SOIL FUMIGATION AND SOIL BORNE DISEASES OF POTATO

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Introduction

Soil fumigation is a common practice throughout the Columbia Basin before potatoes are planted. Weeds, insects and soil borne pathogens (nematodes and fungi) can be controlled by fumigation, but not all fumigants kill these organisms equally. A fumigant is any substance or mixture of substances which produce gas or vapor intended to destroy soil pests.

Three fumigants are used in the area, metam sodium (Vapam, Soil Prep, etc), Telone II, and Telone C-17. Metam sodium, whose active ingredient is methyl isothiocyanate, is identified by the label to have a wide range of disease control on many crops. This product is effective in controlling nematodes in some situations, and is very useful in the basin to control Early Dying disease of potato. Telone II, controls nematodes and certain other fungi, by label information, through the active ingredient 1, 3 dichloropropene. A third product, Telone C-17, contains both 1, 3 dichloropropene and chloropicrin, reportedly kills soil nematodes, insects, as well as soil borne fungi.

Beside controlling pests that cause early dying and/or nematodes, these fumigant can also impact populations of other soil borne pests that could impact yield and quality. Phythium Leak, Rhizoctonia, Early Blight, Sclerotinia, Powdery Scab, and others are included on this list. Not all fumigants, however, impact these disease organism equally.

These materials also differ in cost. Metam sodium, applied through the water system, generally costs around $189.00/AC using 55 GPA. Telone II when shanked at approximately 20 inches at 20 GPA and will cost $216.00/AC. Telone C-17, using 27.5 GPA, is the most expensive at $366.00/AC, and also applied by shank. A combination treatment using Telone II (20 GPA) and metam sodium (40 GPA), a common practice, will cost $454.00/AC. Given the differences in activity of these soil fumigants toward soil pathogens and their differences in costs, knowing the pathogen being targeted for control is extremely important. This paper reports the efficacy of the three soil fumigants listed above to control three soil born fungi, Verticillium dahliae, Fusarium Species, and Pythium species, all of which are potential disease agents on potato.

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Materials & Methods

Fifteen treatments, replicated four times, were applied to field plots (16' by 55' in size) established near Umatilla Oregon to investigate the control of Corky Ring Spot in potato. Of those fifteen, eight were selected for analysis to compare fumigation effects on the following soilborne fungi; Fusarium, Pythium, and Verticillium (Table 1). Soil samples were collected at two depths; 0-12 inches and 12-24 inches. Soil samples were collected from 10 locations from each plot and were composited by depth at each sample time. Samples were collected before fumigation (October 23, 1991), after fumigation (March 17, 1992), and late season (August 18, 1992). Standard soil isolation procedures were used to determine colony forming units per gram of dry soil (CFU'S) of each of these fungi in the soil at each sample time. CFU'S were log transformed and treatments were evaluated with ANOVA. LSD was used to separate means only when ANOVA was significant at $P < 0.05$. All differences reported are at $P < 0.05$ unless otherwise noted.

In September, aerial photography was used to compare overall plant vigor in each treatment. This was done qualitatively by assigning each replication in each treatment a number based on the intensity of "red" in each plot. Plots with the most intense red coloration were given a 5 and those with the least red were given a 1.

Potato quality and yield with each treatment were also determined.

RESULTS AND DISCUSSION

Impact on Soilborne Pythium

Before fumigation (sample 1) there was no difference in Pythium numbers in the soil between treatments at either depth. After fumigation (sample 2), Vapam treatments (11, 12, 13, 14) had significantly reduced Pythium levels in the first foot of soil compared to the non-Vapam treatments (1, 2, 5, & 7) (Table 2). This same trend was evident in the lower soil profile but the differences were not significant. The impact of fumigation continued into August (sample 3) in some treatments at depth 1 but the results are not as evident as sample 2. Only treatments 7, 12, and 14 (Telone C-17, Vapam at 75 GPA, and Telone II plus Vapam, respectively) showed a reduction in numbers over some of the other treatments. Significantly fewer numbers of Pythium were found in the second foot depth at each sample time.

Impact on Soilborne Fusarium

Fusarium CFU'S did not differ between treatments before fumigation at depth 1 or at depth 2 (Table 3). At sample 2, treatments 13 & 14 (Vapam 100 GPA and Vapam 55 GPA + Telone II, respectively) at depth 1 had significantly lower numbers than most other treatments. No significant differences were found between treatments at depth 2.

At sample 3, treatment 14 (double fumigation) had significantly fewer numbers than treatments 1, 2, 5, and 11, and equal to the others. No differences between treatments were found in the lower soil sample. Soil population numbers at depth 1 were significantly higher than at depth 2 at each of the three sample times.

Table 1. Identification of treatments for soilborne fungi analysis.

