EFFORTS TO CONTROL SHALLOW AND DEEP-PITTED SCAB [1/]

by
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SUMMARY

Heavy sprinkler irrigation reduced shallow but not deep-pitted scab. Neither ammonium sulfate fertilizer alone or coated with N-Serve® nor incorporated straw controlled either type of scab.

Terraclor® reduced deep-pitted but not shallow scab near Eureka, Wa., and reduced shallow scab near Ruff, Wa. Contrary to previous reports for control of shallow scab, heavy sprinkler irrigation with a Terraclor treatment did not increase scab control.

Nitro-sul®, Thio-sul®, That® sulfur and Echol West Micronized Soil Sulfur reduced deep-pitted but not shallow scab on the Russet Burbank cultivar. None controlled scab on the very susceptible Kennebec cultivar. Popcorn® sulfur gave no scab control and it decreased yield. That sulfur and Echol West's Micronized Soil Sulfur caused an epidermal blackening and reduced netting on Russet Burbank tubers.

None of the cultural and/or chemical treatments reduced deep-pitted scab sufficiently that tubers would pass U.S. grade standards.

INTRODUCTION

Common or shallow scab is caused by Streptomyces scabies (Thaxter) Waksman and Henrici (35). Deep-pitted scab has been reported to be caused by a severe reaction to S. scabies or to other Streptomyces spp. (1, 4, 20, 24, 29). Larvae of the scab gnat, Pnyxia scabiei (Hopkins) had been thought to be one of the causal factors in deep-pitted scab (11, 30, 37). In 1973 only 6 scab gnat larvae were found in 96 deep-pitted scab lesions examined from our experimental plot near Eureka, Wa. (personal communication, L. Fox, Entomology Research Division, Agr. Res. Serv., USDA, Yakima, Wa). Recent work by Tamaki, et al. (31) showed that scab gnat feeds only on fungus debris in deep-pitted scab lesions. Recently we found that heat-pasteurized soil artificially infected with S. cinerochromogenes (Miyari and Takashima) Shshimizu & Sakai, S. mirabilis Rushmann, S. resistomycificus Lindenbein & Olfermann, and other unidentified Streptomyces spp. from deep-pitted scab lesions, caused severe deep-pitted scab on the Kennebec cultivar (Archuleta and Easton, unpublished data). S. scabies ATCC 3352 caused a few deep-pitted lesions in over 40% of the Kennebec tubers.

1/ This investigation was made possible through grants and/or chemicals supplied by the Washington State Potato Commission, Chevron Chemical Company, Collier Carbon and Chemical Company, Dow Chemical Company, Echol West, Kerley Chemical Corporation, and Olin Agricultural Division. K2H Farm and Sunspiced, Incorporated, furnished land, fertilizer, potato seed, a solid set sprinkler system, irrigation water, planted potato seed, did most of the normal cultural operations and furnished personnel to apply the rates of irrigation. The USDA Entomology Investigations Laboratory, Yakima, Wa. furnished personnel to assay tubers for scab gnat larvae and furnished vehicle for summer worker to apply the rates of irrigation in 1974. Mention of a product used in these studies does not constitute a recommendation of the product by WSU over other products. Information paper. Project 1709. Agricultural Research Center, College of Agriculture, Washington State University.

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Photographs by Arthur (2) clearly show deep-pitted scab on tubers of a Russet potato as early as 1897 in Indiana. Landis et al. (16) reported the first deep-pitted scab in Washington on the White Rose cultivar near Toppenish, Wa. in 1948. In 1970 fields of Russet Burbank and Norgold Russet cultivars near Eureka, Wa. developed severe deep-pitted scab. In 1978 tubers with deep-pitted scab were brought into our laboratory from several large fields in Franklin County, Washington, and in a field near Hermiston, Or. Since its first reporting, over 6000 acres have been removed from potato production due to deep-pitted scab.

Maintaining high soil moisture prior to tuberization and for 4 to 6 weeks following tuberization reduced shallow scab but not enough to meet U.S. No. 1 grade standards (8, 17, 18, 19, 27, 28). Only high soil moisture plus either sulfur dust (600 lb/a, applied to the open row at planting) or Terraclor® (25 lb ai/a incorporated preplant into infected soil) have yielded tubers of acceptable U.S. No. 1 grade (8). It has been theorized that soil moisture inhibits common scab by promoting a multiplication of bacteria that are antagonistic to S. scabies (21). Lenticles on young tubers apparently are more readily infected under low moisture conditions, but become resistant as they age (14, 15).

