Distribution and Persistence of Oxamyl in Oxamyl-Treated Seed Potatoes and in Plants Grown from Oxamyl-Treated Seed Potatoes

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A direct linear relationship between oxamyl concentration of treatment solutions and oxamyl deposit on soaked potato seed tubers (cv. Russett Burbank) was observed. Increasing the duration of soaking from 1 to 40 min had no effect on oxamyl deposit. No decrease in the oxamyl concentration of the treatment solutions was observed after the tubers were soaked. During 32 weeks of storage at 4 °C the concentration of oxamyl on the surface of treated seed tubers decreased by 62%. Oxamyl diffused into the potato tissue in low concentrations during storage. Potato plants grown from oxamyl-treated seed tubers both in pots and in the field were analyzed for oxamyl at intervals after planting. Concentrations of translocated oxamyl (in soil, foliage, and roots) were much higher in potted plants than in field plants. No oxamyl was found in the new tubers or in any plant parts or soil from field-grown plants at harvest.

Oxamyl is the active ingredient of the insecticide/nematicide Vydate L, which is registered in Canada for use on potato, *Solanum tuberosum* L., as a foliar spray against several insect pests. Treatment of potato seed tubers with oxamyl has been proposed (Townshend and Olthof, 1988) as an alternative to preplant fumigation for control of the root lesion nematode *Pratylenchus penetrans* Cobb, a primary plant-parasitic nematode associated with potato in Ontario (Olthof et al., 1982). Seed treatment offers the potential to target the application of nematicide where it will be most effective, while minimizing the total amount applied to the field. A greenhouse study (Townshend and Olthof, 1988) showed that by treating seed tubers in 32 mg/mL oxamyl and planting in pots containing *P. penetrans* infested soil nematode numbers were reduced in the soil by 73–86% and in the roots of young potato plants by 86–97%. Furthermore, this protection of root systems was observed throughout the 10-week duration of the experiment. Other greenhouse studies have shown oxamyl seed potato treatment to be effective in suppressing the development of *Globodera rostochiensis* cysts on roots (Brodie, 1983; Proudfoot and Morris, 1972) and the numbers of stunt and lance nematodes in soil and lesion nematodes in roots (Rodriguez-Kabana and Ingram, 1977).

The present work was undertaken as a follow-up to the greenhouse study (Townshend and Olthof, 1988) to determine the following: (a) the effect of concentration of the Vydate treatment solution and duration of soaking of tubers on the deposit of oxamyl on the treated tubers; (b) the difference in oxamyl deposit on cut and whole treated seed tubers; (c) the effect of the soaking of tubers on the oxamyl concentration of the Vydate treatment solution; (d) the concentration of oxamyl translocated into the flesh of stored treated seed tubers as a function of storage duration; (e) the persistence of oxamyl residues on treated tubers in storage; and (f) the distribution of oxamyl in potato plants grown from treated tubers in pots and in the field as a function of time.

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MATERIALS AND METHODS

Treatment of Seed Tubers. Vydate treatment solutions of approximately 2, 8, and 32 mg/mL oxamyl were prepared by diluting 4, 16, and 64 mL of Vydate L, respectively, to a final volume of 500 mL with water. Four whole Russet Burbank seed tubers (mean weight 44 g) were soaked in each of the solutions for 20 min and then removed from the solution and placed on a 6.4-mm mesh screen over a drip tray to dry for 1 h. Each tuber was then weighed, extracted, and analyzed by high-performance liquid chromatography (HPLC) as outlined below.

Six whole tubers and six tubers with one cut face (mean weight 27 g) were soaked for 20 min in 32 mg/mL oxamyl. The tubers were allowed to dry for 1 h as above and then extracted and analyzed.

Twenty whole seed tubers (mean weight 41 g) were added to a 32 mg/mL oxamyl solution, and four tubers were removed for drying and extraction at each of the following intervals: 1, 5, 10, 20, and 40 min. This experiment was repeated by using 20 tubers (mean weight 27 g), each having one cut surface.

Three 1-mL aliquots were obtained from each of the Vydate treatment solutions of the above experiments both before and after the tubers were soaked and analyzed by HPLC.

