Table 3b. Percent infection, % culls, and infection index of Russet Burbank potato tubers caused by *Meloidogyne chitwoodi* from Fosthiazate-Vapam treated field plots, WSU-IAREC, 2002.

Treatment (rate ai/A)	% Infection[1]	% Culls[2]	Infection index[3]
Untreated	100 a	100 a	6.0 a
Telone II 20 gal Fall *	74 b	60 b	2.9 b
Fosthiazate EC 4.5 lb Spring	35 b	18 b	0.9 b
Fosthiazate EC 6.0 lb Spring	14 b	6 b	0.3 b
Vapam 37.5 gal + Fos 4.5 lb Spring	1 b	0 b	0.01 b
Vapam 37.5 + Fos 6.0 lb Spring	2 b	0 b	0.03 b
Vapam 37.5 + Fos 3.0 (mix) + Fos 3.0 (at plant)	1 b	1 b	0.04 b
Agri-Mek 48 Fl oz/A	96 a	89 a	4.9 a

Values are means of five replicates. Values in each column followed by the same letter are not significantly different at $P < 0.05$, according to student t-test.

[1] % infection = any tubers infected with *M. chitwoodi*.

[2] % culls = tubers with six or more infection sites.

[3] Infection index: 0 = no infection; 1=1-3; 2=4-5; 3=6-9; 4=10+; 5=50+; 6 =100+ = infection sites.

***** Telone II 20 gal Fall application was not successful as soil conditions were too wet

Table 3c. Yields (lb/plot) of Russet Burbank potato tubers from field plots infected with *Meloidogyne chitwoodi* and treated with Fosthiazate-Vapam, Pear Acres Unit, WSU-IREC, 2002.

Treatments (rate ia/A)	Grade		Total Yield
	No. 1	No. 2	
Untreated	42 a	2.7 a	50.6 a
Telone II 20 gal Fall *	82 b	20.8 b	106 b
Fosthiazate EC 4.5 lb Spring	58 a	8.4 b	68.2 a
Fosthiazate EC 6.0 lb Spring	64 a	12.4 b	82.6 b
Vapam 37.5 gal + Fos 4.5 lb Spring	73.8 b	23 b	97.9 b
Vapam 37.5 + Fos 6.0 lb Spring	85.1 b	30 b	118.7 b
Vapam 37.5 + Fos 3.0 (mix) + Fos 3.0 (at plant)	72.2 b	25 b	102.3 b
Agri-Mek 48 Fl oz/A	34.4 a	3 a	41.4 a

Values are means of five replicates. Values in each column followed by the same letter are not significantly different at $P < 0.05$, according to student t-test

***** Telone II 20 gal Fall application was not successful as soil conditions were too wet

Table 4a. Populations of *Meloidogyne chitwoodi* at pretreatment, mid season, and post-harvest from Kapam and Vapam treated Russet Burbank potato field plots, WSU-IAREC, Prosser, WA, 2002.

Treatment (rate ai/A)	Apr 02	Aug 02	Nov 04
Untreated	511 + 206 a	363 + 141 a	2240 + 390 a
Telone II 20 gal, Spring	429 + 220 a	0 b	2 + 2 b
Vapam HL 37.5 gal	243 + 52 b	1 + 1 b	5 + 2.7 b
Kapam 30.0 gal	388 + 82 a	9 + 9 b	40 + 35 b

Table 4b. Percent infection, % culls, and infection index of Russet Burbank potato tubers caused by *Meloidogyne chitwoodi* from Kapam and Vapam treated field plots, WSU-IAREC, Prosser, WA., 2002.

Treatment (rate ai/A)	Infection index[1]	% Culls[2]	% Infection[3]
Untreated	6 a	100 a	100 a
Telone II 20 gal, Spring	0 b	0 b	0 b
Vapam HL 37.5 gal	1.5	25 b	29 b
Kapam 30.0 gal	0.3 b	13 b	6 b

Values are means of five replicates. Values in each column followed by the same letter are not significantly different at $P < 0.05$, according to student t-test.

