Special Report

Cost of Fungicides Used to Manage Potato Late Blight in the Columbia Basin: 1996 to 1998

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ABSTRACT

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The cost of managing potato late blight with fungicides in the Columbia Basin of Washington and Oregon in 1996 to 1998 was documented and compared with the cost of managing the epidemic in 1995. Mean number of fungicide applications on late-season potatoes from 1996 to 1998 ranged from 5.3 to 8.8 in the north Columbia Basin of Washington and 8.5 to 12.3 in the southern basin of Washington and Oregon. Mean cost per hectare of fungicides and application on late-season potatoes in 1998 was $316 per hectare ($128 per acre) in Washington's north basin and $472 per hectare ($191 per acre) in Washington's south basin. Even though the price of most fungicides had increased since 1995, total cost of control per hectare over the season was less during 1996 to 1998 than in 1995 because of altered management practices. These included fewer fungicide applications, a shift toward lower cost fungicides, substitution of aerial application by chemigation, and a reduction in the number of fields chemically desiccated before harvest. Total cost of managing late blight and tuber rot loss was $22.3 million in 1998, whereas it was $30 million in 1995. The 1998 cost included $19.8 million for fungicide applications and materials, $1.1 million for canopy desiccation, and $1.4 million loss due to tuber rot in storage.

Economic impacts of plant diseases and the costs associated with managing them are often substantial (4,8,9). Such information is necessary in developing and implementing economical disease management strategies (4,5,13). Often, reliable, quantitative estimates of plant disease losses are not available (1,4,10).

Late blight of potato (*Solanum tuberosum*), caused by *Phytophthora infestans* (Mont.) de Bary, was first reported in the Columbia Basin of Washington and Oregon in 1947. It was reported next during 1974 and occurred in fields during 7 of 16 years between 1974 and 1989 (7). More recent outbreaks have occurred since 1990, with an especially severe epidemic in 1995. The persistence of the disease is likely due to several factors, including an aggressive population of *P. infestans* that is insensitive to the fungicide metalaxyl (11,12), higher than normal precipitation in the spring (7), widespread use of overhead sprinkler irrigation in this semiarid environment (7), and early planting of very susceptible cultivars such as Shepody and Russet Norkotah (3).

The Columbia Basin is a major potato growing area that produces 20% of the U.S. potato crop (15). Fungicide application and product cost associated with managing late blight on late harvested potatoes in 1995 was estimated from production records representing 38% of the potato production area to average $450 per ha ($182 per acre) (8). Total cost for managing late blight during 1995 in the entire region approached $30 million (8). As a result of these high costs, the potato industry has attempted to reduce costs of late blight management by integrating horticultural and fungicide application strategies. The purpose of this study was to document the costs and the evolving fungicide use and application patterns associated with managing late blight in this region since 1995.

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MATERIALS AND METHODS

The Columbia Basin was divided into three geographical regions: the north and south basin in Washington and the basin in Oregon (8). Potatoes are planted earlier and the growing season is longer in Oregon and the south basin in Washington than in the north basin in Washington. Because management resources expended on long-season, late-harvested potatoes exceed those on short-season, earlier harvested potatoes, the potato crop was further partitioned according to time of harvest. Potatoes harvested in July or August were classified as early- to mid-season, consisted primarily of the cultivars Russet Norkotah, Shepody, and Ranger Russet, and accounted for approximately 15,800 ha (39,000 acres) in the Washington basin (15). Potatoes harvested in September and later were classified as late season. Late-season potatoes, which accounted for approximately 45,000 ha (110,000 acres) (15), were predominantly the Russet Burbank cultivar.

The dominate genotype of *P. infestans* recovered from the Columbia Basin from 1995 through 1998 was US 8 (11). Late blight was first observed in the basin in 1995, 1996, 1997, and 1998 on 5 June, 3 July, 16 June, and 15 June, respectively. Late blight occurred in or adjacent to approximately, 65,000 ha in 1995, 32,000 ha in 1996, 48,000 ha in 1997, and 47,000 ha in 1998.