Persistence and Redistribution of Oxamyl in Stored Treated Tubers. Several whole tubers were soaked in 32 mg/mL oxamyl for 20 min. After the tubers had dried, an initial sample of five cores was obtained from one tuber as outlined below. The remaining tubers were then placed in a double paper bag and stored in a cold room at 4 °C. Individual tubers were removed from the bag for sampling of cores after 2, 4, 8, 16, and 32 weeks. The total storage period approximates the normal storage period for seed potatoes from harvest to planting.

Cores were obtained as follows. Each tuber was halved by cutting a groove around the middle to a depth of about 6 mm and twisting the halves apart, thus avoiding knife contact with the center of the tuber. A 1.9-cm-diameter core was taken starting from the inner surface and moving outward toward the skin surface, and the core was then pushed through the corer so as not to contaminate the untreated portion of the core. The cores were frozen prior to slicing to make them rigid. The inside surface of each core was fixed to the specimen block of an American Optical Model 815 Microtome using a Bailey Instruments Tissue-Freez apparatus and Tissue-Tek O.C.T. compound (Miles Scientific). Starting at the outside (skin) surface of the core, 2-mm-thick slices were cut from the core. The microtome blade was rinsed thoroughly with methanol between slices to remove any residues of oxamyl.

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Distribution of Oxamyl in Potato Plants Grown from Oxamyl-Treated Seed Tubers. Experiments were performed in the field and in pots placed in the greenhouse. For the field study, 20 cut seed tubers (average weight 66 g) were soaked for 20 min in 32 mg/mL oxamyl and 4 in water only. The tubers were allowed to dry on a screen. Four treated tubers were analyzed to determine the initial oxamyl deposit. Sixteen treated and four untreated tubers were planted in about 10 kg of sandy loam soil at a depth of 13 cm in clay tiles (30 cm × 20 cm i.d.) which had been buried in a field (Olthof et al., 1985). After 25, 40, 73, and 132 days, plants and soil from four treated and one untreated tubers were removed from their tiles. The samples were separated into the following fractions: soil, roots, seed piece, above-ground portion (foliage), and new tubers. The soil was sieved to remove small root fragments, and a 200-g subsample was placed in a 1-qt Mason jar. Roots, seed pieces, and new tubers (100-g subsample maximum) were placed in separate Mason jars. The smaller of either the entire foliage sample or a 50-g subsample was placed in a Mason jar. Samples were frozen until they could be extracted and analyzed.

For the greenhouse study, 20 cut seed tubers were treated for 20 min in 32 mg/mL oxamyl. The average weight of the tubers was 46 g to correspond with the weight of tubers used in the previous greenhouse study (Townshend and Olthof, 1988). Fifteen of the treated tubers were planted in about 1.3 kg of sandy loam soil in clay pots (15 cm diameter × 13 cm high) and placed in the greenhouse. Five treated tubers were saved for determination of initial oxamyl deposit. The contents of five pots were sampled after 27, 40, and 70 days to approximately correspond with the sample dates of the field study and to match the duration of the previous greenhouse study. Samples were taken as in the field study.

Extraction and Analysis Techniques. Foliage, seed tuber, and new tuber samples were cut into small pieces and extracted with methanol (HPLC grade, Baker) by using a Polytron homogenizer (Brinkman Instruments). Core slices were extracted in scintillation vials by adding 4.5 mL of methanol and allowing the slice to soak for 1 h.

Root samples were extracted twice by soaking overnight in methanol. The extracts were analyzed separately and the results added. A third extraction of the 25-day field root samples recovered a negligible amount of oxamyl (only 0.3% of the total recovered). If no oxamyl was found in the first extract, the sample was not extracted a second time. All extracts except 0-day seed piece extracts were cleaned up on small columns containing 0.2 g of Nuchar Attaclay (Supelco Canada) (McGarvey et al., 1986).

Recovery tests were performed to validate the extraction and cleanup procedures. Four control seed potatoes were spiked with 300 μg of oxamyl and extracted and cleaned up as described previously. The mean recovery from the four spiked samples was 90.3% [coefficient of variation (CV) = 4.5%]. Five 200-g samples of control soil were spiked with 20 μg of oxamyl and extracted and cleaned up as previously described. The mean recovery of oxamyl was 93.6% (CV = 6.7%). The extraction procedure for core slices was evaluated by using slices of two cores from one treated tuber. Each slice was extracted twice, the second time with maceration of the slice using a spatula. The mean recovery of oxamyl in the second extraction was only 7.8% of the total oxamyl recovered in both extractions, indicating that one extraction provides an adequate recovery of oxamyl.