[1] Infection index: 0 = no infection; 1=1-3; 2=4-5; 3=6-9; 4=10+; 5=50+; 6 =100+ infection sites.

[2] % culls = tubers with six or more infection sites.

[3] any tubers infected with *M. chitwoodi*

Table 4c. Tuber yields (lb/plot) of Russet Burbank potato treated with Kapam and Vapam against *Meloidogyne chitwoodi* plots, Pear Acres Unit, WSU-IAREC, 2002

Treatments (rate ia/A)	Grade		Total Yield
	No. 1	No. 2	
Untreated	37.0 a	3.9 a	41.1 a
Telone II 20 gal, Spring	88.2 b	3.6 a	94.3 b
Vapam HL 37.5 gal	62.7 b	0.5 b	63.9 b
Kapam 30.0 gal	79.0 b	1.0 b	81.1 b

Values are means of five replicates. Values in each column followed by the same letter do not differ at $P < 0.05$, according to student t-test.

Observation of a Pathogen Shift Among the Bacterial Soft Rot Pathogens on Potato in Washington State

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Bacterial tuber soft rot, aerial stem rot, and blackleg of potato are significant problems in Washington State. These diseases can be caused by *Pectobacterium* (*Erwinia*) *carotovorum* subsp. *carotovorum* (*Pcc*), *Pectobacterium* (*Erwinia*) *carotovorum* subsp. *atrosepticum* (*Pca*), and *Pectobacterium* (*Erwinia*) *chrysanthemi* (*P. chrysanthemi*). Until recently, *P. chrysanthemi* was generally regarded as a subtropical to tropical pathogen while *Pcc* and *Pca* were considered to be pathogens on potatoes in temperate climates (Pérombelon and Kelman, 1980).

Infection of potato tubers begins at wounds, lenticels, or stolon attachments. Tuber soft rot is characterized by symptoms which range from light vascular discoloration to complete seed piece decay. The infected tuber tissue is often cream colored and soft to the touch. Blackleg symptoms range from seed piece decay to lesions which extend up the stem from the soil line. Under conditions of high humidity, the infected plant tissue is water soaked and soft to the touch. A cross section of the stem will demonstrate that that the vascular system of affected plant tissue is discolored. Poor stands and plant stunting are observed as a result of seed piece rot. Aerial stem rot, characterized by water soaking of the aerial portions of the plant does not originate from seed piece infection. The water soaked tissue is very soft to the touch and can range from light green, yellow to light brown in color (Powelson and Franc 2001). The impact of these diseases at the plant level is obvious and the affect of these diseases is observed in a yield loss that can range from 3 to 10 tons/ acre (Cobb, W. T.; personal communication).

In the Pacific Northwest, in particular the Columbia Basin of Washington and Oregon, these diseases are commonly found in most irrigated fields. In a study by Powelson in 1980, the incidence of blackleg symptoms early in the season was low, and *Pca* was the primary pathogen associated with these symptoms. Towards the end of June and into July, *Pcc* was the primary pathogen isolated from potato plants exhibiting blackleg symptoms. In the middle of the season, aerial stem rot symptoms began to appear, usually after row closure. *Pcc* was always isolated from theses plants (Powelson 1980). In the late 1970's and during the 1980's, *P. chrysanthemi* was seldom isolated from diseased tissue in Oregon (Cappaert et al. 1988). In research by D. C. Gross (personal communication), on these diseases of potato in the Columbia Basin, only one isolate of *P. chrysanthemi* was recovered.

During 2001, unusual bacterial soft rot symptoms on aerial portions of the potato plant in the field were seen (G. Pelter, personal communication). Plants exhibiting aerial soft rot symptoms had more chlorosis and it appeared that the disease was more destructive to the plant than in previous years. In 2001, a limited survey of potato fields in the Columbia Basin of Washington State was conducted for bacteria

