POTATO SEED PIECE TREATMENT[1, 2/]

Gene D. Easton, Michael E. Nagle, and Donald L. Bailey
Associate Plant Pathologist, Senior Experimental Aide,
and Assistant Experimental Aide

Department of Plant Pathology
Washington State University
Irrigated Agriculture Research and Extension Center
Prosser, Washington

SUMMARY

Although a slight amount of seed piece decay occurred, blackleg did not develop, and yield was not reduced in trials with untreated seed pieces of Norgold Russet and Russet Burbank in 1968 and 1969. Chemical seed piece treatments reduced seed piece decay, but did not increase yield. Storing untreated cut seed of these two varieties up to 5 days at 50-90°F and 35-86% relative humidities with adequate ventilation did not affect seed piece decay, blackleg, or yield.

INTRODUCTION

Seed piece decays are caused by Fusarium spp. (1, 23, 24), bacteria (7, 17, 21), and a **combination of bacteria and Fusarium** spp. (1, 23) or **other fungi (2).**

1/ Investigation made possible by grants supplied by the Washington State Potato Commission, Niagara Chemical Division, and Crown Zellerbach Corporation.

2/ Any trade name of a product used in these studies does not constitute a guarantee or warranty of the product by Washington State University or that the behavior of similar products would be the same or different from the ones used.

Scientific paper 3409 . College of Agriculture, Washington State University, Pullman, Washington 99163. Project 1709.

Bacterial seed piece decay may be caused by either the blackleg bacterium [Erwinia atroseptica (Van Hall) Jennison (7) = Plectobacterium carotovorum var. atrosepticum (Van Hall) Dowson (17)] or the soft rot bacterium [Erwinia carotovora (Jones) Holland (7) = Plectobacterium carotovorum (Jones) Waldee (17)]. Bacteria of the soft rot type can also produce blackleg stem symptom when grown under the required environmental conditions (11, 16, 19). Pseudomonas fluorescens Migula may also be associated with seed piece decay, but it does not cause blackleg (3). Due to the close relationship of the bacteria (except for Pseudomonas spp.) causing seed piece decay (16), hereafter they will be referred to as "blackleg bacteria."

Fusarium spp. cause a dry or wet pitting of seed pieces stored a week or longer (23). Wet rot may develop rapidly and often means that bacteria are also present. Fusarium dry rot is a firm, slowly developing rot. Planting infected seed may result in reduction of stands, fewer stems per plant, weak or small plants and loss in yield (23).

Field infection by the blackleg bacteria usually occurs through seed pieces (21), which generally decay completely before the bacteria spread into the stems, stolons, or newly formed tubers. Soft rot may also develop in the above ground stems, where an inky-black color usually appears. This discoloration is the basis for the name "blackleg", first described by Jones of Vermont in 1905 (21).

There are three possible sources of inoculum of the blackleg bacteria: seed tubers, soil, and seed corn maggots (21). Naturally infected seed tubers do initiate both seed piece rot and blackleg plants but the number of plants with symptoms usually do not exceed 10% (2, 14, 21). Leach (21) has stated that development of blackleg requires that the bacteria escape from the vascular bundles of infected tubers. This occurs only if the seed piece can no longer form cork (suberization). Bonde (2) reported the Green Mountain variety was symptomless for 4 years in a tuber unit experiment when the seed was planted the same day as cut but developed 2 to 18% blackleg plants when the cut seed was stored 6 to 15 days before planting. Incidence of blackleg is higher in wet, heavy soil (21), when cut seed is stored at warm temperatures or with inadequate aeration (2, 21), and frozen prior to planting.

Blackleg has been observed in practically all countries of the world (2). Blackleg bacteria have been shown to survive in soil in Main (2), Minnesota (21), and South Carolina (2). The organism from soil has caused blackleg seed piece decay (21). It can be assumed that the bacteria in the soil can infect seed tubers if wound cork formation is inhibited.