Samples were analyzed by HPLC using a Hewlett-Packard 1090 LC followed by either a conventional two-stage postcolumn reactor or a simplified single-stage postcolumn reactor and a Kratos FS970 fluorescence detector (McGarvey, 1989). A 25 × 0.46 cm Spherisorb ODS2 5-μm column (Chromatography Sciences Co., Montreal, or Phenomenex, Torrance, CA) was used with an isocratic mobile phase consisting of 20% acetonitrile in water (both HPLC grade, Baker) at a flow rate of 1.0 mL/min.

RESULTS

Treatment of Seed Tubers. The amount of oxamyl deposited on treated tubers was directly proportional [correlation coefficient (r) = 0.9998] to the oxamyl concentration of the Vydate treatment solution (Table I).

Table I. Amount of Oxamyl Deposited on Treated Seed Potatoes (Milligrams per Tuber) Relative to Oxamyl Concentration of Vydate Treatment Solution (Milligrams per Milliliter)

oxamyl concn of Vydate treatment solution, mg/mL	oxamyl deposited on treated seed potatoes, mg/tuber	(CV)
2.11	0.96	(11.8%)
8.34	3.6	(7.4%)
33.5	13.1	(10.2%)

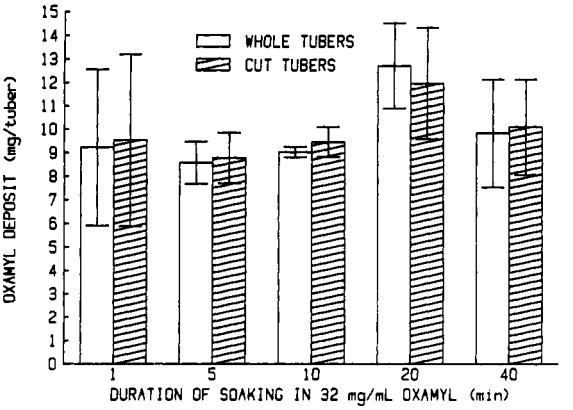

Figure 1. Duration of soaking (minutes) in 32 mg/mL oxamyl vs oxamyl deposit (milligrams/tuber) on whole and cut seed tubers. Bars indicate ± 1 standard deviation.

Table II. Concentration of Oxamyl in Vydate Treatment Solutions before and after Treatment of Seed Tubers

experiment	expected concn, mg/mL	actual concn,[a] mg/mL (CV) before	actual concn,[a] mg/mL (CV) after
effect of	2	2.11 (1.4%)	2.12 (0.7%)
concentration of	8	8.34 (1.0%)	8.40 (1.0%)
treatment solution	32	33.5 (1.6%)	33.4 (0.4%)
whole vs cut tubers	32	30.7 (9.4%)	30.8 (10.8%)
effect of duration	32	34.7 (2.1%)	34.8 (1.8%)
of soaking	32	32.3 (2.5%)	32.4 (1.5%)

[a] Mean of three aliquots.

The mean amounts of oxamyl deposited on individual whole and cut tubers soaked in 32 mg/mL oxamyl for 20 min were 5.8 (CV = 28.6%) and 16.2 mg (CV = 7.9%), respectively.

The amount of oxamyl deposited on tubers treated with 32 mg/mL oxamyl did not increase with duration of soaking (Figure 1).

No decrease in oxamyl concentration of the Vydate treatment solution was observed after the potato tubers were soaked (Table II). The slight observed increase after soaking was probably due to concentration by evaporation.

Persistence and Redistribution of Oxamyl in Stored Treated Tubers. Where necessary, individual replicates of core slice samples were rejected as outliers on the basis of Dixon's test (Caulcutt and Boddy, 1983) at the 5% significance level. A plot of the mean oxamyl concentration on the first slice (skin surface) of cores removed from treated potato tubers versus the time the tubers had been in storage showed a strong linear correlation (r = −0.90) with a slope of −2.0 μg cm^{-2} week^{-1} (Figure 2). The mean for week 4 was rejected as an outlier on the basis of Dixon's test on the residuals of the regression line at the 1% significance level. The surface residue after 32 weeks of storage was 62% less than the initial deposit.

