tuber treated 20 January. Field planted 22 February and harvested 12 July. Each value is the mean of four 25-plant samples. Standard error is indicated.

confirms the soil assay data showing that the pathogen was present in the soil in Tulelake.

In five field trials in Kern County where yield data were obtained, the increase in percentage of marketable tubers resulting from reducing stem and stolon lesions was very close to what would be predicted based on the individual plant sampling data (Tables 1–3). The mean RSI for plants from nontreated tubers in these trials was 13.4. Based on the individual plant sampling data, controlling this level of disease should result in a 4% increase in marketable tubers. The mean increase in marketable tubers in the field trials was 4.6%. Furthermore, the mean decrease in cull tubers as a result of seed tuber treatment was 4.8%.

A potentially important and completely unexpected benefit of seed tuber treatment with formaldehyde was a definite improvement in the appearance of progeny tubers. The formaldehyde treatment resulted in a lighter color of the skin and in fewer discolored lenticels. The effect was most striking with tubers that had growth cracks. Cracks on tubers from treated seed tended to be white and smooth, whereas those on tubers from nontreated seed were often dark brown and rough. Samples of 80 tubers with growth cracks were collected at harvest from a seed tuber treatment trial in Kern County. Of those from plots where the seed tubers had been treated with 2% a.i. formaldehyde, 73% of the cracks were white and smooth, compared with 53% when the seed tuber had not been treated.

Source of *R. solani* AG 3 inoculum: Soil vs. tubers. *R. solani* AG 3 was isolated from five fields in the Tulelake area, but it was not detected in soil collected from any of the other 39 fields. Rhizoctonia lesions developed on plants grown in Tulelake soil from which the pathogen had been isolated. There was no infection of plants growing in soil from Kern County.

In 1978, a comparison was made between the amount of sclerotia on seed tubers and subsequent stem and stolon canker severity. Eleven seed lots, including four cultivars (Red La Soda, Kennebec, Centennial, and White Rose) were sampled. The sclerotial index ranged from 0.1 to 55. There was a significant correlation between SI and RSI ($r = 0.63$, $P = 0.05$). In 1979, a total of 15 seed lots was evaluated. The sclerotia index ranged from 0 to 26, and the RSI for plants from untreated tubers ranged from 0 to 15.7. The correlation coefficient was 0.49 (significant at $P = 0.05$). In all cases, treating the seed with formaldehyde controlled the disease. The mean RSI for plants from treated tubers was 0.2.

DISCUSSION

Evidence obtained from single-plant sampling and from field evaluation of seed tuber treatments showed that stem and stolon canker had a definite impact on tuber development. The most consistent effect was on the percentage of marketable tubers. The individual plant sampling data revealed a close relationship between severity of stem and stolon canker and production of marketable tubers. As disease severity increased, the percentage of marketable tubers decreased and the percentage of cull tubers increased. Stem and stolon canker had little effect on total yield or on the percentage of small tubers.

The results from this study may explain why previous workers did not find a consistent relationship between Rhizoctonia stem and stolon canker and

Table 2. Control of Rhizoctonia stem and stolon canker on White Rose cultivar by seed tuber treatment and effect on production of marketable tubers as determined by commercial harvest and grading in Kern County[a]

			Yield					
			Total	Percentage of total			Increase in	
Treatment	**Rate**	**Mean RSI[b]**	**(metric tons/ha)**	**Marketable**	**Small**	**Cull**	**marketable tubers (%)**	**Predicted increase (%)[c]**
Formaldehyde	2% a.i., 5 min dip	1.3	65.3	85	6	9	7	4
None	···	11.2	63.7	78	6	16	···	···

[a]Two 1.0-ha blocks were compared. One block was planted with treated and one with nontreated seed tubers.
[b]Rhizoctonia stem lesion index; mean percentage of stem surface covered by lesions.
[c]Based on individual plant sampling data presented in Figure 1.

