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The Influence of Metam Sodium (Vapam) and 1,3-dichloropropene (Telone II) on Russet Potato Yield and Potato Early Dying Suppression in 2011

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Introduction

This study was established to evaluate the influence of fumigation and potato variety on potato yield and disease incidence. It was conducted in a field with a history of early-dying. *Verticillium dahliae* is considered the primary causal agent of early dying. The study was a split-plot design. Whole-plot treatments were metam sodium and/or 1,3-Dichloropropene applied in fall 2010 at different rates. In spring 2011, three russet potato varieties with varying susceptibility to early dying were planted in each fumigation plot. Potato varieties included: Russet Norkotah (highly susceptible to early-dying), Russet Burbank (moderately susceptible to early dying), and Classic Russet (moderately resistant to early-dying). Fumigation and variety treatment combinations were replicated five times. Data included pre and post-fumigation *Verticillium* colony forming units in the soil, foliar and tuber disease severity ratings, tuber yield, tuber size, and tuber quality evaluations. Potato pack-out revenue minus fumigation cost was calculated for each fumigation and variety combination. All plots were managed the same with regard to irrigation, fertilization, and insect/weed management. NO fungicides were applied to the study site.

General Trial Information

Location:	IREC, Tulelake, CA
Soil Type:	Tulebasin mucky silty clay loam
Planting Date:	May 27, 2011
Vine Kill Date:	September 15, 2011
Days to Vine Kill:	111 days
Harvest Date:	October 14, 2011
Irrigation:	Solid-set sprinklers

Plot Size: 4 beds (12 ft) wide by 25 ft long (2 center rows were harvested for yield)

In-Row Spacing: 11.3 inches

Row Spacing: 36 inch wide rows

Number of Reps: 5 replications

Fertilizer per acre: 202 lbs N – 80 lbs P_2O_5 – 48 lbs K_2O – 10 lbs S

Fall Fumigation Application Information

Metam Sodium (Vapam) Fumigation Date: 10/10/10

Vapam application soil temperature and soil moisture: 60.5°F at 6 inch depth; adequate soil moisture as tested by look and feel method.

Vapam application method: Spay boom mounted in front of a rotary tiller that immediately incorporated the Vapam in the top 6 inches of soil. The soil surface was compacted with a roller immediately after incorporation.

1,3-dichloropropene (Telone II) Fumigation Date: 11/4/2010

Telone II application soil temperature and soil moisture: 50°F at 6 inch depth; adequate soil moisture.

Telone II application method: Shank-injected using chisels set at an 18 inch soil depth with injection points laterally spaced 13 inches apart.

Potato Pack-Out Revenue Assumptions

IREC Grade Size	Market/Packaging	4 yr Price Avg. $/cwt	Packaging & Handling Cost $/cwt
4-8 oz tubers	20% to 90 & 100 count	14.13	5.75
	80% to 10 lb. poly bags	9.15	5.75
8-12 oz tubers	70, 80, 90 count	16.45	5.75
>12-20 oz	50 & 60 count	17.33	5.75
<4 oz and culls	Bulk culls	1.15	5.75
No. 2	100 lb burlap sacks	8.60	5.75

Fumigation Cost Assumptions

Fumigant	Cost Assumptions
Metam Sodium (Vapam HL)	$5.10 per gallon; $71 per acre application cost
1,3 dichloropropene (Telone II)	$14.90 per gallon; $40 per acre application cost

Results

Potato yield, tuber size distribution, plant stand, tubers per plant, average tuber size, and pack-out revenue for each variety and fumigation combination are presented in Table 1.

Vapam at certain rates increased total potato yield for all three varieties. Russet Norkotah showed a greater yield response to Vapam averaged across Vapam rates. Russet Norkotah total yield increased 33 cwt/A and average tuber weight increased 0.725 ounces compared to the untreated control. Russet Burbank total yield increased 18.75 cwt/A and average tuber weight increased 0.5 ounces compared the untreated control. Classic Russet total yield increased 9.75 cwt/A and average tuber weight increased 0.15 ounces compared to the untreated control. These differences are related to the varieties' susceptibility to early dying.