The seed-corn maggot, Hylemyia cilicrura Rond., is commonly associated with decayed seed pieces in Maine (2) and Minnesota (21), and is also present in Washington (20). The blackleg pathogen retains viability after passage through the intestinal tract of either larvae or adult flies (21). Bacteria in the puparia survive and emerge with the adult fly and are essential for the normal development of the larvae on potato seed. The maggot cannot complete its life cycle on healthy potato tissue. Blackleg has been produced by inoculation of tubers with infected larvae in the laboratory (2). To what extent seed-corn maggots disseminate blackleg bacteria is not known. Nielsen (23) could not demonstrate they spread blackleg under Idaho conditions. Landis and Onsager (20) of Washington found that treatment of potato seed pieces with Captan controls the seed-corn maggot.

The inter-relationship between seed piece decay caused by Fusarium solani (Mart.) Appel & Wr. and blackleg was first observed by Blodgett in Idaho (1). Nielsen (23) found more blackleg in plants developing from seed pieces infected with F. solani than when F. solanum was not present. He stated that blackleg bacteria and other organisms gained entrance to seed pieces through Fusarium decay wounds. Bonde in Maine (2) found blackleg bacteria and other bacterial pathogens present in tuber lesions caused by buttonhole rot (Phoma spp.), powdery scab [Spongospora subterranea (Wallr.) Lagerheim], and dry rot [Phytophthora infestans (Mont.) DBy]. These fungus lesions undoubtedly serve as avenues of infection for the blackleg bacteria.

In general, results on control of seed piece decay by chemical treatment have been variable and inconclusive. Tests have been performed in Connecticut (27), Idaho (15, 23, 24), Maine (2, 3, 4, 5, 6), Minnesota (21, 22), New York (8, 9, 25), Oregon (28), Scotland (12, 13), Washington (18), West Virginia (10), and Wisconsin (26). These investigations showed, for the most part, that protectant chemicals were not needed if the potato seed was cut and planted the same day and planting was followed by favorable environmental conditions for seed germination (2, 10, 18, 21, 22, 23, 24). Protectant seed piece treatments were of benefit, however, if cut seed were planted in dry soil (15, 21) or overly wet, heavy soil (21, 23) or if weather conditions after planting changed to wet and cold (23).

Bonde and fellow workers (3, 4, 5, 6) in Maine demonstrated that streptomycin reduced blackleg but increased rots due to Phoma and Fusarium spp. (5, 6). Waggoner (28) of Connecticut also reported increased Fusarium decay in streptomycin treated seed. Later, Bonde and Hyland (6) found that streptomycin reduced the rate and the extent

of healing (suberization) in cut potato seed. Others have reported streptomycin to help slightly in control of blackleg (12), to be ineffective (10, 13, 15, 26), or to cause severe seed piece decay (10, 26). Combining streptomycin with other chemical protectants has had varied success in controlling seed piece decays (10, 15) and has been reported to reduce the other protectants' effectiveness in controlling Fusarium decay (6).

Studies were initiated in 1968 to determine the effect of chemical protectants on seed piece decay and blackleg in the Russet Burbank and Norgold Russet varieties. Antibiotics were not included because of their reported adverse effects to healing (suberization) of cut seed. Normal practices of seed treatment and handling in Washington were followed. Since potato seed is one source of blackleg bacterial inoculum (cause of seed piece decay and blackleg), data were collected on the occurrence of blackleg in the Othello Seed Lot Trials for 1966-1969.

METHODS AND MATERIALS

In 1968, treatments consisting of Captan 50% wettable powder (7.5 lbs actual/100 gal water) alone, Captan 50% wettable powder (7.5 lbs actual/100 gal water) plus dimethyl sulfoxide liquid [(DMSO) 4 gal/100 gal water], Polyram 7% dust (1 lb active/100 lbs cut seed potatoes) and water were applied to freshly cut seed of Russet Burbank and Norgold Russet potatoes (table 1). Planting was completed 24 to 48 hours after cutting and seed piece treatment. Plantings were at Prosser, Washington on April 2 and May 16, and at Othello, Washington on April 5 and May 14. The experimental plot at Prosser was harvested on September 19 and at Othello on September 24.