Table. 3. Control of Rhizoctonia stem and stolon canker on White Rose cultivar in commercial fields in Kern County by seed tuber treatment and effect on marketable tubers as determined by sampling during harvest

			Yield					
			Total	Percentage of total			Increase in	
Treatment	**Rate (a.i.)[a]**	**Mean RSI[b]**	**(mean kg/5 m of row)**	**Marketable**	**Small**	**Cull**	**marketable tubers (%)**	**Predicted increase (%)[c]**
				1979[d]				
Formaldehyde	2.0%	0.1 ± 0.01	23.8 ± 0.6	85	4	11	4	4
Benomyl	0.45 kg/45 kg	5.0 ± 2.1	27.4 ± 0.3	80	4	16	0	
Captan	0.34 kg/45 kg	13.9 ± 3.0	24.3 ± 1.7	77	6	17	0	
None	···	15.8 ± 3.3	23.9 ± 0.5	81	6	13	···	
				1980: Field A[e]				
Formaldehyde	0.5%	0	25.2 ± 0.5	83	8	9	5	
Formaldehyde	1.0%	0	25.2 ± 0.5	84	8	8	6	
Formaldehyde	2.0%	0	26.6 ± 0.8	83	9	8	5	2
None	···	6.0 ± 5.0	25.4 ± 0.8	78	6	16	···	
				1980: Field B[e]				
Formaldehyde	0.5%	0	22.4 ± 0.4	90	7	3	2	
Formaldehyde	1.0%	0	23.0 ± 0.3	92	6	2	4	
Formaldehyde	2.0%	0	22.7 ± 0.6	90	7	3	2	4
None	···	12.4 ± 2.5	22.0 ± 0.3	88	7	5	···	

[a]Tubers were dipped in formaldehyde solution for 5 min and allowed to air-dry. Benomyl was used as 2.5% dust; captan was used as 10% dust.
[b]Rhizoctonia stem lesion index; mean percentage of stem surface covered by lesions. Each value is the average of three 15-plant samples. Standard error is indicated.
[c]Based on individual plant sampling data presented in Figure 1.
[d]Yield data based on six replicates.
[e]1980 trials were in two fields planted with different seed lots. Yield data from field A were based on six replicates; those from field B were based on nine replicates.

tuber yield (3,7–10,15,16). Two points appear to be particularly noteworthy. First, the primary effect of *R. solani* AG 3 appears to be on the relative distribution between marketable and cull tubers, not on total yield. Although there are reports that control of stem and stolon canker resulted in increased yield, this effect was not consistent and may have been the result of other factors. Also, several variables, including cultural conditions, the environment, and time of infection, may influence whether the disease will affect total yield. Second, the magnitude of the impact of Rhizoctonia stem and stolon canker is not large. The occurrence and distribution of the disease in commercial fields is variable, and the RSI seldom exceeds 30–40. Based on the single-plant data (Fig. 1), this would not be expected to reduce the percentage of marketable tubers by more than 8–10%. This, however, may be economically significant.

The effect of *R. solani* AG 3 on potato yield observed in this study was on plants that grew to maturity and does not take into consideration losses due to poor stand establishment that may occur in some potato-growing areas. It seems likely that the effects of this disease have not generally been recognized because attention has focused on total yield rather than percentage of marketable tubers and because the magnitude of loss is such that it is frequently obscured by the many sources of variation inherent in field studies.

In recent studies, researchers have become increasingly aware of the importance of both soilborne and tuberborne inoculum. Several authors concluded that tuberborne inoculum was most important (3,8,10,13–15). Frank and Leach (6) made a comparative study and found that both sources of the fungus are important in the development of the Rhizoctonia disease of potato. In reviewing the literature and evaluating our own investigation, we find that a very important consideration is whether the pathogen can become established and persist in a given field soil. It is not uncommon for *R. solani* AG 3 to be absent from soil even though it has been introduced many times. For example, in Kern County, the major potato-growing area in the state, we have never found the fungus to be present in the soil. The best evidence for its absence is the consistently effective control obtained by seed tuber treatments to eliminate tuberborne inoculum.