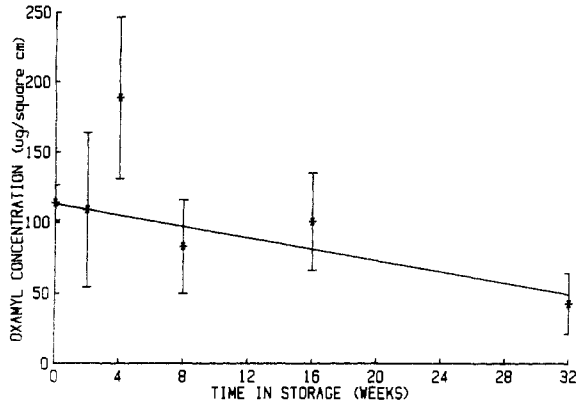

Figure 2. Time of storage of treated whole seed potatoes (weeks) vs mean concentration of oxamyl on first slice (skin) of cores removed from treated potatoes ($\mu g/cm^2$). Bars indicate ± 1 standard deviation.

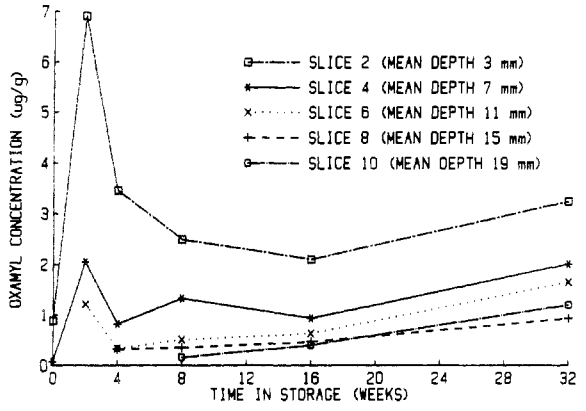

Figure 3. Time of storage of treated whole seed potatoes (weeks) vs mean concentration of oxamyl found in 2-mm slices obtained at five depths from cores removed from treated potatoes (micrograms per gram). On week 8 only, the mean depths of slices 4, 6, 8, and 10 were 6, 10, 14, and 18 mm, respectively.

At a mean depth of 3 mm in treated tubers the mean oxamyl concentration increased from 0.9 to 6.9 $\mu g/g$ during the first 2 weeks, then declined during the next 6 weeks, after which time there was no significant change (Figure 3). At a mean depth of 7 mm the oxamyl concentration showed a substantial increase during the first 2 weeks and a decline during the next 2 weeks, after which time there was a slight linear increase at the 1.3% significance level. The concentrations at the remaining depths exhibited a slight linear increase with time after the fourth week at the 0.5% level of significance.

Distribution of Oxamyl in Potato Plants Grown from Oxamyl-Treated Seed Tubers. From an initial level of 388 $\mu g/g$ the oxamyl concentration in the treated seed pieces planted in the field declined exponentially with time (Table III); a plot of log oxamyl concentration vs time yielded a straight line ($r = -0.9967$, slope = −0.031). The remaining plant parts and soil showed a continuous decrease in oxamyl concentration from a maximum in the first available sample. This decrease was most rapid in the foliage. The maximum observed concentration of oxamyl in the roots was 6.0 $\mu g/g$ in the first available sample. Oxamyl was not detected in any of the new tuber samples or in any of the plant parts or soil at harvest (132 days).

The oxamyl concentration of the potted seed pieces in the greenhouse declined exponentially as in the field (Table IV), but at a slower rate (slope of log oxamyl concentration vs time = −0.023). Concentrations of translocated oxamyl (i.e., in foliage, roots, and soil) were much higher in potted samples than in field samples. A low concentration of oxamyl was also found in new tubers after 70 days.

Plants grown in the field were much larger than those grown in greenhouse pots. The ratio of mean weight of field-grown plants over mean weight of greenhouse plants (excluding seed piece) ranged from 3 (at 4 weeks) to 28 (at 10 weeks).