When comparing Vapam rate, the 56.25 gal/A rate produced the highest yield for all varieties while the 18.75, 37.5, and 75 gal/A rates produced similar yields (Table 1). The reason total yield decreased at the 75 gal/A rate compared 56.25 gal/A is unknown. Early season potato phytotoxicity was not observed in any plot. One explanation is the 75 gal/A rate killed more beneficial microorganisms compared to the lower Vapam rates, but other microorganism populations were not measured.

Regression analysis of Vapam rate and US No. 1 yield for all varieties had a low R^2 value suggesting a large amount of unexplained variability (Figure 1). The unexplained variability may be related to the large difference in pre-fumigation *Verticillium* soil inoculum levels throughout the trial area. Pre-fumigation *Verticillium* inoculum levels in the soil varied by more than 150 colony forming units across treatments and replication (Table 2). *Verticillium* inoculum levels in the soil also varied by more than 150 colony forming units within untreated control plots (data not shown).

Spring post-fumigation *Verticillium* inoculum levels in the soil for all fumigation treatments were not statistically different from the untreated control, although numerically the 75 gal/A rate of Vapam had less than half the inoculum compared to other treatments (Table 2). None of the fumigation treatments were capable of "crashing" soil *Verticillium* inoculum unlike trials conducted on sandy soil types.

The high rate of Telone and high rate of Telone + Vapam increased potato yield for all three potato varieties (Table 1). Similar to Vapam, Russet Norkotah showed the greatest yield response to Telone when comparing varieties. Both rates of Telone and both rates of Telone + Vapam increased Russet Norkotah total yield, US No. 1 yield, and average tuber size. The high rate of Telone and both rates of Telone + Vapam increased total yield for Russet Burbank and Classic Russet.

Potato revenue after subtracting fumigation cost for all Vapam rates and varieties is shown in Table 1 and Figure 2. Vapam treatments that significantly increased potato revenue after subtracting fumigation cost were Vapam at 18.75 and 56.25 gal/A in Russet Norkotah plots (Figure 2). Russet Burbank and Classic Russet pack-out revenues at all Vapam rates were similar or lower than the untreated control after subtracting fumigation costs (Figure 2). Pack-out revenues for all tested rates of Telone and Telone + Vapam were similar to the untreated control for all varieties after subtracting fumigation cost (Table 1).

The incidence of Verticillium wilt symptoms differed greatly between varieties averaged across fumigation treatments (Table 3). As expected, Russet Norkotah was the most susceptible, Russet Burbank was moderately susceptible, and Classic Russet was the least susceptible. Visual differences in the incidence of Verticillium wilt symptoms did not differ between fumigation treatments within individual varieties (Table 4).

Rhizoctonia (black scurf) coverage on tuber surfaces, tuber stem-end necrosis, and tuber vascular discoloration were evaluated post-harvest (Table 4). Fumigation did not decrease the incidence or severity of black scurf compared to the untreated control. Several fumigation treatments decreased the incidence of stem-end necrosis, but the effect was not consistent across varieties or fumigation rates.

Summary

Vapam and Telone II alone and in combination increased potato yield and average tuber size for all varieties. The economic benefit (increased revenue after subtracting fumigation cost) was dependent on variety with the greatest benefit occurring with the more susceptible varieties. Russet Norkotah pack-out revenue after subtracting fumigation cost increased at Vapam rates of 18 gal/A and 56 gal/A compared untreated control. In contrast, Russet Burbank and Classic Russet pack-out revenue after subtracting fumigation cost was similar or lower compared the untreated control at all Vapam rates. These results suggest variety choice is an important factor when deciding whether fumigation is economical. Results also suggest choosing a variety with low susceptibility to Verticillium wilt is an effective option for minimizing yield loss associated with early-dying. Vapam and Telone II did not decrease visual Verticillium wilt symptoms, *Verticillium* inoculum levels in the soil, and Rhizoctonia (black scurf) coverage on tubers compared to the untreated control. The experiment will be duplicated in 2012 with the same varieties and fumigation treatments.

Special Thanks to the California Potato Research Advisory Board for funding support and Mike Davis, UC Davis Plant Pathologist, for analyzing soil samples for Verticillium colonies in the soil.