Following the 1996, 1997, and 1998 growing season, potato growers and crop consultants in Washington were interviewed or asked to provide field records of management practices and expenses incurred for late blight management. Number and method of late blight fungicide applications, type and rate of fungicide, and associated costs were recorded. When an individual grower reported on multiple fields for the same cultivar and harvest period, applications and cost were combined and averaged. The data base for the north and south basins included 51 growers with 5,988 ha (14,796 acres) in 1996, 45 growers with 2,475 ha (5,500 acres) in 1997, and 43 growers with 2,375 ha (5,863 acres) in 1998. In some situations in 1997 and 1998, individual growers did not provide the location of fields, and these were not included in the results separating the north and south basins of Washington. The data from these growers were used, however, for overall applications, costs, and fungicide use. Thirty-nine producers with 3,480 ha (8,616 acres) in 1997, and 27 with

3,835 ha (9,477 acres) in 1998 were in this category.

In Oregon, application data were obtained from six chemical supply dealerships only for 1998. The growing area represented more than 80% of the approximately 12,000 ha (29,000 acres) of potato in that region.

Fungicide cost was based on price of materials sold to growers and rates applied in fields. Comparison of costs among types of fungicides and percentage of change between 1995 and 1998 are shown in Table 1. Application costs were estimated at $5.50 per acre for ground and $7.00 per acre for air application. Ground and air application costs were based on cost of custom applications, which did not appreciably vary throughout the basin during the study. Estimates of mean application costs for chemigation ranged from $2.00 to $3.50 per acre. Variable factors influencing cost of chemigation included labor costs, costs of leasing, repairing equipment, and utilities. The higher estimate was used in the study so as not to undervalue the effect of chemigation on the overall cost of late blight management. Economic data are reported as dollars per acre, which can be converted to dollars per hectare by multiplying by 2.471.

RESULTS

In Washington, mean number of fungicide applications made only for late blight in 1998 on early- and mid-season potatoes was 5.9 for the entire Columbia Basin. Mean number of applications on late-season potatoes from 1995 to 1998 ranged from 5.3 to 8.8 in the north basin and 8.9 to 12.3 in the south basin (Table 2). In Oregon, mean fungicide applications on late-season potatoes ranged from 8.5 to 9.4 (Table 2). Except for the north basin in 1997, fewer applications were made from 1996 to 1998 than in 1995 (Table 2). Because mixtures of late blight fungicides were sometimes used, more than one type of late blight fungicide may have been applied during a single application.

Price per acre of individual fungicide product and prices among products varied and represented an increase from 1995 except for triphenyltin hydroxide and the mean for Section 18 materials (crisis exemption materials approved by the Environmental Protection Agency: propamocarb + chlorothalonil, dimethomorph + mancozeb, cymoxanil + mancozeb or chlorothalonil) (Table 1). Cost of triphenyltin hydroxide decreased due to reduced rates. Cymoxanil was marketed without a protectant after 1997, although the label required mixing with a protectant on site, and the price was lower thereafter.

Chlorothalonil and EBDC (ethylene bisdithiocarbamate) fungicides were used most frequently and accounted for approximately 70 to 80% of the fungicides applied from 1996 to 1998 (Table 3); whereas this usage was 59% in 1995 (8). A shift from chlorothalonil to EBDC fungicide use occurred from 1996 to 1998. Use of the Section 18 materials declined in 1996 and 1997 but returned to the 1995 level in 1998.

The metalaxyl mixtures are a combination of metalaxyl and a protectant fungicide, of which approximately equal applications of metalaxyl + chlorothalonil or metalaxyl + EBDC were applied in 1998. Although metalaxyl was not effective against *P. infestans* strains present in the Columbia Basin during this study, they were included in late blight application programs because the protectant component was targeted and effective against late blight. Metalaxyl was targeted against the tuber rots, pinkrot, and Pythium leak. However, only the protectant fungicide in the mixture was used to calculate the cost of fungicides for late blight control (Table 4).