In earlier studies we found no control of deep-pitted scab with Telone C (1, 3-dichloropropene and related chlorinated aliphatics) + chloropicrin (16). Various soil applied chemicals such as Difolatan® (22), sulfur (9, 34), Terraclor (8, 22) and urea formaldehyde (2, 5, 6, 26, 36) have controlled shallow scab.

Applying ammonium sulfate rather than ammonium nitrate and the application of a nitrifying inhibitor, N-Serve®, to ammonium sulfate was reported to control shallow scab (13). However, Davis (8) found N-Serve actually caused an increase in shallow scab.

The general misconception is that massive doses of sulfur applied to calcareous soils will lower the pH and control common scab. However, Terman et al. (33) found that 2000 lb/a of sulfur applied to acid soils reduced the pH 1 pH unit at the most. Sulfur applied to a calcareous soil at 600 lb/a changed the pH only 0.1 to 0.4 units (9). Vlitos and Hooker (34) considered sulfur might be providing biological rather than fungicidal control since it expressed no fungicidal action on S. scabies in laboratory tests. It seemed to increase bacterial populations in field soil which in turn might inhibit S. scabies.

Increasing calcium levels in soil increased shallow scab (12). Tuber peels of severely scabbed tubers were found to be high in calcium (10). Control treatments which reduced shallow scab also lessened calcium in tuber peels (10). This suggests but does not prove that calcium in the tuber peel controls susceptibility to scab.

We began work in 1972 to examine various chemical and cultural methods for control of shallow and deep-pitted scab. This is a study of the serious disease that has now eliminated from production about 5% of the land in Washington that is suitable for potato growing.

METHODS AND MATERIALS

Infested soil from a field near Eureka, Wa. was used in greenhouse and field experiments from 1973 to 1978. Russet Burbank cultivar grown in this field in 1970 and in subsequent years had deep-pitted scab. This is a fine sandy loam soil of the Ritzville series (25). One-half of our 8-acre experimental field, that had been cropped to potatoes 2 years previously, was infested with scab in both 1973 and 1974 by spreading 1/8 to 1/4 inch of scab infested soil from the Eureka, Wa. field by dump truck, and then incorporating by plowing 12 inches in depth.

Irrigation was by a solid set system in 1973, 1974, 1975, 1976 (Tables 1, 2, 3, 4, and 5) and 1977 (Table 8, common scab, Ruff, Wa.). A center pivot system with a supplemental solid set system installed within tower wheels of the center pivot system water the plot in 1977 and 1978 (Tables 7 and 9).

In 1973, water was applied after 20, 50 and 80% of available soil moisture had been evapotranspired according to nearby evaporation pan readings and soil moisture determinations (oven dry weights) of soil at 1- and 2-ft levels (Table 1). In 1975 and 1976 (Tables 4 and 5) irrigation rates were calculated from water collected by catch bottles in each plot. In 1977 (Table 8) rates were based on orifice diameter, irrigation time and water pressure. Amount of irrigation needed was determined every 2 to 3 days based on pan evaporation, soil moisture (oven dry weights) and soil tensiometer readings.

Chemicals evaluated for scab control were applied in various ways. The Collier Carbon Popcorn ^{R} sulfur was sidedressed 5 inches to each side of recently emerged potato plants. Difolatan 4F and Terraclor 2EC were sprayed over the surface of plowed soil in 26 gal of water/a followed by immediate rototilling 6 to 8 inches in depth. Nitro-sul ^{R} and Thio-sul ^{R} were applied the same way but not diluted. In 1978, Thio-sul was sprayed in a 12-inch band, either over soil surface with no incorporation where the row was to be planted, or was sprayed over the row after planting and herbicide incorporation, but prior to emergence. That ^{R} sulfur and Echol West's Micronized Soil Sulfur (MSS) were sprayed in the open furrow in a 12-inch band in 200 gal water/a at planting.