In 1969, treatments of Captan 5% dust (1 lb actual/100 lb seed) and Polyram 7% dust (1 lb actual/100 lb seed) were applied to freshly cut seed of Russet Burbank and Norgold Russet potatoes (table 2). A non-treated control was included as a check. After cutting and treating, the seed treatments were stored with adequate ventilation under three conditions before planting, as follows: 1) 63 to 70°F and 83 to 95% relative humidity (RH) in a closed, insulated storage for one day, 2) 50°F minimum night to 92°F maximum day temperatures and 35 to 86% RH for 5 days and nights in uninsulated storage, and 3) 73 to 78°F and about 68% RH in closed, uninsulated storage for one day and 50°F minimum night and 80°F maximum day temperatures at 68 to 84% RH for an additional day outside in the open. At the end of their storage periods, treatments 2 and 3 were placed under the conditions for treatment 1 until all treatments were planted (1-3 days). Planting at Othello

began on April 21 and was completed on April 23. The plot was harvested October 7.

The average per cent of soil moisture (oven dry basis) in the 0-7 inch depth was determined. Soil temperature at the 6 inch depth as recorded by a hydrothermograph (except at Prosser in 1968) was taken at time of planting for both years. The plants in one row of each treatment were pulled about 7 weeks after planting and the seed pieces were examined for decay (tables 1 and 2).

Each experimental field plot consisted of 4 rows (3 ft spacing) and 20 ft in length. All data shown in tables 1 and 2 are means of 6 random replicated plots.

Soils at both Othello and Prosser were known from past experiments to be infested with the Verticillium wilt organism.

Data on the occurrence of blackleg in the Othello Seed Lot Trials (conducted by personnel of Washington State University and the Washington State Potato Commission) for 1966-1969 are presented in table 3. Each lot, consisting of a 300 tuber sample, represented a commercial lot of seed of varying size. Whole, uncut, and untreated tubers of each lot were planted in a field at the Othello Research Farm which had not raised potatoes the previous year. The tubers were dropped individually down the planting tube of a tuber-unit planter to prevent mechanical injury and exposure to blackleg bacteria at planting.

RESULTS

Seed piece decay did not develop to any great extent even in the water treatment of cut seed potatoes of Norgold Russet and Russet Burbank in 1968, regardless of the location or the time of planting (table 1). Even so, all three seed piece treatments (Captan, Captan plus DMSO, and Polyram) significantly reduced the number of decayed seed pieces in Russet Burbank in the May plantings at Othello and Prosser, compared to the water treatment. Seed piece decay was higher in the Captan treatment than the water treatment in the April planting of Norgold Russet at Prosser. No blackleg plants were observed in any of the treatments. Yield was not affected by seed piece treatment or date of planting. Russet Burbank yielded significantly more than Norgold Russet at Prosser for both plantings and at the May but not April planting at Othello. Soil moisture at planting (April 2 and May 16) at Prosser and at planting (April 5 and May 14) at Othello averaged 12.9, 11.6, 12.5 and 10.7%, respectively. The soil

temperature at Othello on April 5 and May 14 was 45-49° F and 58-61°F, respectively. Soil temperature was not recorded at Prosser.

In 1969, Captan and Polyram applied to seed pieces of Russet Burbank and Norgold Russet varieties significantly reduced seed piece decay, compared to the untreated control (table 2). Storage of seed after cutting and treating had no affect on seed decay. The seed pieces of Russet Burbank and Norgold Russet were soft and flabby after 5 days storage in the uninsulated storage (storage 2 treatment). None of the seed piece or storage treatments affected yield. Russet Burbank significantly outyielded Norgold Russet. Soil moisture was 10.7% and soil temperature varied from 63 to 69°F at time of planting.