Table 1. Influence of Fall-Applied Fumigants on Russet Norkotah, Russet Burbank, and Classic Russet Tuber Yield, Stand, and Revenue at IREC in 2011.

			Tuber Yield (cwt/A)											
			U.S. No. 1's (cwt)											
Variety[1]	Vapam[2] gal/A	Telone II[3] gal/A	Total 1's	12-16oz	8-12oz	4-8oz	<4oz	>16oz	Culls + 2's	Total	Plants/ Plot[4]	Tubers/ Plant	Avg Tuber Size (oz)	Potato Revenue $/A[5]
Norkotah	0	0	221	37	75	109	38	25	36	320	47	5.4	6.5	$1,894
	18.75	0	233	56	88	89	26	39	49	347	47	4.9	7.8	$2,238
	37.5	0	238	55	86	97	31	38	38	344	46	5.4	7.1	$2,056
	56.25	0	282	68	105	108	33	37	29	380	47	5.7	7.2	$2,351
	75	0	253	62	95	96	37	15	38	341	46	5.7	6.8	$1,730
	0	20	254	53	94	107	33	45	31	363	47	4.9	7.3	$2,138
	0	25	259	68	85	107	36	38	52	385	45	6.0	7.3	$2,096
	18.75	15	255	66	91	97	33	36	49	374	46	5.5	7.6	$2,071
	37.5	20	260	57	101	101	34	40	40	374	46	5.7	7.3	$1,957
Burbank	0	0	296	39	116	141	45	14	40	395	47	6.8	6.4	$2,373
	18.75	0	322	46	134	142	37	18	39	416	45	6.9	6.9	$2,534
	37.5	0	276	49	100	127	38	27	59	401	47	6.2	7.0	$2,188
	56.25	0	328	55	124	148	35	38	44	445	47	6.6	7.4	$2,619
	75	0	289	30	102	157	48	16	40	393	46	6.9	6.3	$1,726
	0	20	296	49	107	141	44	14	46	400	48	6.5	6.7	$2,033
	0	25	316	58	116	143	47	21	52	437	46	7.1	6.8	$2,248
	18.75	15	316	58	126	131	37	20	64	436	47	6.5	7.3	$2,335
	37.5	20	322	62	123	137	37	34	44	436	46	6.7	7.2	$2,343
Classic	0	0	330	43	138	149	29	7	35	401	45	6.6	6.9	$2,640
	18.75	0	329	49	132	148	25	13	43	409	46	6.4	7.2	$2,558
	37.5	0	322	38	140	144	30	9	39	400	45	6.5	7.0	$2,337
	56.25	0	360	69	138	153	33	13	33	439	48	6.7	7.0	$2,655
	75	0	316	50	118	147	30	9	40	395	45	6.4	7.0	$2,068
	0	20	341	54	132	154	32	14	33	419	46	6.6	7.1	$2,449
	0	25	359	59	150	150	32	17	40	448	45	7.1	7.2	$2,646
	18.75	15	341	54	148	139	28	17	55	441	46	6.5	7.6	$2,506
	37.5	20	356	53	156	147	31	20	41	447	45	7.0	7.2	$2,488
95% confidence interval			23	14	15	13	6	12	12	25	1	0.4	0.4	$322

[1] Russet Norkotah has high susceptibility to potato early dying; Russet Burbank has moderate susceptibility to potato early dying; Classic Russet has low susceptibility to potato early dying.

[2] Vapam (metam sodium) was applied on 10/10/10 via spray boom mounted immediately in front of a rototiller that incorporated the metam sodium in the top 6 inches of soil. Soil temp. was 60.5 degrees F at 6 inch depth. Soil moisture was within label guidelines.

[3] Telone II (1,3-dichloropropene) was applied on 11/4/2010 via shank-injection using chisels set at a 18 inch soil depth with injection points laterally spaced 13 inches apart. Soil temp. was 50.1 degrees F at 6 inch depth. Soil moisture was within label guidelines.

[4] Seed spacing was 11.3 inches for both varieties.