In 1975 N-serve 3 lb ai/a was sprayed on ammonium sulfate fertilizer (to be applied at 400 lb N/a) in a cement mixer and stored in closed 20-gal metal drums for 4 days until application (Table 4). The N-serve coated fertilizer was top dressed in two bands over hills of non-emerged plants and incorporated within 15 minutes after application with a Lilliston ^{R} cultivator traveling 4 mph. Other plots received only 400 lb N/a (ammonium sulfate) top dressed and incorporated over hills.

In the 1977 greenhouse experiments (Table 6) Difolatan 4F and Terraclor 2EC were added to scab-infested soil and mixed thoroughly in a poly bag by hand before putting into 10-inch pots. Thio-sul and Nitro-sul were injected by a syringe into the center of each pot of infested, previously fertilized soil with 800 lb N/a (ammonium sulfate), 100 lb P/a (treble superphosphate), 250 lb K/a (potassium chloride) and 10 lb Zn/a. Finely chopped wheat straw had been thoroughly mixed into the infested soil prior to chemical treatments. Each 10-inch pot was planted with untreated Russet Burbank seed-pieces 3 days after chemical application. The weight of tubers with shallow and/or deep-pitted scab were recorded 4 months after planting. Each treatment was replicated 9 times.

In field experiments in 1977 (Tables 7 and 8) loose, unchopped straw was scattered by hand over the soil surface of plots and incorporated 6 to 8 inches in depth by rototilling twice.

Plots of all field experiments were four rows wide (12 ft.) by 20 ft. in length. Chemical, straw, and N-serve treatments were randomly replicated 4 to 10 times and rates of irrigation were randomly replicated 4 times. Russet Burbank was the cultivar used in all experiments except Kennebec was included in 1978. Field experiments were planted in April or early May and harvested in September or early October.

Weights of tubers with shallow scab, deep-pitted scab, % U.S. No. 1 grade tubers and total yield were recorded from a 20-ft row of each treatment.

RESULTS

Incorporating scab-infested soil into a nearby soil resulted in a significant increase in deep-pitted scab in 1973, but not in 1974 (Tables 1 and 3). Shallow scab was increased in 1974 but not in 1973. The non-infested soil produced only a small amount of scab even after four consecutive crops of potatoes. No tubers had enough scab to be rejected by U.S. Grade Standards.

Rate of irrigation had no effect on deep-pitted scab (Tables 1 and 4). However, tubers at the highest rate of water usually had significantly less common scab, more U.S. No. 1 tubers, and a higher yield than the lowest rate of water (Tables 4, 5 and 8).

Terraclor (50 lb ai/a) did not control either shallow or deep-pitted scab in greenhouse tests (Table 6), but it reduced shallow scab in the field near Ruff, Wa. when applied at 25 lb ai/a under the lowest irrigation rate (Table 8). It did not reduce shallow scab significantly in 1975, 1976 or 1977 near Eureka, Wa. (Tables 4, 5 and 7). Deep-pitted scab was reduced by Terraclor in field tests in 1975 and 1977 (Tables 4 and 7).

N-Serve coated on ammonium sulfate fertilizer did not reduce shallow or deep-pitted scab or affect production in the field (Table 4).

In the greenhouse, incorporated chopped straw at 10 and 30 ton/a reduced shallow and deep-pitted scab (Table 6). However, 6 ton/a of incorporated unchopped straw gave no control of either scab in the field (Tables 7 and 8).

Nitro-sul at 800 lb/a sulfur did not reduce shallow scab in the greenhouse but significantly reduced deep-pitted scab at 400 lb/a, but not at 800 lb/a, sulfur rates in the field (Tables 6 and 7). Thio-sul injected into scab-infested soil at 800 lb/a sulfur eliminated both types of scab in greenhouse tests (Table 6). It also reduced deep-pitted, but not shallow scab, in the field at the 800 lb/a sulfur rate in 1977 (Table 7). In 1978, Thio-sul gave no control at the 287 and 500 lb/a sulfur rates (Table 9). Neither That sulfur nor Micronized Soil Sulfur (MSS) reduced shallow scab on Kennebec or Russet Burbank nor deep-pitted scab on Kennebec (Table 9). In the 1978 tests, That sulfur at 208 and 416 lb/a, but not at 832 lb/a, sulfur rates, and MSS at 800 lb/a, but not at 400 lb/a sulfur rates, reduced deep-pitted scab on Russet Burbank. However, epidermal blackening and reduced netting on Russet Burbank occurred with these products. "Popcorn" sulfur at 800 lb/a sulfur did not control either scab in 1974 (data now shown) or in 1975 (Table 4), and it decreased yield over 70 cwt/a (Table 2).