In the Othello Seed Lot Trials, 25 to 30 per cent of the seed lots of the Norgold Russet variety had 1 to 2 plants with blackleg, 7 to 8% (except for 1966) of the lots had 3 to 6 plants with blackleg, and 0 to 6% of the lots had 6-15 plants with blackleg from the period 1966 to 1969 (table 3). Tuber lots of Russet Burbank variety seed planted in the Othello Seed Lot Trials during this period had so few blackleg plants that they were not even recorded.

DISCUSSION

Very little seed piece decay and no blackleg developed from untreated seed pieces of Russet Burbank or Norgold Russet planted either within a day or two after cutting or stored with adequate air ventilation for up to 5 days under fluctuating temperatures (50-90°F) and 35 to 86% relative humidities. Normal healing (suberization) of cut seed pieces occurred. Leach (21) found that deficient oxygen conditions inhibited suberization of seed and that much loss occurred due to blackleg under such conditions.

Why blackleg did not develop could be because either the seed (Russet Burbank and Norgold Russet) was free of blackleg bacteria, the bacteria were not present in the soil, or environmental conditions were not favorable for disease development. Other workers (3, 21) have shown that even artificial inoculation of seed with blackleg bacteria did not produce blackleg in the field. Bonde (2) found that blackleg plants grown from discolored tubers of blackleg hills did not exceed 10%.

Emergence of plants was not delayed by environment existing at planting or later periods of weather change in either 1968 or 1969. Other workers (2, 10, 21, 23) have indicated that seed piece treatment is not required if the cut seed is planted soon after cutting and weather conditions are favorable for germination.

Blackleg was associated with some of the lots of Norgold Russet seed grown for commercial production in Washington each year. The blackleg organism may be inside seed tubers, in soil attached to the outside of tubers, or associated in fungus lesions on the tuber. Leach (21) of Minnesota and Bonde (2) of Maine did not feel that systemic infection of tubers by blackleg bacteria was the most important source of infection. Bonde (2) and Blodgett (1) and Nielsen (23) found blackleg bacteria in association with other fungi in lesions on outside of seed to increase blackleg. These fungus lesions could serve as avenues of infection for the blackleg bacteria from the soil.

Practices Which Prevent Seed Piece Decay and Blackleg

1. ACCEPT AND PLANT ONLY SOUND, UNBLEMISHED SEED.
2. Do not bruise or mishandle seed, especially when seed is cold.
3. Warm seed at 50-60°F three to six days, depending on prior storage temperature, before cutting.
4. Avoid longer periods of storage at temperatures above 40°F before cutting.
5. Never pile, transport, or store seed before or after cutting without adequate air ventilation (oxygen).
6. Avoid storing seed after cutting. If necessary, store at 90-95% relative humidity and 45-50°F. (Do not store it above 50°F.)
7. Do not plant seed in cold soil (below 40°F).
8. Do not plant seed in either wet or dry soil.
9. Do not irrigate potato field until plants have emerged.

Table 1. Effect of seed piece protectants on seed piece decay and production of potatoes near Othello and Prosser, Washington in 1968.

Protectants [1]	Mean decayed seed pieces [2]		Mean yield (cwt/A)	
	Date of planting at Othello			
	Apr.	May	Apr.	May
Russet Burbank Variety				
Captan 50 WP	0	0.3 a [3]	479 [4]	500 a
Captan 50 WP + DMSO	0	0 a	486	515 a
Polyram 7D	0	0.5 a	471	529 a
Water control	0.5	4.0 b	500	522 a
Norgold Russet Variety				
Captan 50 WP	0.2 a	0.2	450	457 b
Captan 50 WP + DMSO	0 a	0.3	450	457 b
Polyram 7D	1.5 a	0.8	464	464 b
Water control	0.5 a	1.0	421	442 b
	Date of planting at Prosser			
	Apr.	May	Apr.	May
Russet Burbank Variety				
Captan 50 WP	0.2	0.8 a	537 a	406 a
Captan 50 WP + DMSO	0	0.8 a	500 a	479 a
Polyram 7D	0.7	0.2 a	500 a	457 a
Water control	1.5	3.0 b	537 a	457 a
Norgold Russet Variety				
Captan - 50 WP	1.8 b	0	464 b	421 b
Captan - 50 WP + DMSO	0 a	0.2	435 b	370 b
Polyram 7D	1.0 a	0.7	500 b	399 b
Water control	0.3 a	1.0	457 b	413 b

1/ Freshly cut seed pieces treated with Captan (7.5 lbs actual/100 gal water) alone, Captan + DMSO (7.5 lb actual/100 gal water + 4 gal/100 gal water), Polyram (1 lb active/100 lbs cut seed) and water and stored for 24-48 hr at 50-55°F and 90% relative humidity before planting.