DISCUSSION

The results of analyses of core slices obtained immediately after treatment indicate that there was very little penetration of the skin by oxamyl during soaking. The concentration of oxamyl in the second slice (mean depth 3 mm) amounted to only 0.2% of the concentration found on the outer slice (skin). Also, extending the duration of soaking from 1 to 40 min did not appear to influence the deposit of oxamyl on either cut or whole tubers. This suggests that even on a cut surface, oxamyl did not penetrate substantially into the potato tissue during soaking. However, in spite of the smaller size of the cut tubers, the amount of oxamyl deposited on them was the same as that deposited on the whole tubers (Figure 1), suggesting that more oxamyl was deposited on a cut surface than on a skin surface. This conclusion is substantiated by the fact that more than twice as much oxamyl was deposited on cut tubers as on whole tubers of similar weight when they were soaked in 32 mg/mL oxamyl for 20 min.

The fact that the concentration of oxamyl in the Vydate treatment solution was not reduced by the soaking of tubers in the solution is further evidence that the treatment solution merely coated the surface of the potato and that oxamyl was not preferentially absorbed by the tuber from the solution. This is consistent with the linear relationship between concentration of the treatment solution and the deposit of oxamyl found on treated tubers. It would therefore be unnecessary to add additional Vydate to a bulk treatment solution in a commercial operation to restore the oxamyl concentration to the initial concentration after some tubers had been treated.

The bulk of the oxamyl residue remained on the skin surface of treated whole tubers in storage throughout the storage period. In the initial sample, about 99.7% of the total oxamyl found was on the first 2-mm slice. After 32 weeks of storage, about 95% of the total oxamyl found was in the first slice. The 62% decline in surface residue during storage suggests that, in the absence of other reasons to do so, it would not be recommended to treat seed tubers prior to storage due to the reduced protection available at planting.

Oxamyl migrated into the tissue of seed potatoes in low concentrations during storage. The highest observed mean concentration (6.9 $\mu g/g$) occurred at a mean depth of 3 mm after 2 weeks of storage. A substantial increase in concentration in the tissue near the skin (to a mean depth of 11 mm) during the first 2 weeks was followed by a significant decrease, after which the concentration increased slowly. Oxamyl moved slowly into the deeper tissue for the duration of the storage period.

Oxamyl diffused into soil and was translocated into the roots and foliage of potato plants grown from Vydate-treated seed tubers both in pots and in the field. In general, most of the oxamyl recovered was found in the soil, followed by the seed piece, foliage, and root. In a previous study, oxamyl absorbed by potato tissue from an aqueous treatment solution was found to be free to diffuse out when the tissue was transferred to oxamyl-free medium (Peterson et al., 1978). Since the oxamyl in field soil was distributed in about 10 kg of soil, the average soil

Table III. Distribution of Oxamyl in Potato Plant Parts and Soil at Time Intervals after the Planting of Vydate-Treated Seed Tubers in Field Microplots

		days after planting				
	unit	0	25	40	73	132
seed piece	μg/g[a]	388 ± 57	43 ● 10	16 ± 7.9	2.0 ± 3.0	nd[f]
	μg[b]	26070 ± 4010	2893 ± 689	1128 ± 509	120 ± 199	
	%[c]		42.8	40.4	21.8	
	%[d]	100	11.1	4.3	0.5	
foliage	μg/g	na[g]	12 ± 3.3	0.8 ± 0.4	nd	nd
	μg		510 ± 237	137 ± 84		
	%		7.5	4.9		
	%		2.0	0.5		
root	μg/g	na	6.0 ± 2.6	1.2 ± 0.56	0.01 ± 0.02	nd
	μg		53 ± 20	25 ± 11	0.28 ± 0.55	
	%		0.8	0.9	0.05	
	%		0.2	0.1	0.001	
soil	μg/g	na	0.33 ± 0.09	0.15 ± 0.08	0.04 ± 0.03	nd
	μg		3300 ± 890	1500 ± 800	430 ● 270	
	%		48.8	53.8	78.2	
	%		12.7	5.7	1.6	
new tubers	μg/g	na	na	nd[e]	nd	nd
total	%[d]	100.0	28.9	11.9	2.3	

[a] Oxamyl concentration (micrograms per gram) ± standard deviation, mean of four replicates. [b] Total amount of oxamyl in sample (micrograms) ± standard deviation, mean of four replicates. [c] Average percentage of total oxamyl recovered from plant parts and soil. [d] Average percentage of total oxamyl initially applied to seed piece. [e] One replicate only, detection limit approximately 0.1 μg/g. [f] nd, not detected, detection limit approximately 0.02 μg/g. [g] na, not available.

