Utility of chloropicrin for disease control in potato systems

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The historic soil fumigation program for potato producers in Wisconsin has consisted of metam sodium (Vapam, Sectagon). The fumigant has been used for control of nematodes and soilborne fungi, particularly *Verticillium dahliae* involved in the Potato Early Dying (PED) complex which can cause premature crop defoliation resulting in yield and quality losses in susceptible cultivars. Metam sodium does have some efficacy on weeds at higher rates (Hutchinson et al., 2003), but this is not one of the primary reasons for its use in Wisconsin.

Chloropicrin was first registered as a broad-spectrum soil fumigant in the U.S. in 1975, but has been used specifically for nematode control since 1919 (Matthews, 1920). Chloropicrin was typically formulated with methyl bromide due to its effectiveness as a warning agent. With the current phasing out of methyl bromide, there has been increased interest in chloropicrin formulations as methyl bromide alternatives, and more recently, as alternatives or enhancements to other fumigants such as metam sodium in fungal disease control in potato and vegetable systems (Hutchinson, 2005; Sydorovych et al., 2008). Chloropicrin used alone or in a mixture has historically not been a fumigant used in Wisconsin potato production. However, in recent years, commercial producers have been experimenting with chloropicrin for control of challenging soilborne diseases such as common scab, PED, and powdery scab. To best support producers in their own, on-farm research, we undertook research of chloropicrin in potato systems for the control of common scab and PED in Wisconsin at the Langlade County Research Area in Antigo during 2010-2012.

In 2010, in collaboration with Tri-Est Fumigation partners and a grower cooperator, we evaluated the effectiveness of fall-applied chloropicrin (2 formulations, 4 rates, Table 1) for the control of common scab in Langlade County. With the exception of the 83 lb/A broadcast rate of C60 Pic, all chloropicrin treatments resulted in common scab incidence that was not statistically different from the untreated control (Table 2). Overall yield, however, was significantly increased with chloropicrin applications compared to control by roughly 55-120 cwt/A increase (Table 2).

Table 1. Chloropicrin fumigation treatments evaluated in 2010-2011 for potato ('Pike') common scab control in Langlade County, WI.

Trt No.	Trade Name	Active Ingredient	Rate	Time of Fumigation
1	C-60 Pic	chloropicrin 60%	83 lb/A broadcast	30 Sep 2010
2	C-60 Pic	chloropicrin 60%	167 lb/A broadcast	30 Sep 2010
3	C-60 Pic	chloropicrin 60%	250 lb/A broadcast	30 Sep 2010
4	C-60 Pic	chloropicrin 60%	333 lb/A broadcast	30 Sep 2010
5	Pic Plus	chloropicrin 85% + proprietary solvent	117 lb/A broadcast	30 Sep 2010
6	Pic Plus	chloropicrin 85% + proprietary solvent	234 lb/A broadcast	30 Sep 2010
7	Pic Plus	chloropicrin 85% + proprietary solvent	351 lb/A broadcast	30 Sep 2010
8	Pic Plus	chloropicrin 85% + proprietary solvent	468 lb/A broadcast	30 Sep 2010
9	Untreated Control	NA	NA	NA

Table 2. Effect of chloropicrin treatments on yield, grade and incidence of common scab on tubers (treatment numbers as listed in Table 1).

		US#1			Undersize[1]			Culls				
Trt no.	Total cwt/A	cwt/A		%	cwt/A		%	cwt/A		%	Disease[2] Incidence	
1	308.0	250.4	bc[3]	81.3%	34.1	a	11.1%	23.5	ab	7.6%	62.5%	a
2	338.9	276.6	bc	81.6%	35.0	a	10.3%	27.3	ab	8.1%	72.5%	ab
3	362.2	278.1	bc	76.8%	38.6	ab	10.6%	45.5	b	12.6%	81.3%	ab
4	372.4	302.8	c	81.3%	34.1	a	9.2%	35.5	ab	9.5%	77.5%	ab
5	296.8	232.0	b	78.2%	33.0	a	11.1%	31.8	ab	10.7%	83.8%	ab
6	324.7	250.0	bc	77.0%	32.4	a	10.0%	42.3	ab	13.0%	77.5%	ab
7	328.0	255.0	bc	77.7%	39.8	ab	12.1%	33.2	ab	10.1%	78.8%	ab
8	305.8	248.1	bc	81.1%	33.9	a	11.1%	23.8	ab	7.8%	81.3%	ab
9	240.1	171.4	a	71.4%	46.8	b	19.5%	21.9	a	9.1%	86.3%	b

1. Undersize indicates potatoes <1 7/8" in diameter
2. The percentage (out of 20 tubers per treatment) with common scab symptoms
3. Analysis of variance was performed on each data set, and Fisher's protected least significant difference (LSD) was calculated (alpha=0.05).

Disease control results of the commercial/cooperator trial in 2010-2011 were unexpected and evaluation of the complete potato production system was considered in attempt to further understand the outcome. The deep spring tillage practice was hypothesized as having had negative impact on the outcome of the fall broadcast chloropicrin applications. To investigate this hypothesis, a 2011-2012 trial was undertaken at the Langlade County Research Area to evaluate the influence of spring tillage on chloropicrin efficacy in potato, 'Russet Norkotah.'