In Washington in 1998, 59% of the applications were made by air and 37% by chemigation through center-pivot sprinkler irrigation systems. Ground applications accounted for 4% of the applications, and they were only applied before row closure

Table 2. Number of fungicide applications used for managing late blight on late-harvested potatoes in three areas of the Columbia Basin in Washington, 1995 to 1998

Fungicide applications per field[a]	North basin Washington	South basin Washington	All Washington[b]	Oregon Basin
1995				
Mean	8.2	12.3	10.0	9.4
Standard error	0.5	1.1	0.7	0.5
Sample size	16	12	28	23
1996				
Mean	5.3	8.9	6.8	8.7
Standard error	0.3	1.1	0.6	0.3
Sample size	13	9	22	3
1997				
Mean	8.8[c]	10.6	9.7	8.5
Standard error	–	0.7	1.0	1.3
Sample size	3[c]	20	62[d]	6
1998				
Mean	7.5	11.2	8.4	8.8
Standard error	0.6	0.8	0.4	1.0
Sample size	31	12	70[d]	10

[a] More than one fungicide may be present in an application.
[b] Mean of north and south Columbia Basin of Washington.
[c] Based on only three samples, where one sample was a consultant average of 20 fields.
[d] Additional management records added in 1997 (39) and 1998 (27) that were located in the basin but not designated to a region.

Table 1. Fungicide cost per acre for a single application in 1995 and 1998 and percent change between the 2 years[a]

Class of fungicide	1995 Mean cost	1995 Range	1995 SD	1998 Mean cost	1998 Range	1998 SD	% Change mean cost
Chlorothalonil	$8.87	$5.20-$13.41	$1.86	$10.72	$7.67-$16.88	$2.16	+21%
EBDC[b]	$6.02	$2.00-$9.07	$1.64	$6.92	$2.15-$7.32	$0.71	+15%
Copper[c]	$5.15	$3.63-$7.20	$0.88	$6.08	$4.08-$8.16	$1.98	+18%
Tin[d]	$6.19	$2.82-$7.50	$1.09	$4.55	$3.11-$6.21	$1.06	–26%[e]
Section 18[f]	$29.31	$14.30-$51.51	$9.41	$17.40	$13.40-$31.50	$7.47	–41%[g]
Metalaxyl mixture[h]	$26.39	$22.00-$33.54	$3.75	$29.74	$16.57-$41.43	$5.26	+13%

[a] Mean cost of fungicide per application based on grower reported cost of fungicide and use rates.
[b] Ethylene bis-dithiocarbamate (maneb, mancozeb) and metiram.
[c] Copper hydroxide.
[d] Triphenyltin hydroxide.
[e] Rates for an application decreased from approximately 3 oz/acre to 2 oz/acre.
[f] Propamocarb hydrochloride + chlorothalonil, dimethomorph + mancozeb, cymoxanil + mancozeb.
[g] Cost decrease due to price reduction in all Section 18 fungicides and shift to least expensive fungicide.
[h] Metalaxyl + chlorothalonil, metalaxyl + mancozeb, metalaxyl + copper hydroxide.

(Table 4). Mean cost per acre in 1998 for an application of fungicide (mean for method of application and products used) was $17.06 (Table 4). Mean cost per acre through the growing season in 1998 for fungicide application and materials on late-season potatoes was $128 in the north basin and $191 in the south basin.

Foliage of early- and mid-season potatoes intended for fresh pack are normally chemically killed before harvest to induce periderm maturation of tubers. Foliage of early- and mid-season potatoes for processing are generally not killed. Late-harvested potatoes are mainly stored, and foliage is usually only killed to prevent tuber infection due to *P. infestans*. Less than 30% of the late-harvested potato crop in the Washington basin was chemically killed in 1998, while more than 95% of the crop was killed in 1995 (8). The cost for vine killing 30% of the 1998 late-harvested crop was approximately $1.1 million.

Losses in storage due to late blight were not reported in 1996. Storage losses primarily due to late blight in 1997 included: 5,000 T (2,000 lb or 907.2 kg/t) of Russet Burbank tubers in the north basin and 300 T of Ranger Russet in the south basin. Storage losses due to late blight in 1998 included: 4,400 T of Bannock Russet potato tubers in the north basin, 2,500 T of Bannock Russet in the south basin, and 20% of 15,000 T of Russet Ranger were lost and 2,800 T had to be washed and dried before processing in the south basin. Dollar losses in storage using $95 per T for stored tubers were estimated at $500,000 in 1997 and $1.4 million in 1998.