[5] Revenue per Acre = Gross Revenue using the 4 year average for Columbia Basin Carton and Bag Prices - $5.75/CWT Packing and Handling Charges - Fumigation Cost (Vapam = $5.10/gallon + $71/A application cost; Telone II $14.90/gallon + $40/A application cost)

Figure 1. Influence of Fall-Applied Vapam Rate on US No. 1 Potato Yield at IREC in 2011

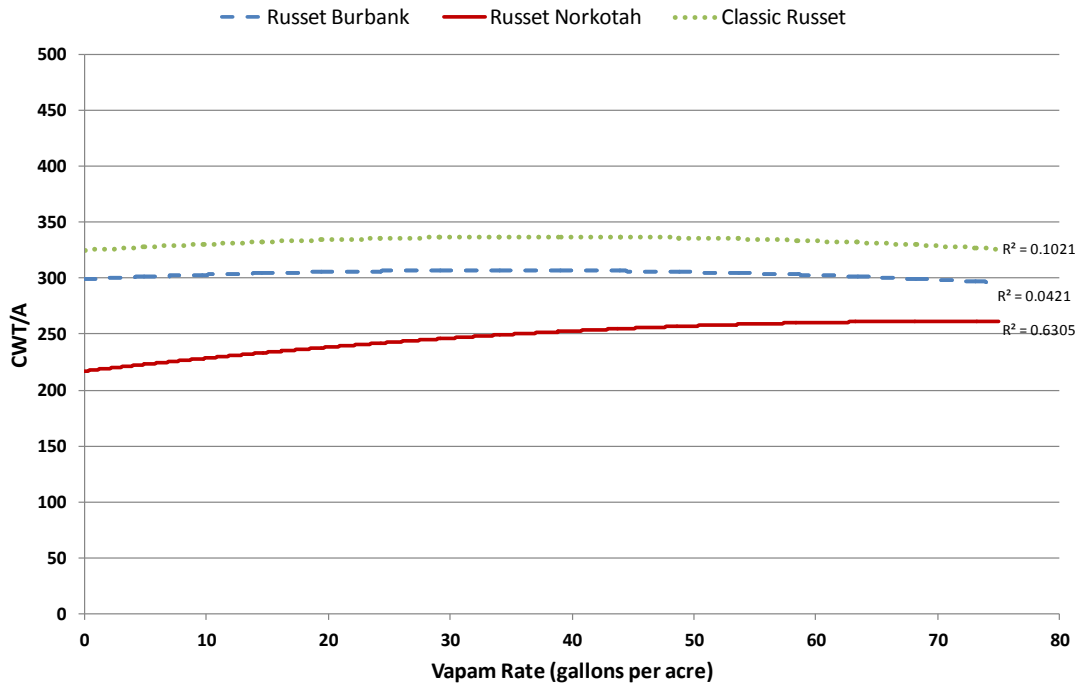

Figure 2. Influence of Fall-Applied Vapam Rate on Potato Revenue (Pack-out Revenue - Fumigation Cost) at IREC in 2011