Fumigation (PicPlus 140 lb/Acre) was applied in-line on 19 October 2011 and furrows were mechanically covered to create a bed. The field was irrigated after bed formation to create a soil crust for enhanced fumigation. Rye seed was broadcast over field after fumigation. Prior to planting in the spring, treatment plots were tilled using one of the following four methods: no-

till, moldboard, chisel, or deep rip. A randomized complete block design with four replications was used for the trial. The center two rows of each plot were harvested 18 September 2012. Tubers were graded into marketable (US#1), undersize, and cull categories on 18 September 2012. There were no statistical differences from one level of treatment to another across the yield and cull data (Table 3). Numerical increases in total yield (lbs/A) were observed when fumigation was combined with no-till, chisel plow, and deep-till practices. Fumigated plots that were not tilled in the spring showed a numerical reduction of culls from 48.3 to 44.4 cwt/A. With the exception of moldboard plow tillage, all other treatments produced higher marketable yield (US#1) values when they were combined with fumigation of chloropicrin at 140 lb/A.

Table 3. Effects of varying tillage practices on fumigated plots for control of potato common scab, 2012.

Treatment and fumigation rate/A*	Total Yield (lbs/A)	Culls (cwt/A)	Marketable Yield (cwt/A)	% Culls of Total Yield (cwt/A)
No-till……	102.3	48.3	240.0	16.2
Chisel plow……...	109.0	49.7	252.7	15.3
Deep-till……	114.3	78.6	246.2	23.1
Moldboard plow……...	127.9	60.7	302.3	16.4
No-till + Pic Plus at 140 lb……...	107.1	44.4	253.8	13.8
Chisel plow + Pic Plus at 140 lb……..	136.0	88.3	297.4	22.5
Deep-till + Pic Plus at 140 lb……	151.4	96.8	337.5	21.0
Moldboard plow + Pic Plus at 140 lb...	127.8	69.4	295.5	18.0

* Fall fumigation applied on 19 Oct, 2011.

A concurrent chloropicrin study was undertaken at the Langlade County Research Area in 2010-2011 which compared broadcast chloropicrin treatments to standard treatments of metam sodium, and an in-furrow treatment of Blocker (pentachloronitrobenzene, PCNB) in a common scab disease nursery. Fumigants were applied in the fall of 2010 in preparation for potato seed planting in May of 2011. Shallow tillage was practiced uniformly across the plot in the spring prior to planting of 'Yukon Gold' potato. Seedpieces were planted according to treatments configured in a randomized complete block design. Each treatment had four replications. Harvested tubers were graded for marketable yield and evaluated for severity and incidence of common scab symptoms.

Disease pressure was high in this field trial with 100% of tubers in the untreated control exhibiting common scab symptoms (Table 4). Numerically, all treatments controlled common scab better than the untreated control, with Vapam 40 gal, Pic Plus (at all three rates), and Pic-C60 (at all three rates) treated plots having significantly less symptomatic tubers. Overall symptom severity ranged from 8.5 in plots treated with Pic Plus 234 lb to 37.3 in the untreated plots. Treatments consisting of Pic Plus 234 lb, Pic-C60 333 lb, and Pic-C60 167 lb had numerically less overall symptom severity, respectively, than the untreated control. Marketable yield was greatest and significantly different from the untreated control in treatments with the Vapam 40 gal and Pic-C60 (at all three rates) applications. There were no significant differences in cwt/A of culls among treatments.

Table 4. Effects of fumigants applied with in-furrow treatments for control of potato common scab, 2011.

Treatment and rate/A[1]	Symptomatic tubers (%)		Overall symptom severity	Marketable yield (US#1) cwt/A		Culls cwt/A
Unfumigated control	100.0	b[2]	37.3	162.2	c	43.3
Vapam 40 gal	51.3	a	14.3	284.6	a	24.0
Blocker 4F 10 pt	72.5	ab	24.0	182.1	bc	33.0
Pic Plus 117 lb	51.3	a	12.8	232.8	abc	24.9
Pic Plus 234 lb	37.5	a	8.5	228.6	abc	25.8
Pic Plus 351 lb	50.0	a	16.5	236.5	abc	43.3
Pic-C60 167 lb	46.3	a	11.5	251.9	ab	26.1
Pic-C60 250 lb	55.0	a	24.0	244.1	ab	31.9
Pic-C60 333 lb	42.5	a	9.5	257.4	ab	32.4

1. Fall fumigation applied on 30 Sep, 2010.
2. Analysis of variance was performed on each data set, and Fisher's protected least significant difference (LSD) was calculated (alpha=0.05).

In summary, we have seen variable disease control results with chloropicrin use when applied in fall prior to spring potato planting in northern Wisconsin field trials. However, we have consistently seen an increase in overall yield with chloropicrin fumigation when compared to the unfumigated controls. Further evaluation of chloropicrin for soilborne disease control is warranted to assess actual impact on soilborne pathogen populations and evaluate economic return on investment in moderate to high disease pressure fields.

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