DISCUSSION

Very little deep-pitted scab developed in our own experimental field even after scab-by soil was incorporated in two separate years and four consecutive croppings of potatoes (Tables 1 and 3). We have also observed several fields or parts of fields where deep-pitted scab has not occurred even after 3 to 4 cropping of potatoes. Possibly a natural soil suppressive factor is present in these soils which inhibits multiplication or survival of pathogenic Streptomyces spp. Menzies (23) reported biological factors which inhibited common scab in old soils cropped for 50 years or more, but he was not able to find these factors in newly farmed soils. Whether or not pathogenic Streptomyces spp. were present in these old soils was not reported. Factors suppressive to take-all disease of wheat appeared in soils after only 3 to 10 years of consecutive dryland wheat (R. J. Cook, 1978 report W-147 Regional Project) (3).

A factor which may confuse soil suppressive studies is the potato cultivar. Russet Burbank, our most commonly grown variety, is quite resistant to common scab and moderately susceptible to deep-pitted scab (32) (Table 9). Potato lines tested in the field near Eureka, Wa. in 1977 and 1978 varied from severe deep-pitted scab to no scab (M. Martin, personal communication). Therefore, lack of scab may be due to a varietal resistance rather than soil suppression. In the future, both soil suppression factors and varietal resistance should be investigated as means of control.

The shallow and deep-pitted scab near Eureka, Wa. appears different from shallow scab in areas such as the United Kingdom (17, 18, 19) and Idaho (8, 9, 10). Not only are symptoms different, but measures used for shallow scab control such as ammonium sulfate fertilizer (13), N-Serve coated ammonium sulfate (13), higher rates of irrigation prior to and following tuberization (8, 17, 18, 19) and chemicals such as Terraclor (8, 22) and sulfur (9, 34) either gave no control or inadequate control in Washington fields. Principles that normally applied to shallow scab did not apply to our deep-pitted scab problem near Eureka, Wa.

Supposedly, bacterial flora multiply during periods of high soil moisture around developing tubers and inhibit Streptomyces spp. thus reducing common scab (7). Either these bacteria have no inhibitory affect or do not exist in Washington soils because high moisture did not effectively reduce deep-pitted scab (Table 4).

Straw incorporated into soil in greenhouse and field gave a varied control of shallow and deep-pitted scab (Tables 7 and 8). Studies should be conducted to determine whether the straw incorporated into soil for 30 years or more in dryland wheat near Warden, Wa. will allow scab development when the land becomes irrigated by the East High Canal.

Unfortunately, the only sure control we have for shallow and deep-pitted scab in Washington is to never grow potatoes in these infected areas. Chemical controls are not adequate. The only promising controls of the future lie in the development of resistant potato cultivars or isolation and utilization of natural factors of the soil which suppress potato scab.

LITERATURE CITED

1. Afanasiev, M. M. 1937. Comparative physiology of Actinomyces in relation to potato scab. Nebr. Agric. Sta. Res. Bul. 92.

2. Arthur, J. C. 1897. Formalin for prevention of potato scab. Purdue Univ. Agr. Exp. Sta. Bul. 65. 36 pp.

3. Baker, K. F. and R. J. Cook. 1974. Biological control of plant pathogens. In Chapter 4, pp. 61-106. W. H. Freeman, San Francisco. 433 pp.

4. Bruyen, H. L. 1939. Investigation of certain Actinomyces that cause potato scab. Tijdschr. Plantinziekten. 45:133-156.

5. Bush, L. V. and G. C. Ashton. 1964. Chemical control of common scab of potato. Amer. Potato J. 41:92-94.

6. Cetas, R. C. and R. L. Sawyer. 1962. Evaluation of Uracide for control of common scab of potatoes on Long Island. Amer. Potato J. 39:456-459.