2/ Number of decayed seed pieces from 20 plants 7 weeks after planting.

3/ Means with the same letter are not significant according to Duncan's Multiple Range Test at the 5% level.

4/ Data with means notfollowed by a letter are not significant according to the F test at the 5% level.

Table 2. Effect of preplant storage and seed piece protectants on seed piece decay and production of potatoes near Othello in 1969.

Protectants [1]	Mean decayed seed pieces [2] Storage treatments [3]			Mean yield (cwt/A)		
	1	2	3	1	2	3
Russet Burbank Variety						
Captan 5D	6a [4]	4a	5a	407a	414a	465a
Polyram 7D	7a	7a	7a	414a	392a	443a
Control	8b	10b	10b	421a	414a	385a
Norgold Russet Variety						
Captan 5D	9a	8a	7a	327b	356b	319b
Polyram 7D	9a	8a	8a	334b	341b	356b
Control	13b	13b	14b	334b	327b	356b

1/ Freshly cut seed pieces treated with Captan (1 lb actual/100 lb seed), Polyram (1 lb actual/100 lbs seed) and no treatment (control) and placed in respective storage 1, 2 and 3 before planting.

2/ Number of decayed seed pieces from 20 plants 7 weeks after planting.

3/ Storage treatments: 1) 63 to 70°F and 83 to 95% RH in closed, insulated storage for 1 day, 2) 50° minimum night to 92°F maximum day and 35 to 86% RH for 5 days and 5 nights in uninsulated storage, 3) 73 to 78°F and about 68% RH in closed, uninsulated storage for 1 day and 50°F minimum night and 80°F maximum day at 68 to 84% RH outside in the open for an additional day. At end of their storage treatments, treatments 2 and 3 were placed under conditions for treatment 1 until all treatments were planted (1-3 days).

4/ Means with the same letter are not significant according to Duncan's Multiple Range Test at the 5% level.

Table 3. Blackleg in Norgold Russet potatoes planted in the Othello seed lot trials from 1966-1969.

Year	Total lots planted	Range of plants in lots with blackleg 1/ % Lots with 1-2 plants	% Lots with 3-6 plants	% Lots with 6-15 plants
1966	31	25.8	35.5	6.5 2/
1967	80	25.0	7.5	0
1968	132	34.8	8.3	0.7
1969	152	30.9	7.2	4.6

1/ Each lot consisted of 300 whole, uncut tubers

2/ 1 lot with 53 blackleg plants.

LITERATURE CITED

1. Blodgett, E. C. 1947. Comments on black rot, a storage disease of potatoes in Idaho. Pl. Dis. Reptr. 31:10-13.

2. Bonde, R. 1950. Factors affecting potato blackleg and seed-piece decay. Univ. Me. Agr. Exp. Sta. Bul. 482. 31 pp.

3. Bonde, R. and P. DeSouza. 1954. Studies on the control of potato bacterial seed-piece decay and blackleg with antibiotics. Amer. Potato J. 31:311-316.

4. Bonde, R. 1955. Antibiotic treatment of seed potatoes in relation to seed-piece decay, blackleg, plant growth, and yield rate. Pl. Dis. Reptr. 39:120-123.

5. Bonde, R. and J. F. Malcolmson. 1956. Studies in the treatment of potato seed pieces with antibiotic substances in relation to bacterial and fungus decay. Pl. Dis. Reptr. 40:615-619.