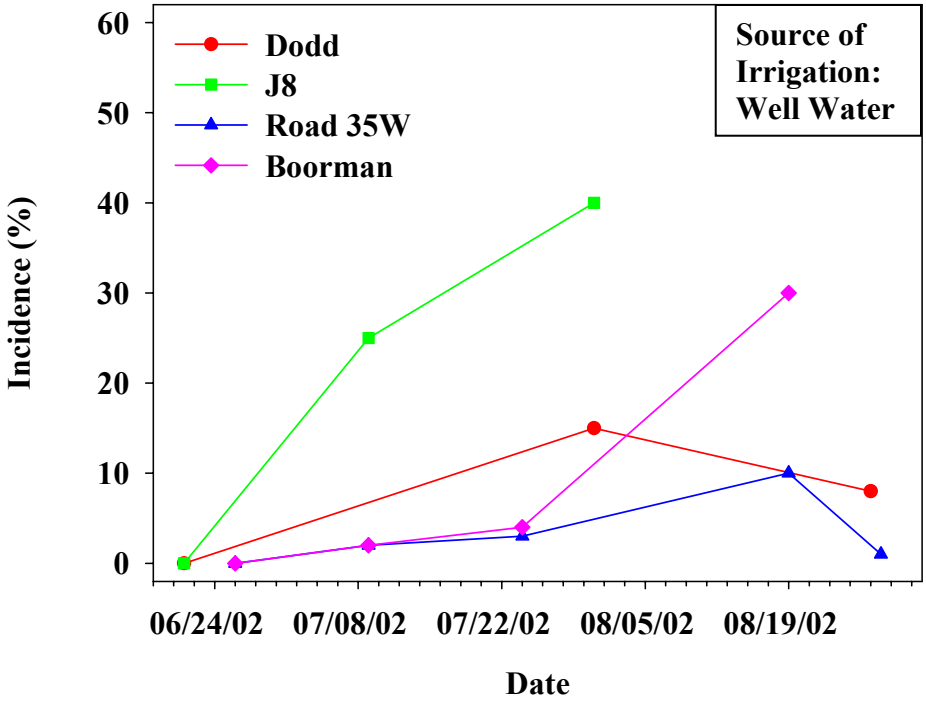
associated with symptoms of aerial soft rot, blackleg, and tuber soft rot. Of the 272 strains collected, 110 (41%) were identified as *P. chrysanthemi*. This suggests that a pathogen shift has occurred among the soft rot bacteria in the Columbia Basin. This is of considerable significance because strains of *P. chrysanthemi* are more destructive than *Pcc* or *Pca.* In addition, corn is also a host for *P. chrysanthemi,* but not *Pcc* or *Pca* (Boccara et al. 1991). The presence of *P. chrysanthemi* in the Columbia Basin could have long ranging affects not only on potato, but also on corn production as well.

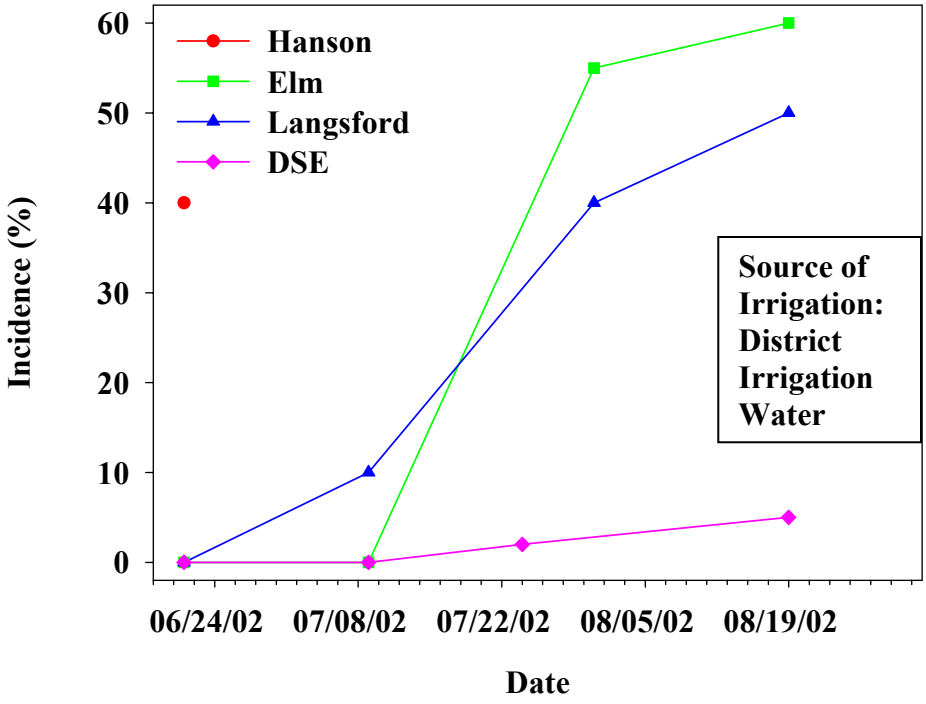
The seed piece is well recognized as the primary source of inoculum for blackleg. The decaying seed piece and bacteria washed from diseased stems are the sources of inoculum for tuber soft rot, and irrigation water was implicated as a source of inoculum for aerial stem rot and tuber soft rot. High populations of *Pcc* were isolated from surface waters and irrigation holding ponds whereas population size and recovery of *Pca* from these same sources was low. In contrast, populations of these bacteria are nondetectable or extremely small in well water (Jorge and Harrison, 1986; Harrison et al. 1987). With the emergence of *P. chrysanthemi* as a cause of soft rot diseases of potato in the Pacific Northwest, and the increased pressure to conserve water for agricultural uses, we thought it would be prudent to reexamine our irrigation water sources for populations of *Pcc*, *Pca,* and *P. chrysanthemi*.