7. Conn, H. J. 1932. A microscopic study of certain changes in the microflora of the soil. New York (Geneva) Agr. Exp. Sta. Tech. Bul. 204.

8. Davis, J. R., G. M. McMaster, R. H. Callihan, J. G. Garner and R. E. McDone. 1974. The relationship of irrigation timing and soil treatments to control potato scab. Phytopathology 64:1404-1410.

9. Davis, J. R., J. G. Garner and R. H. Callihan. 1974. Effects of gypsum, sulfur, Terraclor and Terraclor Super-X for scab control. Amer. Potato J. 51:35-43.

10. Davis, J. R., R. E. McDole and R. H. Callihan. 1976. Fertilizer effects on common scab of potato and the relation of calcium and phosphate-phosphorus. Phytopathology 66:1236-1241.

11. Gui, H. L. 1928. The potato scab gnat. Proc. 13th Ann. Meeting Ohio Veg. Grow. Assoc. 24-32.

12. Horsfall, J. S., J. B. Hollis and H. G. M. Jacobson. 1954. Calcium and potato scab. Phytopathology 44:19-24.

13. Huber, D. M. and R. D. Watson. 1970. Effect of organic amendment on soil-borne plant pathogens. Phytopathology 60:22-26.

14. Jones, A. P. 1931. The histology of potato scab. Ann. Appl. Biol. 18:313-333.

15. Labruyere, R. E. 1971. Common scab and its control of seed potato crops. Versl. landbouwk. Onderz. Ned. No. 767. 71 pp.

16. Landis, B. J., G. D. Easton, L. Fox, M. E. Nagle and D. L. Bailey. 1972. Trials with chemicals for control of common scab and potato scab gnat on Russet Burbank potatoes. 11th Annu. Washington State Potato Conf. 99-104. Washington State Potato Commission, Moses Lake, Wa.

17. Lapwood, D. H. 1967. Observations on the timing of irrigation and the incidence of potato common scab (Streptomyces scabies). Plant Pathology 16:131-135.

18. Lapwood, D. H., L. W. Wellings and W. R. Rosser. 1970. The control of common scab of potatoes by irrigation. Ann. Appl. Biol. 66:397-405.

19. Lapwood, D. H. and M. J. Adams. 1973. The effect of a few days rain on the distribution of common scab (Streptomyces scabies) on young potato tubers. Ann. Appl. Biol. 73:277-283.

20. Leach. J. G., P. Decker and Hannah Decker. 1939. Pathogenic races of Actinomyces scabies in relation to scab resistance. Phytopathology 29:204-209.

21. Lewis, B. G. 1970. Effects of water potential on the infection of potato tubers by Streptomyces scabies in soil Ann. Appl. Biol. 66:83-88.

22. McIntosh, A. H. 1973. Glasshouse tests of chemicals for control of potato common scab. Ann. Appl. Biol. 73:189-196.

23. Menzies, J. D. 1959. Occurrence and transfer of a biological factor in soil that suppresses potato scab. Phytopathology 49:648-652.

24. Millard, W. A. and S. Burr. 1926. A study of twenty-four strains of Actinomyces and their relation to types of common scab of potato. Ann. Appl. Biol. 13:580-644.

25. National Coop Survey, Ritzville Series. 1977. Franklin County, Pasco, Wa. USA.

26. Potter, H. S., H. L. Warren and W. J. Hooker. 1961. Soil fungicides for potato scab control. Michigan Quarterly Bul. 43:532-538.

27. Sanford, G. B. 1926. Some factors affecting the pathogenicity of Actinomyces scabies. Phytopathology 16:525-547.

28. Sanford, G. B. 1923. The relation of soil moisture to the development of common scab of potato. Phytopathology 13:231-236.

29. Schaal, L. A. 1940. Variation in the tolerance of certain physiologic races of Actinomyces scabies to hydrogenion concentrations. Phytopathology 30:699-700.

30. Shands, W. A. and B. J. Landis. 1964. Potato insects, their biology and cultural control. USDA Agric. Hand. No. 264. 61 pp.

31. Tamaki, George, Lee Fox, H. H. Toba, H. R. Moffit and D. M. Powell. 1976. Reevaluation of the scab gnat as a causative agent of deep-pitted scab of potatoes. Env. Entomol. 5:59-62.