6. Bonde, R. and F. Hyland. 1960. Effects of antibiotic and fungal treatments on wound periderm formation, plant emergence, and yields produced by cut seed potatoes. Am. Potato J. 37:279-288.

7. Burkholder, W. H. and W. L. Smith, Jr. 1949. Erwinia atroseptica (van Hall) Jennison and Erwinia carotovora (Jones) Holland. Phytopathology 39:887-897.

8. Clayton, E. E. 1929. Potato seed treatment experiments on Long Island with special reference to the organic mercury instant dips. N. Y. St. Agr. Exp. Sta. Bul. 564.

9. Cunningham, H. S. and O. A. Reinking. 1946. Fusarium seed piece decay of potato on Long Island and its control. N. Y. Cornell Univ. Agr. Exp. Sta. Bul. 721. 32 pp.

10. Duncan, H. E. and M. E. Gallegly. 1963. Field trials for chemical control of seed piece decay and blackleg of potato. Am. Potato J. 40:279-284.

11. Graham, D. C. and W. J. Dowson. 1960. The coliform bacteria associated with potato blackleg and other soft rots. Ann. Appl. Biol. 48:51-57.

12. Graham, D. C. and Z. Volcani. 1961. Experiments on the control of blackleg disease of potato by disinfection of seed tubers with mercury compounds and streptomycin. Eur. Potato J. 4:129-137.

13. Graham, D. C. 1962. Blackleg disease of potatoes. From: Scottish Agr., Spring.

14. Gratz, L. O. 1930. Diseases and climate as pertaining to the Florida and Maine potato sections. Phytopathology 20:267-288.

15. Guthrie, J. W. 1960. The influence of seed-piece treatment on disease control and yield of Russet Burbank potatoes. Univ. Ida. Agr. Exp. Sta. Bul. 329. 8 pp.

16. Hellmers, E. and W. J. Dowson. 1953. Further investigations of potato blackleg. Acta. Agric. Scand. 3:103-112.

17. Hellmers, E. 1959. Plectobacterium carotovorum var. atrosepticum (van Hall) Dowson, the correct name of the potato blackleg pathogen; a historical and critical review. Eur. Potato J. 2:251-271.

18. Hoyman, W. G. 1964. Treatment of potato seed tubers. 3rd. An. Wash. St. Potato Conf. Proc., Moses Lake, 5-6.

19. Jones, D. R. 1950. On the nomenclature and identity of the coliform soft-rot bacteria Trans. Brit. mycol. Soc. 33:73.

20. Landis, B. J., J. A. Onsager, and L. L. Foiles. 1969. Chemical control of the seed-corn maggot Hylemya platura (Meigen), in potato seed pieces. J. Ec. Ent. (In review for publication).

21. Leach, J. G. 1931. Blackleg disease of potatoes in Minnesota. Univ. Minn. Agr. Exp. Sta. Tech. Bul. 76. 36 pp.

22. Line, R. F. and C. J. Eide. 1960. Control of seed-piece decay. Pl. Dis. Reptr. 44:698-701.

23. Nielsen, L. W. 1949. Fusarium seed piece decay of potatoes in Idaho and its relation to blackleg. Univ. Ida. Agr. Exp. Sta. Res. Bul. 15. 31 pp.

24. Sparks, W. C., K. W. Knutson, W. M. Iritani, J. E. Bryan. 1962. A study of factors affecting storage losses of potato tubers cut several months prior to planting. Univ. Ida. Agr. Res. Progress Report No. 63. 13 pp.

25. Tucker, J. 1929. The effect of seed treatment on blackleg. 15th Ann. Proc. Amer. Potato Assoc. Meeting, New York. pp 71-73.

26. Wade, E. K. 1967. Potato seed piece treatments conducted in Wisconsin. Am. Potato J. 44:341.

27. Waggoner, P. E. 1956. Chemical treatment of potato seed in Connecticut, 1955. Pl. Dis. Reptr. 40:411-413.

28. Young, R. A. and J. A. Milbrath. 1952. Control of potato seed-piece decay by seed-piece treatment. Phytopathology 42:26.