Furthermore, the variety picture in the Pacific Northwest has changed dramatically since 1980, when the first study on bacteria associated with bacterial soft rot symptoms of potato was completed. At that time, Russet Burbank and Norgold Russet were the principle cultivars grown. Today, Russet Burbank accounts for approximately 32% of the total potato varieties planted in Washington, followed by Ranger Russet (20 %), Russet Norkotah (17%), Umatilla (12%), and Shepody (12%) (Thornton 2001; *Potato Progress* 2001).

The first objective of our research was to determine the incidence and causal agents of tuber soft rot, aerial stem rot, and blackleg of potato in Ranger Russet under two different sources of irrigation water: well water and district irrigation water. Eight fields of Ranger Russet were chosen. Four fields designated Dodd Road, J8 Olberding, Road 35 W and Boorman were irrigated with well water and four fields designated Hanson Loop, Elm Road, Langsford field and D SE were irrigated with district irrigation water. These fields were evaluated for incidence of tuber soft rot, aerial stem rot, and blackleg several times throughout the growing season. As expected, the disease incidence was quite low at the beginning of the growing season and began to increase as the plants grew, with an increase in the disease incidence occurring after row closure and flower drop. The disease incidence varied from field to field and was not dependent on the irrigation source. The observed disease incidence for the fields which were irrigated using well water varied from 0 to 40% depending on the time of evaluation. At the end of the season the disease incidence was around 30 to 40%.

The observed disease incidence for the fields which were irrigated with district irrigation water ranged from 0 to 60% depending on the time of evaluation. When looking at the data presented in the graphs below it would appear that the disease incidence is greater for the fields irrigated with district irrigation water. However, the disease incidence observed in the field designated D S.E. which was irrigated using district irrigation water was only 5% at the end of the season.





This was the lowest disease incidence for any of the fields evaluated. In addition, only one evaluation of disease incidence was made for the Hansen field which was under district irrigation because the incidence of late blight was so great that no more observations could be made. See graphs above. All three pathogens, *Pectobacterium carotovorum* subsp. *carotovorum*, *Pectobacterium carotovorum* subsp. *atrosepticum* and *Pectobacterium chrysanthemi,* were isolated from diseased plant tissue sampled from these fields and others throughout the growing season. Of the isolates obtained, 44% were *P. c.* subsp. *carotovorum*, 14 % were *P. c.* subsp. *atrosepticum* and 42 % were *P. chrysanthemi.*