32. Taylor, C. F. 1934. Field experiments on potato-scab control in western New York. Amer. Potato J. 11:40-45.

33. Terman, G. L., F. H. Steinmetz, and A. Hawkins. 1948. Effects of certain soil conditions and treatments upon potato yields and the development and control of potato scab. Univ. Maine Agr. Exp. Sta. Bul. 463. 31 pp.

34. Vlitos, A. J. and W. J. Hooker. 1951. The influence of sulfur on populations of Streptomyces scabies and other Streptomyces in peat soil. Amer. J. of Botany 38:678-683.

35. Waksman, S. A. and A. T. Henrieci. 1943. The nomenclature and classification of the Actinomycetes. J. Bacteriol. 46:337-341.

36. Weinhold, A. R., T. Bowman and J. Bishop. 1964. Urea-formaldehyde for control of common scab of potato. Amer. Potato J. 41:319-321.

37. Wood, A. A. 1937. The potato scab gnat outbreak in Middlesex in 1937. p. 71. 68th Ann. Rep. Entomol. Soc. Ont. 91 pp.

Table 1. Effect of irrigation and soil infestation of scab on Russet Burbank potato near Eureka, Wa. in 1973.

Type of Scab	Percent water removal before irrigation[1]					
	20%		50%		80%	
	Inf.[2]	Non-Inf.	Inf.	Non-Inf.	Inf.	Non-Inf.
Shallow[3]	.5 a[5]	.5 a	1.3 a	1.2 a	1.2 a	.4 a
Deep-pitted[4]	1.7 a	0 b	5.3 a	0 b	1.8 a	0 b

[1] Water replaced by sprinkler irrigation after 20, 50 and 80% of available moisture in the top two ft had been evapotranspirated.

[2] Scab infested soil was spread on soil surface by dump truck in layer 1/8 to 1/4 in depth on April 6 and incorporated by plowing 12 inches in depth.

[3] Shallow surface lesions only.

[4] Scab lesions 1/8 to 1/4 inch in depth.

[5] Horizontal means with the same letter of the alphabet not significantly different according to F test and Duncan's Multiple Range Test at P = .05.

Table 2. Effect of "popcorn" sulfur on yield of Russet Burbank potatoes near Eureka, Wa. in 1974.

Treatments	Cwt/a
Sulfur - 800 lb/a	231 b[2/]
Not treated	302 a

[1/] Side dressed in 2 bands 5 inches from potato seed pieces when plants were about 3 inches in height.

[2/] Means with the same letter of the alphabet are not significantly different according to Duncan's Multiple Range Test at P = .05.

Table 3. Effect of soil infestation on scab on Russet Burbank potato near Eureka, Wa. in 1974.

Type of Scab	Percent (lb)	
	Infested[1/]	Non-Infested
Shallow[2/]	27 a[4/]	5 b
Deep-Pitted[3/]	1 a	1 a

[1/] Scab infested soil was spread over the soil surface by a dump truck in layer 1/8 to 1/4 inch in depth in 1973 and 1974 and incorporated by plowing 12 inches in depth.

[2/] Shallow surface lesions only.

[3/] Scab lesions 1/8 to 1/4 inch in depth.

[4/] Horizontal means with the same letter of the alphabet are not significantly different according to the Duncan's Multiple Range Test at P = .05.

Table 4. Effect of chemicals and rate of irrigation on scab and production of Russet Burbank potato near Eureka, Wa. in 1975.

Scab Type and Production	Chemicals and Rate Per Acre: Terraclor[1/] (25 lb ai/a)	"Popcorn" sulfur[2/] (800 lb)	N-Serve[3/] (3 lb ai)	None --	Inches Water Per Season[4/]: 11.8	20.6	35.2
% Shallow (lb)[5/]	24 a[7/]	22 a	25 a	26 a	44 a	16 bc	11 c
% Deep-Pitted (lb)[6/]	17 b	28 a	26 a	27 a	23 a	26 a	25 a
% U.S. No. 1 (lb)	26 a	28 a	27 a	27 a	20 b	30 a	30 a
Yield (cwt/a)	385 a	392 a	431 a	408 a	315 b	446 a	446 a

1/ Terraclor 2 EC was sprayed at 30 psi on surface of plowed soil in 26 gal of fungicide-water mixture per acre as a preplant treatment and incorporated within 15 minutes by rototilling 6 inches in depth.