1.	(1)*	Non-treated control #1
2.	(2)	Non-treated control #2
3.	(5)	Telone II at 20 GPA
4.	(7)	Telone C-17 at 27.5 GPA
5.	(11)	Vapam at 55 GPA
6.	(12)	Vapam at 75 GPA
7.	(13)	Vapam at 100 GPA
8.	(14)	Telone II at 20 GPA plus Vapam at 55 GPA

*The numbers in ( ) referred to the number assigned to these treatments in the overall Corky Ring Spot test.

Table 2. Effect of soil fumigation on soilborne populations of Pythium.

	Pre-fumigation		Post Fumigation		Late Season	
	Depth 1	Depth 2	Depth 1	Depth 2	Depth 1	Depth 2
trt 1	97.5a+	30.4a	48.6a	7.1a	84.4 d	7.3a
trt 2	65.1a	18.7a	37.8a	16.1a	20.2 bcd	3.6a
trt 5	35.2a	23.5a	25.4a	10.7a	62.6 cd	10.9a
trt 7	47.4a	45.5a	27.1a	7.1a	12.9abc	7.1a
trt 11	42.1a	26.3a	9.0b	1.8a	65.0 bcd	7.3a
trt 12	56.5a	36.9a	10.8b	1.8a	1.9ab	0.0a
trt 13	94.7a	50.8a	7.2b	1.8a	51.8 bcd	9.1a
trt 14	80.7a	28.0a	1.8b	0.0a	9.1a	21.8a
Ave	65.9**	33.32	21.0**	5.8	39.5**	7.9

+ Numbers represent Colony Forming Units (CFU'S) per gram of dry soil. Numbers followed by the same letter not significantly different (P=0.05).

** Significantly different (P=0.01) between depth 1 and depth 2.

Impact on Soilborne Verticillium dahliae

Numbers of Verticillium dahliae at sample 1 did not differ between treatments at either depth (table 4). Numbers at sample 2 were significantly lower in treatments 7, 12, 13, and 14 when compared to the rest. These same treatments had fewer numbers at depth 2 than at depth 1 but did not differ statistically from the other treatments at this level. No treatment effects were found between treatments at sample 3 at either soil depth. Numbers of Verticillium were not significantly different between depth 1 and 2 at sample 1 but were significantly less at depth 2 than at depth 1 at sample 2 and 3.

Plant Vigor Evaluation From Aerial Photography

I-R aerial photography taken in September indicated differences in the overall vigor of the plants in the treatments. Ratings for treatments 1, 2, 5, 7, 11, 12, 13, & 14 averaged 2.5, 2.2, 2.2, 2.0, 4.7, 4.7, 5, & 5, respectively. Lowest ratings (less vigor) were from control (untreated), Telone II, and Telone C-17 treatments whereas plants with the best vigor had been treated with Vapam.

Table 3. Effect of soil fumigation on soilborne populations of Fusarium.

	Pre-fumigation		Post Fumigation		Late Season	
	Depth 1	Depth 2	Depth 1	Depth 2	Depth 1	Depth 2
trt 1	768.3a+	396.7a	1116.0 cd	338.8a	1228.2 b	144.8a
trt 2	790.7a	280.2a	1171.2 d	463.0a	529.7 b	217.7a
trt 5	468.9a	233.3a	907.2 bc	71.3a	1046.8 b	144.8a
trt 7	666.8a	455.5a	884.2 cd	321.0a	255.7ab	125.7a
trt 11	947.0a	490.0a	684.0 bcd	142.7a	1480.2 b	273.2a
trt 12	529.5a	299.2a	504.0 cd	374.2a	579.8ab	182.3a
trt 13	457.8a	298.2a	216.4ab	53.5a	778.3ab	126.2a
trt 14	649.5a	297.5a	36.3a	53.7a	352.7a	90.5a
Ave	666.0**	348.0	689.9**	227.3	781.4**	163.1

+ Numbers represent Colony Forming Units (CFU'S) per gram of dry soil. Numbers followed by the same letter not significantly different (P=0.05).

** Significantly different (P=0.01) between depth 1 and depth 2.

Table 4. Effect of fumigation on soilborne populations of Verticillium dahliae.

	Pre-fumigation		Post Fumigation		Late Season	
	Depth 1	Depth 2	Depth 1	Depth 2	Depth 1	Depth 2
trt 1	3.0a+	1.3a	2.0 bc	1.5a	10.0a	4.5a
trt 2	6.0a	6.0a	4.0 bc	0.5a	13.0a	4.0a
trt 5	2.0a	1.3a	4.5 c	2.0a	4.5a	2.0a
trt 7	7.5a	3.5a	0.0a	0.0a	3.0a	0.5a
trt 11	3.5a	8.0a	1.5ab	0.5a	6.0a	7.0a
trt 12	5.5a	8.5a	0.0a	0.0a	5.0a	6.0a
trt 13	2.0a	3.0a	1.0a	0.0a	7.5a	15.0a
trt 14	5.5a	3.5a	1.0a	0.0a	5.5a	5.5a
Ave	4.5	4.6	1.8*	0.6	6.8*	5.6

+ Numbers represent Colony Forming Units (CFU'S) per gram of dry soil. Numbers followed by the same letter not significantly different (P=0.05).

