Residual Effect of Soil Fumigation with Vine Burning on Control of Verticillium Wilt of Potato

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ABSTRACT

Soil fumigation in a potato field left a residual effect for a year which increased tuber yields even though it did not measurably reduce *Verticillium albo-atrum* in soil or potato stems. Current-season fumigation, however, reduced populations of the pathogen and increased tuber yields more than the 1-year-old residual effect of fumigation. The residual effect of fumigation with yearly vine burning increased potato yields as much as current-season fumigation. By the second year after fumigation, with or without continued vine burning, no residual effect of fumigation was detected on either pathogen propagules or potato yields. Beneficial effects from repeated current-season fumigations were not cumulative since a single current-year fumigation gave tuber yields equal to repeated annual fumigations.

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Additional key words: Solanum tuberosum, inoculum potential, propagules, vine burning.

Powelson and Carter (10) reported a residual effect on yield of potatoes (*Solanum tuberosum* L.) by soil fumigation applied the previous year in a field where Verticillium wilt was severe. Kunkel and Weller (8) also

TABLE 1. Effect of continuing and ceasing soil fumigation with and without preharvest vine burning on *Verticillium albo-atrum* (microsclerotial type) and potato production in 1971 and 1972

Treatments[s]	*V. albo-atrum* propagules (no. per gram oven-dried soil)[t]						Number wilted plants[u]		*V. albo-atrum* propagules (no. per g stem tissue)[v] ($\times 10^6$)	Yield (quintals per hectare)	
	1971[w]			1972[x]			30 Aug	12 Sept			
	7 Apr	22 Apr	18 Aug	29 Mar	11 Apr	6 Oct	1971	1972	13 Oct 1971	1971	1972
Vines burned annually:											
Never fumigated	63 a[y]	76 b	80 a	29 a	72 b	291 a	16 b	26 c	9.68 c	731 b	655 b
Fumigated 1966-1970	29 a	38 b	52 a	60 a	46 b	331 a	3 a	28 c	7.81 c	900 a	623 b
Fumigated 1966-1972	25 a	0 a	92 a	445 a	27 a	716 a	0 a	2 a	0.98 a	894 a	731 a
Fumigated 1971 only	84 a	4 a	153 ab	. . .[z]	. . .	. . .	0 a	. . .	1.88 a	871 a	. . .
Vines not burned:											
Never fumigated	207 b	218 c	438 ab	504 b	286 c	341 a	30 c	31 d	3.28 b	585 c	544 c
Fumigated 1966-1970	317 b	267 c	602 ab	152 b	194 c	501 a	28 c	34 d	9.24 c	692 b	515 c
Fumigated 1966-1972	129 b	28 a	37 a	337 b	16 a	1380 a	0 a	10 b	3.04 b	877 a	690 a
Fumigated 1971 only	232 b	21 a	117 ab	. . .	. . .	. . .	1 a	. . .	2.38 b	877 a	. . .

[s]Results for fumigation with DD + Picfume or Telone + Picfume at 187 + 46.75 liters per hectare applied each spring were statistically equal so data were combined. Experimental plot planted continuously to potatoes 1966-1972.

[t]Average number of propagules as determined by counts made on 54 assay plates per treatment.

[u]Values given based on examination of 34 plants per treatment.

[v]Average number of propagules as determined by counts of 36 assay plates per treatment from potato stems collected before vine burning and harvest on 8 November 1971.

[w]Soil fumigated 8 April 1971 and planted 30 April 1971.

[x]Soil fumigated 31 March 1972 and planted on 14 April 1972.

[y]Vertical means followed by the same letter of the alphabet are not significantly different ($P = 0.05$) according to the individual degrees of freedom test and Duncan's multiple range test.

[z]Data not recorded.

reported a residual effect based on yield of potatoes when soil was fumigated, but the original cause of yield decline and yield response to fumigation was never determined. The residual effect of fumigation on populations of *Verticillium albo-atrum* Reinke and Berth. in potato field soil and potato tissue the year after fumigation has not been reported.

We reported that spring fumigation for 5 consecutive years reduced the populations of *V. albo-atrum* (microsclerotial type) in field soils, delayed plant infection and wilt symptoms, and increased yield of potatoes (3). Annual preharvest burning of potato vines to destroy the microsclerotia in stem tissue, also increased yields after two successive years of treatment. However, there was no delay in reduction of soil populations of *V. albo-atrum* and reduction of disease appearance until vine burning was performed for three consecutive years.

After five consecutive years of soil fumigation, we sought to determine the residual effect on the pathogen when fumigation ceased, compared either to continued fumigation or fumigation for the first time, with and without vine burning.