2/ "Popcorn" sulfur was banded level to and 5 inches to each side of seed pieces of newly emerged plants.

3/ N-Serve coated ammonium sulfate fertilizer (21% N) at rate of 400 N/a was top dressed in two bands over hills of non-emerged plants and incorporated within 15 minutes after application with a Lilliston R cultivator traveling at 4 mph. Other plots received only 400 lb N/a (ammonium sulfate).

4/ Rates of water per season calculated from water collected in three 3.75 inch diameter catch bottles per plot receiving water through 7/64, 9/64 and 11/64 inch diameter orifices of a solid set sprinkler system, respectively.

5/ Shallow surface lesions only.

6/ Scab lesions 1/8 to 1/2 inch in depth.

7/ Horizontal means of data with the same letter of the alphabet are not statistically different according to Duncan's Multiple Range Test at P=.05.

Table 5. Effect of Terraclor and/or rates of irrigation on shallow scab and production of Russet Burbank potato near Eureka, Wa. in 1976.

Inches Water[1/]	Terraclor[2/] lb ai/a	% Shallow Scab (lb)[3/]	% U.S. No. 1 (lb)	Yield cwt/a
8.2	0	36 c[4/]	27 c	283 a
16.9	0	28 bc	55 ab	363 a
25.2	0	14 ab	68 a	363 a
8.2	25	23 bc	27 c	218 a
16.9	25	17 b	49 b	361 a
25.2	25	1 a	71 a	334 a

1/ Rates of water per season calculated from water collected in four 3.75 inch diameter catch bottles per plot receiving water through 7/64, 9/64 and 11/64 inch diameter orifices of a solid set system, respectively.

2/ Terraclor 2 EC was sprayed at 30 psi on surface of plowed soil in 26 gal of fungicide-water mixture per acre as a preplant treatment and incorporated within 15 minutes by rototilling 6 inches in depth.

3/ Shallow surface lesions only.

4/ Horizontal means of data with the same letter of the alphabet are not statistically different according to Duncan's Multiple Range Test at P=.05.

Table 6. Effect of chemicals and/or straw on scab of Russet Burbank potato in naturally infested soil in greenhouse in 1977.

Chemicals	Rate Per Acre	Straw[1] Tons/Acre	% Shallow[2] Scab (g.)	% Deep-pitted[3] Scab (g.)
Difolatan[4]	100 lb ai	30	0.8	5.4
"	"	10	19.2	0
"	"	0	17.0	3.8
Thio-sul[5]	800 lb sulfur	30	0	0.8
"	"	10	12.0	0
"	"	0	0	0
Terraclor[4]	50 lb ai	30	0	0
"	"	10	0	0
"	"	0	11.1	20.9
Nitro-sul[5]	800 lb sulfur	30	0	0
"	"	10	16.0	10.2
"	"	0	19.5	23.7
Not Treated	-	30	0	0
"	-	10	6.7	0
"	-	0	13.4	25.5

1/ Wheat straw was finely chopped and thoroughly incorporated into each 10 inch diameter pot (9 pot replications for each treatment).

2/ Shallow surface lesions only.

3/ Scab lesions 1/8 to 1/4 inch in depth.

4/ Chemical added to soil and mixed thoroughly before potting.

5/ Chemical injected into soil in the center of each pot with a syringe.

Table 7. Effect of chemicals with and without straw on scab on Russet Burbank potato near Eureka, Wa. in 1977.

Chemicals	Rate per Acre	Straw[1] Tons/Acre	% Shallow[2,4] Scab (lb)	% Deep-pitted[3] Scab (lb)
Difolatan 4F[5]	100 lb ai	0	11	15 ab[7]
"	"	6	11	20 a
Nitro-sul[6]	400 lb sulfur	0	6	12 bc
"	"	6	8	14 ab
"	800 lb sulfur	0	10	14 ab
"	"	6	10	14 ab
Terraclor[5]	50 lb ai	0	10	13 bc
"	"	6	6	11 c
Thio-sul[6]	400 lb sulfur	0	15	16 a
"	"	6	11	18 a
"	800 lb sulfur	0	8	11 c
"	"	6	9	10 c
Not Treated	-	0	13	21 a
"	-	6	13	16 a

1/ Loose unchopped straw scattered by hand over soil surface of plots prior to chemical application and incorporated by rototilling twice at a depth of 6 to 8 inches.