Additional evidence for the importance of tuber inoculum in these situations was the positive correlation between the amount of sclerotia on seed tubers and the incidence of stem and stolon canker. The success of seed tuber treatments in other areas of the world indicated that the fungus is not present in these soils (2,3,15). It is of practical and scientific interest that the pathogen does survive in some soils. In these situations, such as Tulelake, very severe disease can result from soilborne inoculum. In determining approaches to control this disease, it is essential to know whether soilborne inoculum is a factor in disease development.

In view of the fact that the potato *Rhizoctonia* AG 3 does not occur in most soils in Kern County, seed tuber treatments provide an effective method of preventive disease control for growers in this region. In our studies on seed tuber treatment, the relationship between stem and stolon canker severity and percentage of marketable tubers was consistent with the results from our single-plant sampling study. This confirms the conclusion that controlling the pathogen will provide a relatively small but economically important increase in marketable tubers.

LITERATURE CITED

1. Banville, G. J. 1978. Studies on the Rhizoctonia disease of potatoes. Am. Potato J. 55:56.
2. Biehn, W. L. 1969. Evaluation of seed and soil treatments for control of Rhizoctonia scurf and Verticillium wilt of potato. Plant Dis. Rep. 53:425-428.
3. Bolkan, H. A. 1976. Seed tuber treatment for the control of black scurf of potatoes. N.Z. J. Exp. Agric. 4:337-361.
4. Bolkan, H. A., and Wenham, H. T. 1973. Pathogenicity of potato sclerotial isolates of *Rhizoctonia solani* to potato shoots. N.Z. J. Exp. Agric. 1:383-385.
5. Davis, J. R., and Groskopp, M. D. 1979. Influences of the Rhizoctonia disease on production of the Russett Burbank potato. Am. Potato J. 56:253-264.
6. Frank, J. A., and Leach, S. S. 1980. Comparison of tuberborne and soilborne inoculum of the Rhizoctonia disease of potato. Phytopathology 70:51-53.
7. Hide, G. A., and Bell, F. 1978. Healthier seed potatoes. I. Effects of inoculating stem cutting stocks with *Polyscytalum pustulans* and *Rhizoctonia solani* on growth, yield and disease. Ann. Appl. Biol. 90:417-426.
8. Hide, G. A., and Bell, F. 1978. Healthier seed potatoes. II. Effects of sprouting and benomyl treatment of stem cutting and commercial stocks on growth, yield and disease. Ann. Appl. Biol. 90:427-436.
9. Hide, G. A., and Bell, F. 1980. Effects of treating seed potatoes from commercial and stem cutting stocks with benomyl, thiabendazole and 2-aminobutane on yield and disease. Ann. Appl. Biol. 94:205-214.
10. Hide, G. A., Hirst, J. M., and Stedman, O. J. 1973. Effects of black scurf (*Rhizoctonia solani*) on potatoes. Ann. Appl. Biol. 74:139-148.
11. James, W. C., and McKenzie, A. R. 1972. The effect of tuberborne sclerotia of *Rhizoctonia solani* Kuhn on the potato crop. Am. Potato J. 49:296-301.
12. Parmeter, J. R., Jr., Sherwood, R. T., and Platt, W. D. 1969. Anastomosis grouping among isolates of *Thanathephorus cucumeris*. Phytopathology 59:1270-1278.
13. Van Emden, J. H. 1965. *Rhizoctonia solani*: Results of recent experiments. Eur. Potato J. 8:188-189.
14. Weinhold, A. R. 1977. Population of *Rhizoctonia solani* in agricultural soils determined by a screening procedure. Phytopathology 67:566-569.
15. Weinhold, A. R., Bowman, T., and Hall, D. H. 1978. Rhizoctonia disease of potatoes in California. Am. Potato J. 55:56-57.
16. Wilson, G. J. 1974. *Rhizoctonia solani* control and effects on potato yield. N.Z. J. Exp. Agric. 2:265-267.