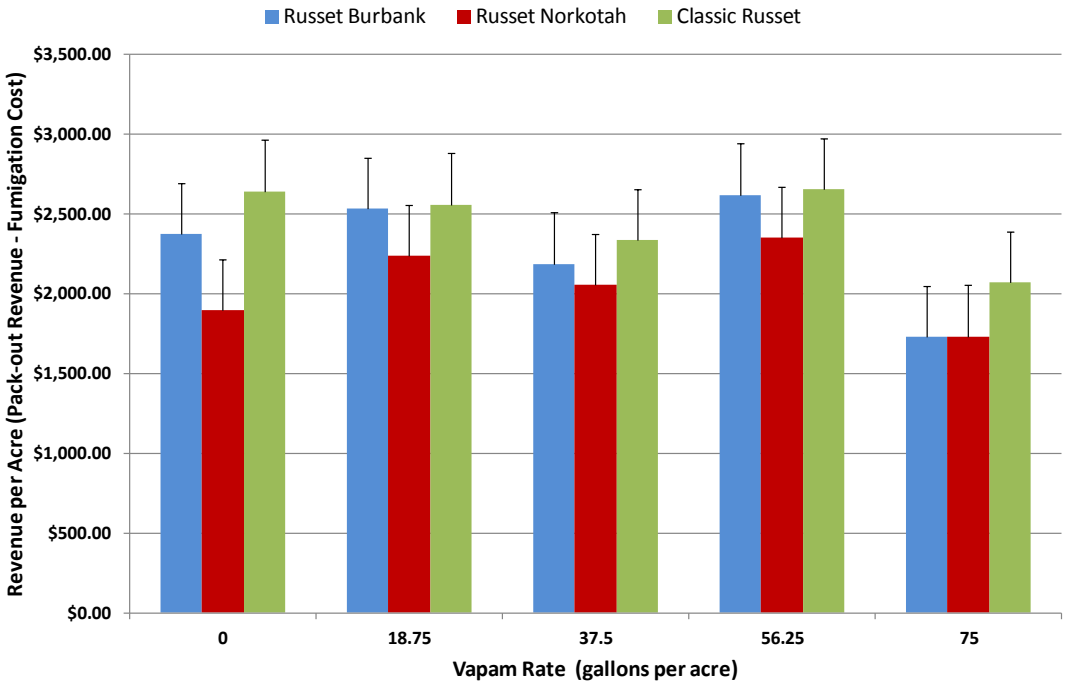

Table 2. Influence of Fall Fumigation on *Verticillium* Colony Forming Units per Gram of Soil at IREC.[1]

Vapam[2] gal/A	Telone II[3] gal/A	fall cfu Vert. per gram of soil[4]	spring cfu Vert. per gram of soil[4]
0	**0**	220	202
18.75	**0**	94	165
37.5	**0**	86	160
56.25	**0**	274	182
75	**0**	147	80
0	**20**	107	160
0	**25**	147	379
18.75	**15**	113	165
37.5	**20**	114	293
95% confidence interval		NS	NS

[1] Twenty soil samples from 0-8 inches were collected and compiled into one composite sample in each fumigation treatment block in fall 2010 and spring 2011. Treatment blocks were replicated five times.

[2] Vapam (metam sodium) was applied on 10/10/10 via spray boom mounted immediately in front of a rototiller that incorporated the metam sodium in the top 6 inches of soil. Soil temp. was 60.5 degrees F at 6 inch depth. Soil moisture was within label guidelines.

[3] Telone II (1,3-dichloropropene) was applied on 11/4/2010 via shank-injection using chisels set at a 18 inch soil depth with injection points laterally spaced 13 inches apart. Soil temp. was 50.1 degrees F at 6 inch depth. Soil moisture was within label guidelines.

[4] Soil samples were collected in the fall before fumigation and the spring post-fumigation before planting.

Table 3. Russet Norkotah, Russet Burbank, and Classic Russet Tuber Yield, Stand, Revenue, & Disease Ratings Averaged Across Fumigation Treatments at IREC in 2011.

Variety	Total U.S. No. 1's (cwt/A)	Total Yield (cwt/A)	Tubers/ Plant	Avg Tuber Size (oz)	Potato Revenue $/A[1]	Vert Wilt Ratings 8/31/11[2]	Vert Wilt Ratings 9/13/11[2]	Avg Rhizoc. % Coverage on Tubers[3]	Rhizoc. Tuber Severity Rating[3]	Tuber Stem End Necrosis %[4]	Tuber Vascular Discolor-ation %[4]
Russet Norkotah	250	358	5.5	7.2	$2,059	7.3	8.8	7%	4.01	4%	6%
Russet Burbank	307	418	6.7	6.9	$2,267	4.0	6.1	7%	3.86	10%	7%
Classic Russet	339	422	6.6	7.1	$2,483	1.1	2.5	7%	4.02	9%	8%
95% confidence Interval	12	17	0.2	NS	$221	0.2	0.2	NS	NS	3%	NS

[1] Revenue per Acre = Gross Revenue using the 4 year average for Columbia Basin Carton and Bag Prices - $5.75/CWT Packing and Handling Charges - Fumigation Cost (Vapam = $5.10/gallon + $71/A application cost; Telone II $14.90/gallon + $40/A application cost)