2/ Shallow surface lesions only.

3/ Scab lesions 1/8 to 1/2 inch in depth.

4/ Vertical means of data are not significantly different according to F test at P=.05.

5/ Chemical sprayed on surface of plowed soil in 26 gal of fungicide-water mixture per acre as a preplant treatment and incorporated immediately by rototilling 6 inches in depth. Soil replowed and packed prior to planting.

6/ Same as 5/ except chemicals sprayed without any dilution with water.

7/ Vertical means with the same letter of the alphabet are not significantly different according to Duncan's Multiple Range Test at P=.05.

Table 8. Effect of rate of irrigation, straw and Terraclor (PCNB) on control of shallow scab and yield of Russet Burbank potato near Ruff, Wa. in 1977.

Total Inches Water Applied[1]	% Shallow Scab (lb)[2]			Yield (cwt/a)		
	PCNB[3]	Straw[4]	None	PCNB[3]	Straw[4]	None
12.6	17 Ab[5]	40 Aa	36 Aa	254 Bc	305 Ba	283 Ba
21.4	4 Bb	16 Bb	15 Bb	334 Aa	407 Aa	334 Aa
32.7	0 Cb	4 Cb	4 Cb	283 Ba	407 Aa	356 Aa

1/ Total inches water applied for 7/64, 9/64 and 11/64 inch diameter nozzles at each irrigation based on length of irrigation and psi and included 2.48 inches of rainfall from May until September. Irrigation scheduling for rate of water applied by 9/64 inch diameter nozzle was based on water lost from daily evaporation pan readings, moisture tensiometer readings and soil moisture (oven dry weight).

2/ Shallow surface lesions only. Less than 5% of tuber surface covered with lesions.

3/ Terraclor (25 lb ai/a) sprayed on the plowed soil surface at 25 psi in 26 gal water per acre and incorporated immediately at 6 to 8 inch depth prior to planting.

4/ Loose unchopped, straw (6 ton/a) was scattered over the soil surface of plots by hand and incorporated by rototilling twice at 6 to 8 inch depth prior to plowing.

5/ Means followed by the same letter of the alphabet are not significantly different according to Duncan's Multiple Range Test at P=.05. Capital letters (vertical) denote irrigation differences. Lower case letters (horizontal) denote differences due to application of either straw or PCNB.

Table 9. Effect of sulfur on scab of Russet Burbank (RB) and Kennebec (K) potatoes near Eureka, Wa. in 1978.

Chemicals	Lb. Sulfur Per Acre	% Shallow Scab (1b)[1/] K[3/]	% Shallow Scab (1b)[1/] RB[3/]	% Deep-pitted Scab (1b)[2/] K[3/]	% Deep-pitted Scab (1b)[2/] RB[3/]
That sulfur[4/]	208	19	4	23	2 b[8/]
That sulfur[4/]	416	25	5	28	3 b
That sulfur[4/]	832	27	4	26	5 ab
Thio-sul[5/]	500	18	6	32	9 ab
Thio-sul[6/]	287	14	3	28	6 ab
Thio-sul[7/]	287	18	3	22	6 ab
MSS[4/]	400	15	10	15	11 a
MSS[4/]	800	23	4	29	3 b
Not Treated	-	25	8	34	11 a

1/ Shallow surface lesions only.

2/ Scab lesions 1/8 to 1/2 inch in depth.

3/ Vertical means of data are not significantly different according to the F test at P=.05.

4/ Sprayed in 200 gal water per acre in 12 inch band in open furrow at planting.

5/ Sprayed over surface of soil followed by immediate rototilling 6 inches in depth prior to planting.

6/ Sprayed in 12 inch band over soil surface where row will be planted later.

7/ Same as 5/ except sprayed over hill after planting and herbicide incorporation but prior to emergence.

8/ Vertical means with the same letter of the alphabet are not significantly different according to Duncan's Multiple Range Test at P=.05.