DISCUSSION

The cost of managing late blight with fungicides continues to have a high impact on potato production in the Columbia Basin since our first report in 1995 (8). This is reflected in part by costs related to a decrease in the number of fungicide applications and an increased cost of materials. Mean cost of late blight fungicides plus application for a 125-acre field of late-season potatoes, based on mean cost per acre and mean number of applications, was approximately $21,000 in 1995 and $17,900 in 1998. The cost per field varied according to year and region based on disease pressure and number of applications. Even though the price of most fungicides has increased since 1995, total cost per acre was similar and overall total cost was less because of altered management practices. These included fewer fungicide applications per season, a shift toward lower cost fungicides, substitution of aerial application by chemigation, and foliage in fewer fields being chemically desiccated.

Fewer fungicide applications were needed to manage late blight in 1996 to 1998 in the south basin and in 1996 and 1998 in the north basin compared with 1995. Rainfall in April and May influences late blight development in the basin by providing favorable weather conditions for inoculum to multiply in fields containing infected volunteer potatoes, in cull piles, and in fields with infected seed, and for dissemination of sporangia to additional fields (7). During1997, the north basin had 20 rainy days in April and May at Othello, which was 13 more rainy days than in the south basin at Prosser, Washington. This resulted in an increase in disease pressure and required more fungicide applications in the north basin.

The relative severity of late blight epidemics was positively related to the date of first occurrence of late blight in the basin and total area affected by the disease. The epidemic in 1995 was more severe than in the other years, but the threat of late blight was high each year based on a late blight forecasting model (6). Effective management of late blight in sprinkler-irrigated fields requires early, consistent, and thorough applications of protectant fungicides. Once potato plants are infected following row closure, microclimatic conditions are generally favorable in the Columbia Basin for late blight development whenever the field is irrigated. Storage losses in 1997 and 1998 were traced to poor timing of fungicide applications and an increase in tuber susceptibility of the new cultivar, Bannock Russet (D. A. Johnson, *unpublished data*).

Another cost-attenuating practice was to alter the choice of fungicides to less expensive but effective fungicides. This has been the trend among growers since 1995. The protectant fungicides chlorothalonil and EBDCs were the most frequently used in the Columbia Basin from 1995 to 1998, constituting approximately 60 to 80% of the total fungicides applied for late blight management (Table 3). The cost of a single application of chlorothalonil was nearly 50% more than an EBDC application. The shift from chlorothalonil to EBDC fungicides in 1998 is evident (Table 3). Copper- and tin-based fungicides by themselves are not as efficacious and thus not recommended (by themselves) for management of late blight in the Columbia Basin.

The use of Section 18 materials decreased from 8% in 1995 to 1% in 1996 and returned to 8% in 1998. After 1995, growers realized from presentations in extension meetings that multiple applica-

Table 4. Comparison of method and mean cost per acre of fungicide application for late blight management on late potato in 1995 and 1998 in the Columbia Basin

	1995	1998
Ratio of air:chemigation:ground application	72:28:<1	59:37:4
Application method cost/acre [a] (SD)	$6.25 ($1.13)	$5.67 ($0.88)
Fungicide cost per application/acre [b,c,d] (SD)	$10.52 ($3.19)	$11.39 ($3.11)
Total mean cost one application/acre (SD)	$16.77 ($3.18)	$17.06 ($3.35)

[a] Cost of application method: air = $7 per acre, chemigation = $3.50 per acre, ground = $5.50 per acre.

[b] Mean cost of fungicide per application based on fungicide cost and use rate each year: 1995 = 28 growers with 280 applications, 1998 = 56 growers with 470 applications.

[c] More than one fungicide may be used in an application.

[d] Cost of metalaxyl component of prepack mixture was not included because metalaxyl was applied for pinkrot and Pythium leak on tubers.

Table 3. Percentage of late blight fungicide applications in the Columbia Basin in Washington State from 1995 and 1998 in which various products were used

Year (n = no. of applications)	Chlorothalonil	EBDC[a]	Copper[b]	Tin[c]	Section 18[d]	Metalaxyl mixture[e]
1995 (n = 400)[f]	36%	23%	15%	11%	8%	7%
1996 (n = 280)	40%	41%	5%	9%	1%	4%
1997 (n = 1,133)	37%	33%	12%	8%	4%	6%
1998 (n = 585)	28%	41%	4%	9%	8%	10%

[a] Ethylene bis-dithiocarbamate (maneb, mancozeb) and metiram.