Isolates from Black Leg Stems	**Number of Isolates**	
P. c. subsp. *carotovorum*	12	(2 from Othello Seed Lot)
P. c. subsp. *atrosepticum*	11	(3 from Othello Seed Lot)
P. chrysanthemi	11	(3 from Othello Seed Lot)

Isolates from Aerial Stem Rot Tissue	**Number of Isolates**
P. c. subsp. *carotovorum*	10
P. c. subsp. *atrosepticum*	2
P. chrysanthemi	7

In addition to sampling from infected plant tissue, a small survey was completed to determine if soft rotting bacteria were present on potato flowers. One hundred and fifty flowers were obtained from 11 different locations, and pectolytic bacteria were isolated from 27 % of these tissues. Incidence for the respective locations ranged from 10 to 70 %. In addition, it was observed that the pectolytic bacteria were isolated from the pistil but not the anther.

The second objective was to monitor population size of *P. c.* subsp. *carotovorum*, *P. c.* subsp. *atrosepticum* and *P. chrysanthemi* in well water and district irrigation waters. Water samples were removed from the water source at each of the above mentioned fields when each field was evaluated for disease incidence. Thirty-five isolates were obtained from the water samples. The populations obtained did not correlate with the observed incidence in the respective fields.

Isolates from water samples	**Number of Isolates**
P. c. subsp. *carotovorum*	12
P. c. subsp. *atrosepticum*	4
P. chrysanthemi	19

The third objective was to determine the incidence of tuber soft rot in the seed lot trials and determine the causal agent. Seed lots were visually evaluated for tubers exhibiting bacterial soft rot. Subsamples of the infected tubers were then processed and an attempt was made to isolate and identify the causal agent. The incidence of soft rot was quite low in the seed lot trials and tubers from Nooksack, Ranger Russet, Russet Burbank, and Shepody were subsequently sampled for the presence of bacterial soft rot. Only 14 bacterial isolates were obtained from tubers.

Isolates from Tubers	**Number of Isolates**
P. c. subsp. *carotovorum*	7
P. c. subsp. *atrosepticum*	1
P. chrysanthemi	6

Later in the season, isolates were obtains from infected potato stems from the seed lot trials.

Isolates from Black leg stems	**Number of Isolates**
P. c. subsp. *carotovorum*	2
P. c. subsp. *atrosepticum*	3
P. chrysanthemi	3

Finally, we did attempt to look at the problem of lenticel infection on potatoes. Samples were received from Dr. Inglis. All the samples received were incubated in moisture chambers for several weeks. No disease developed; therefore no isolates could be obtained or identified.

SUMMARY

The observed disease incidence was quite low in the seed lot trials. Samples were evaluated from Nooksack, Ranger Russet, Russet Burbank, and Shepody. However, *P. chrysanthemi* and *P. c.* subsp. *carotovorum* each accounted for 50 % of the isolates obtained.

The implication of the flower serving as a reservoir for the pectolytic bacteria is interesting. Bacteria are commonly associated with the flowers of the plants they infect. It is possible that the flower provides a nutrient rich environment where the pectolytic bacteria can reside and colonize, possibly providing an inoculum source. While this is interesting, it should be noted that this is preliminary data and further evaluation is necessary to confirm the results. In addition, because of time constraints, these bacteria were not fully identified. This would be necessary to further evaluate this phenomena.

This study indicates that the incidence of bacterial aerial stem rot and blackleg on Ranger Russet potatoes varies from field to field and is not dependent on the source of the irrigation water. Previous to this work, *P. chrysanthemi* was not reported to be present in the Pacific Northwest, or was reported to be present only at low percentages. During the 2002 growing season *P. chrysanthemi* accounted for 42 % of all the isolates obtained from tubers, stems and aerial portions of the potato plant. This provides more information indicating that a pathogen shift has occurred among the pathogenic soft rot bacteria in the Columbia Basin. *P. chrysanthemi* is more destructive than *P. c.* subsp. *carotovorum* and *P. c.* subsp. *atrosepticum,* and certain isolates can have a broader host range than either *P. c.* subsp. *carotovorum* or *P. c.* subsp. *atrosepticum*. This could have long ranging effects on potato, and corn production in the Columbia Basin.

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