MATERIALS AND METHODS.—The cropping history, cultural methods, plot design, methods of fumigation, preharvest vine burning, soil infestation, stem isolations, and soil propagule assay for *V. albo-atrum* (microsclerotial type) were reported previously (2, 3). Telone® (1, 3-dichloropropene and related hydrocarbons) + Picfume® (trichloronitromethane) or DD® (1, 3-dichloropropene, 1, 2-dichloropropane, 3,3-dichloropropene, 2,3-dichloropropene, and related C_3 chloronated hydrocarbons) + Picfume were applied by shanks spaced 22.9 cm apart and 22.9 cm in depth at rates of 187 liters of either Telone or DD + 46.75 liters Picfume per hectare. The same plots were fumigated each spring 1966-1972. However, starting in 1971 one-half of each plot previously fumigated was not fumigated, and one-half of each plot not previously fumigated was fumigated. Soil temperatures at the time of fumigation were 8 and 10 C at a 20-cm depth and soil moisture contents on an oven-dry basis were 12.3% and 12.0% at a 2-20 cm depth for 1971 and 1972, respectively. As in previous years, vine burning was continued on the same whole plots. The experimental field was planted with the potato cultivar Russet Burbank.

Ten stems were collected from each plot in the fall of 1971 to assay for *V. albo-atrum* propagules. The stems were air dried at about 21 C for 3 months then ground and screened through a 74-μm (200-mesh) sieve. The screened stem tissue (0.5 g) was diluted, 1:50, 1:1000, 1:10,000, and 1:100,000 in sterile tap water and the propagule numbers were estimated (2).

RESULTS.—Tuber yields from plots fumigated the previous season (1970), with vines not burned, were equal to those from plots receiving annual vine burning only and significantly greater than yields from untreated plots (Table 1). However, there was no measurable residual effect of the previous season's fumigation on numbers of *V. albo-atrum* propagules in either the soil in the spring before planting or the potato stems in the fall just before harvest.

The residual effect of previous season's fumigation coupled with continued vine burning also failed to measurably reduce numbers of pathogen propagules, but increased tuber yields as much as continued or 1-year current-season fumigations.

By the second year after fumigation, with or wothout continued vine burning, there were no significant residual fumigation effects on either pathogen numbers or tuber yield.

Continuous vine burning, but not soil fumigation reduced numbers of over-wintering propagules in the soil. Continuous and one year's soil fumigation were equally effective and gave more control of *V. albo-atrum* and more yield than vine burning alone. A combination of vine burning and fumigation increased yields no more than fumigation alone. Neither fumigation nor vine burning affected the percentage of U.S. No. 1 tubers (Easton et al., *unpublished*).

DISCUSSION.—Our evidence of a moderate residual effect on yield the year after fumigation with vines not burned agrees with previous work (8, 10). This residual effect was not as great, however, as the effect of continued fumigation and did not continue a second year. *V. albo-atrum* propagule numbers were reduced by fumigation, but after fumigation ceased evidently they increased rapidly in the soil from inoculum not controlled by fumigation. Increase in inoculum was either by propagules spread in irrigation water from nonfumigated plots or from inoculum in stems of infected plants. That soil fumigation is mainly an annual response under our conditions is indicated by the fact that control of *V. albo-atrum* and yield of potatoes in plots with 6 consecutive years of soil fumigation were no better than in those plots receiving only 1 year of soil fumigation.

Very few plants wilted in the soil with 38 or less *V. albo-atrum* propagules either a year after or immediately following spring fumigation with annual vine burning (Table 1). Isaac, et al. (7) reported no infection in potted potato plants with less than 40 propagules of *V. dahliae* Kleb. per g soil.

Verticillium albo-atrum propagules in our soil will practically disappear following a crop of wheat (Easton, G. D., *unpublished*). Whether disappearance of propagules after cropping to this nonhost is caused by a natural reduction of propagules or dormancy of microsclerotia remains to be proven. Colonization of wheat (9) could be important in survival of propagules. Propagules quickly re-establish to cause disease with replanting of potatoes. This extreme fluctuation of propagules doesn't agree with the principle that microsclerotia in the soil stabilize and remain constant (5). De Vay, et al. (1) reported no correlation between numbers of microsclerotia in soil and wilt in cotton fields.

The first year after fumigation with vine burning yields did not decline even though *V. albo-atrum* propagules in soils were not statistically reduced below that of soil in plots with vine burning only (Table 1). Why propagules were not reduced in previously fumigated plots is not known. Pathogenic nematodes were not present; therefore, a nematode-fungus interaction should not have affected *V. albo-atrum* (4). The high rate of ammonium nitrate (448 kg N/ha) applied each year should have surmounted any nitrogen deficiency or the effect of additional nitrogen released by soil fumigation (6). Nitrogen excesses in plots not utilized by plants were removed through leaching by winter precipitation.

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