[b] Copper hydroxide.

[c] Triphenyltin hydroxide.

[d] Propamocarb hydrochloride + chlorothalonil, dimethomorph + mancozeb, cymoxanil + mancozeb.

[e] Metalaxyl + chlorothalonil, metalaxyl + mancozeb, metalaxyl + copper hydroxide.

[f] Number of applications refers to total number of applications from all Washington surveys; each fungicide application in a class is counted regardless if applied by itself or mixed with other late blight fungicides.

tions of protectant fungicides could be applied at less cost than a single application of the Section 18 materials. In addition, early, consistent, and thorough applications of protectant fungicides was an effective control strategy.

The use of Section 18 materials returned in 1998, probably as a result of a price decrease in this class of materials. In 1995, the Section 18 fungicides used accounted for approximately 24% of the cost of all fungicides used; whereas in 1998, they accounted for 15% of the expense for all fungicides used (8). This price decrease was tied to the use of one of the Section 18 materials, Curzate (cymoxanil), which accounted for 78% of the usage in 1998. Acrobat (dimethomorph + mancozeb) accounted for 12% of the Section 18 usage in 1998 and Tattoo C (propamocarb + chlorothalonil) 10%. Curzate was the least expensive of the Section 18 fungicides in 1998, even with the labeled requirement of the additional protectant fungicides of an EBDC or chlorothalonil.

The method of fungicide application also was altered to reduce costs. The cost of application is approximately one-third of the total cost of a potato late blight fungicide program. Chemigation at $2.00 to $3.50 per acre is 30 to 50% of the cost of an air or ground application at $7.00 per acre. In 1995, three-quarters of all fungicide applications for late blight were applied by air; whereas in 1998, there was a marked decrease in air applications with a shift towards chemigation (Table 4). More initial fungicide is deposited on potato foliage by air than by chemigation, but fungicide application by chemigation appears from observations of disease severity in commercial fields to provide adequate control of late blight in the Columbia Basin (2).

Chemical desiccation of the potato canopy 2 to 3 weeks before harvest is useful in reducing potential tuber infections of potatoes that are stored. Nearly 87% of the potato crop in the Columbia Basin is processed, and a high percentage of these potatoes are stored. Canopy desiccation also facilitates harvest by reducing plant foliage. Foliage desiccation may reduce tuber yields by 5% (14) and cost approximately $34.00 per acre per application. This practice may not be as essential in the semiarid environment of the Columbia Basin as in areas with higher rainfall near harvest (D. A. Johnson, *unpublished data*). It should be noted that foliage of fields supplying tubers lost in storage in 1997 and 1998 were chemically desiccated before harvest. In 1998, approximately 30% of the late-season potatoes in the basin were chemically vine killed, while more than 95% of the late potatoes in the basin in 1995 were chemically vine killed (8). The savings of not chemically desiccating 65% of the late russet potato crop in 1998 is approximately $2.5 million.

The total cost of managing late blight in potatoes in the Columbia Basin in 1998 was $22.3 million. This was $7.7 million less than in 1995. The total cost of fungicide application and materials for control of late blight in 1998 was $19.8 million. Even with a 12% increase in potato acreage in 1998, this cost was only $1.7 million less than in 1995 (8). Mean cost per acre of fungicides and applications on late-season potatoes in 1998 ranged from $128 to $191. Expense for canopy desiccation of 30% of late-harvested potatoes in 1998 for late blight management was $1.1 million. Loss in storage due to tuber rot was $1.4 million in 1998. Costs not quantified, and assumed to be the same as in 1995, are added processor costs to manage storage that may have infected tubers.

These data present a valid argument for improving the level of late blight resistance in potato cultivars. The use of cultivars with improved partial resistance, which reduces the rate of late blight development on foliage and tubers, would reduce but not eliminate the dependence on fungicides. On-farm cost of managing the disease should then decrease. Improved host resistance, disease forecasting systems to schedule fungicide applications, and strict sanitation practices are needed to economically manage potato late blight.

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