Table IV. Distribution of Oxamyl in Potato Plant Parts and Soil at Time Intervals after the Planting of Vydate-Treated Seed Tubers in Greenhouse Pots

		days after planting			
	unit	0	27	40	70
seed piece	μg/g[a]	669 ± 138	74 ± 37	42 ● 15	16 ± 12
	μg[b]	30280 ± 4850	3749 ± 1762	1898 ± 801	707 ± 496
	%[c]		35.2	32.4	54.8
	%[d]	100	12.4	6.3	2.3
foliage	μg/g	na[e]	49 ± 29	18 ± 14	1.9 ● 0.9
	μg		256 ± 211	522 ± 156	150 ± 47
	%		2.4	8.9	11.6
	%		0.8	0.2	0.5
root	μg/g	na	16 ± 13	7.0 ± 2.7	0.75 ± 0.51
	μg		135 ± 111	66 ± 36	13.3 ± 9.0
	%		1.3	1.1	1.0
	%		0.4	0.2	0.04
soil	μg/g	na	4.9 ± 1.2	2.0 ● 0.9	0.33 ± 0.21
	μg		6525 ± 1286	2769 ± 1255	415 ± 265
	%		61.2	47.3	32.2
	%		21.5	9.1	1.4
new tubers	μg/g	na	na	na	0.38 ± 0.29
	μg				4.24 ± 3.26
	%				0.3
	%				0.01
total	%[d]	100.0	35.2	19.3	4.3

[a] Oxamyl concentration (micrograms per gram) ± standard deviation, mean of five replicates. [b] Total amount of oxamyl in sample (micrograms) ● standard deviation, mean of five replicates. [c] Average percentage of total oxamyl recovered from plant parts and soil. [d] Average percentage of total oxamyl initially applied to seed piece. [e] na, not available.

concentrations were quite low. However, oxamyl was probably not distributed evenly in the soil, and the concentration in the vicinity of the seed piece and the roots may have been considerably higher. Both in the field and in pots, the amount of oxamyl recovered from the roots, as a percentage of the total found in the plant and soil, was only about 1%. Peterson et al. (1978) found that 12 days after foliar application of oxamyl to potato plants, about 15% of the oxamyl found on the plants was in the roots. This may indicate that the potato seed treatment technique is less efficient than foliar treatment as a means of applying oxamyl to the target area.

The initial oxamyl concentration (in micrograms per gram) on seed tubers planted in pots was 72% higher than that on the tubers planted in the field. This was largely due to the greater relative surface area of the smaller potted tubers. The total amount of oxamyl per tuber (in micrograms) on the potted tubers was only 16% higher than that on tubers planted in the field. The concentrations of oxamyl found in roots, foliage, and soil of potted plants, however, ranged from 3 to 75 times greater than those found in field-grown plants.

The higher concentrations of translocated oxamyl found in potted samples were probably due both to the much lower volume of soil available in a pot than in a field tile and to the smaller size of potted plants. The oxamyl concentration in the soil was diluted much less in a pot than in a field tile, and the oxamyl available for uptake by the roots and translocation to the foliage in a potted plant was therefore much greater in amount and closer in proximity to the roots. Similarly, the smaller size of potted greenhouse plants would lead to less dilution of oxamyl

in the plant and result in higher concentrations. This probably also accounts for the presence of oxamyl in the new tubers of potted plants after 70 days. The absence of oxamyl in the field-grown tubers is consistent with other field studies in which potato plants were treated with oxamyl (Harvey et al., 1978; Olthof et al., 1985) and indicates that the seed-treatment technique would pose no hazard to consumers.

CONCLUSIONS

Oxamyl coated the surface of potato tubers soaked in a treatment solution; more was deposited on a cut surface than on an intact skin surface. Soaking tubers for 1 min resulted in the same oxamyl deposit as soaking for 40 min. The oxamyl concentration of the treatment solution was not reduced by soaking of tubers, so a tank solution for bulk treatment of tubers would not have to be periodically replenished with oxamyl to maintain the desired oxamyl concentration. Treatment of tubers immediately before planting would be preferable to treatment prior to storage due to reduction in oxamyl concentration during storage. Tuber treatment was not an efficient means of delivering oxamyl to roots. Treatment of seed tubers would not present a risk of excess residue in tubers produced from treated seed potatoes.

Further field studies on oxamyl seed treatment of potatoes are in progress.

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