* Significantly different (P=0.05) between depth 1 and depth 2.

Impact On Yield and Quality

All treatments using Vapam resulted in higher yields of number 1 potatoes when compared to the untreated controls (Table 5). Telone II, when used alone, did not increase yields over controls. Greater differences between treatment yields were expected based on aerial photography but proper watering could not be maintained late season when tubers were bulking.

The success of Vapam to control Verticillium dahliae in the lower Columbia Basin was expected. This material has previously been shown to decrease soil numbers of Verticillium dahliae in this area. Apparently this fumigant also has efficacy toward Fusarium and Pythium as well. The use of Vapam significantly increased plant vigor and favorably impacted yield. However, increasing the rate of Vapam did not result in significant improvement over the lowest rate.

Telone II, while considered a soil fumigant, reportedly has little impact on most soilborne fungi. This product has been found to decrease the severity of Verticillium dahliae in potatoes, but this reduction is suspected to be due to the control of plant parasitic nematodes, such as Pratylenchus penetrans which interact with V. dahliae. During the first year of this study there is some evidence of this products efficacy toward Fusarium.

A significant reduction in Fusarium CFU'S occurred at sample 2 in treatment 5 compared to one of the untreated controls, while the other control showed the same trend. Likewise, the treatment with the fewest Fusarium CFU'S at sample 2 was treatment 14, a combination of Telone II and Vapam. The Vapam alone could not be considered solely responsible since treatment 11, with the same amount of Vapam fumigant, had significantly higher numbers. Data to be collected during the second year of this test will be important to see if this trend is repeated.

Table 5. Yield of Number 1 potatoes by Treatment.

Total #1's CWT/Acre

Treatment 1	190a*
Treatment 2	185a
Treatment 5	247ab
Treatment 7	316 bcd
Treatment 11	363 cde
Treatment 12	349 cd
Treatment 13	306 bcd
Treatment 14	358 cde

* Numbers not followed by the same letter are significantly different (p=.05)

Telone C-17 would seem to be a likely all-around soil fumigant. Containing 1, 3 Dichloropropene, an effective nematocide, and C-17, a proven fumigant to control soilborne fungi, this material should theoretically do what Telone II and Vapam do together. This material, however, did not reduce the populations of Pythium or Fusarium, only Verticillium and only at sample 2. Yet, yield in this treatment was significantly better than the untreated controls. Since Verticillium dahliae has the greatest potential of these fungi to cause a yield reduction, failure to control the other fungi may not be as important for overall yield. However, since Fusarium and Pythium cause storage diseases, damage by these other fungi could still occur after harvest.

The consistent reduction of numbers of CFU'S for all fungi in the lower soil depth is not surprising. Since these fungi are generally plant pathogens, they will for the most part be found in the soil profile where the most biological activity related to plant growth is occurring. Since this tranlates to plant roots (or stems in the case of tubers), higher populations are expected in the upper layers where organic matter of the living plant are concentrated.

Soilborne numbers of all fungi stayed constant or were significantly reduced betweeen sample 1 (Fall) and sample 2 (Spring) at both depths (table 6). This reduction probably relates in part to adverse soil conditions (cold) and/or the lack of a host plant which caused a natural reduction to occur during this period.

Levels of Pythium never again reach pre-fumigation levels at depth 1 and actually decreased at depth 2 by late summer. It may be that potato is a poor host for the Pythium species isolated and the population never effectively increased with that crop plant present. This could also explain the low numbers of Fusarium at depth 1 and the reduction by late summer at depth 2. In contrast, V. dahliae, a proven potato pathogen in the field, increased significantly at both depths by sample 3 (table 6).

Table 6. Changes in population of soil fungi between September 1991 and August 1992 in untreated soil.

Sample	Depth 1			Depth 2		
	Pythium	Fusarium	V. dahliae	Pythium	Fusarium	V. dahliae
1	81 b*	780a	4.5a	24 b	318 b	3.7 b
2	42a	879a	3.0a	11ab	401 b	1.0a
3	52a	1144a	11.5 b	5a	181a	4.2 b

+ Numbers represent Colony Forming Units (CFU'S) per gram of dry soil. Numbers followed by the same letter not significantly different (P=0.05).

SUMMARY

Fumigation with Vapam and Vapam plus Telone II significantly reduced the numbers of Pythium, Fusarium, and Verticillium colony forming units (CFU'S) in the soil collected to a 12" depth. Telone C-17 reduce numbers of two of the three fungi compared. Overall plant vigor, based on aerial U-V photography, was best in treatments using Vapam. Vapam and Telone C-17 significantly increase yields compared to control (untreated) and Telone II only. No significant impact due to fumigation was observed in soil collected between 12-24" in any of the treatments at any sample time.

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