[2] = Verticillium Wilt Rating 0-9 scale, 0= 0 Symptoms, 1= Trace, 2= 1-5% of plants show symptoms of disease, 3= 5-10%, 4= 10-20%, 5= 20-40%, 6= 40-60%, 7= 60-75%, 8= 75-90%, 9= 90-100%

[3] = (10 tubers/ plot) % Rhizoctonia Coverage on Tuber Skin; Rhizoctonia Severity Rating on Tuber Skin 1-5 scale, 5= no infection

[4] 10 tubers evaluated from each plot (8-16oz tubers)

Table 4. Influence of Fall Fumigation on Russet Norkotah, Russet Burbank, and Classic Russet Disease Ratings at IREC in 2011.

Variety[1]	Vapam[2] gal/A	Telone II[3] gal/A	Vert Wilt Ratings 8/31/11[4]	Avg Rhizoc. Coverage on Tubers %[5]	Rhizoc. Tuber Severity Rating[5]	Tuber Stem End Necrosis %[6]	Tuber Vascular Discolor-ation %[6]
Norkotah	**0**	**0**	7.6	5%	4.3	10%	6%
	18.75	**0**	7.2	10%	3.6	0%	6%
	37.5	**0**	7.4	12%	3.4	0%	8%
	56.25	**0**	7.2	7%	4.2	4%	6%
	75	**0**	7.5	5%	4.1	7%	10%
	0	**20**	7.2	5%	4.3	0%	0%
	0	**25**	7.2	6%	4.0	8%	8%
	18.75	**15**	7.2	8%	3.8	4%	4%
	37.5	**20**	7.2	4%	4.4	0%	6%
Burbank	**0**	**0**	4.2	5%	4.2	20%	2%
	18.75	**0**	4.4	6%	4.0	6%	10%
	37.5	**0**	3.8	9%	3.7	8%	6%
	56.25	**0**	3.6	3%	4.4	12%	4%
	75	**0**	4.6	7%	3.8	4%	10%
	0	**20**	3.6	8%	3.7	8%	2%
	0	**25**	4.4	9%	3.7	14%	10%
	18.75	**15**	4	9%	3.6	8%	10%
	37.5	**20**	3.8	8%	3.9	8%	6%
Classic	**0**	**0**	1.4	7%	4.0	12%	8%
	18.75	**0**	0.8	13%	3.5	14%	4%
	37.5	**0**	1	9%	3.7	6%	12%
	56.25	**0**	1.2	7%	3.9	6%	6%
	75	**0**	1	3%	4.6	4%	10%
	0	**20**	1.6	6%	4.1	14%	6%
	0	**25**	1	4%	4.4	2%	6%
	18.75	**15**	0.8	10%	3.9	6%	14%
	37.5	**20**	1	5%	4.4	16%	6%
95% confidence interval			NS	4%	0.5	6%	NS

[1] Russet Norkotah has high susceptibility to Potato Early Dying; Russet Burbank has moderate susceptibility to Potato Early Dying; Classic Russet has low susceptibility to Potato Early Dying.

[2] Vapam (metam sodium) was applied on 10/10/10 via spray boom mounted immediately in front of a rototiller that incorporated the metam sodium in the top 6 inches of soil. Soil temp. was 60.5 degrees F at 6 inch depth. Soil moisture was within label guidelines.

[3] Telone II (1,3-dichloropropene) was applied on 11/4/2010 via shank-injection using chisels set at a 18 inch soil depth with injection points laterally spaced 13 inches apart. Soil temp. was 50.1 degrees F at 6 inch depth. Soil moisture was within label guidelines.

[4] = Verticillium Wilt Rating 0-9 scale, 0= 0 Symptoms, 1= Trace, 2= 1-5% of plants show symptoms of disease, 3= 5-10%, 4= 10-20%, 5= 20-40%, 6= 40-60%, 7= 60-75%, 8= 75-90%, 9= 90-100%

[5] = (10 tubers/ plot) % Rhizoctonia (black scurf) coverage on tuber skin; Rhizoctonia severity rating on tuber skin 1-5 scale, 5= no infection

[6] 10 tubers evaluated from each plot (8-16oz tubers)