SUMMARY OF 22 YEARS SEARCH FOR ECONOMIC CONTROL OF *VERTICILLIUM DAHLIAE* IN POTATO [1]

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ABSTRACT

In the past 22 years, only 18 of the 114 chemicals and chemical combinations tested reduced Verticillium wilt and these did not always increase yields. Only one (Lanstan ®) of the 18 chemicals was not a soil fumigant. Most of the 18 chemicals were not cleared for use. In Washington, single fumigants, except for Vapam ® and Vorlex ® have not controlled *Verticillium dahliae*. In the 1960's, fumigation combinations of Telone ® + chloropicrin, DD ® + chloropicrin, ethylene dibromide + chloropicrin and M-2467 (Vidden D ® + propargyl bromide) were tested for control of *V. dahliae*. In the 1970's, Telone C ® (Telone + chloropicrin), Telone C-17 ® (Telone II ® + chloropicrin), DD-PIC ® (DD + chloropicrin) and Terr-O-cides 30 ® (ethylene dibromide + chloropicrin), 30 D ® (DD + chloropicrin), 54-45 ® (ethylene dibromide + chloropicrin) were evaluated. Some of the above combinations are not available today because they were not effective, too expensive, or discontinued by the supplier in Washington. In the 1980's, Vapam ® came into use for control of *Verticillium dahliae* after studies in Israel showed its effectiveness when applied to soil in irrigation water (33).

In general, fumigation increased potato yields on *Verticillium dahliae* infested soils cropped the previous year to potatoes but seldom on soils cropped the previous year to non-hosts of *V. dahliae* such as field corn and sudan grass. Cropping the previous year to sudan grass does not always reduce Verticillium wilt, but this rotation maintains tuber quality and high yields. Yields following sudan grass are 100 cwt/a more than on plots cropped the previous year to potatoes. Fumigation increases yields in soils previously cropped to potatoes but not in soils previously cropped to sudan grass.

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Mention of a product used in these studies does not constitute a recommendation of the product by Washington State University over other products.

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Pseudomonas fluorescens strain M-4, an antagonist of V. dahliae, in vitro, colonized roots produced from the potato seed pieces coated with this organism but did not suppress Verticillium wilt or increase potato production in the field.

Development of a giant hill mutant of Russet Burbank that is resistant to Verticillium wilt and that would not require chemical control of "early dying" appears possible.

INTRODUCTION

In Washington, Verticillium wilt, caused by Verticillium dahliae can decrease yields 20-40%, especially in long, warm seasons which induce moisture stress (6). Nitrogen deficiency also induces stresses which accentuate losses from Verticillium wilt.

In 1948, Nielsen in Idaho determined that Verticillium wilt referred to as "early dying" by growers was caused by Verticillium albo-atrum R. and B. (37). He also showed that proper soil fertilization and crop rotation reduced losses due to this disease. He found fumigation with chloropicrin reduced plant dying and increased yields.

In 1960, on a farm near Moses Lake, Washington, R. Kunkel began fumigation trials for control of "early dying" (35). This field had raised only one crop of potatoes previously. Soil fumigation with chloropicrin, Vapam, Vorlex, Telone, and a combination of Telone + chloropicrin, first suggested by J. R. Fisher, formerly with Dow Chemical, delayed "early dying" and increased yields in plots significantly more than in untreated plots. Telone + chloropicrin, Vapam, and Vorlex increased potato yields not only the first but even the second year following fumigation.

Near Prosser, Wa., in 1963, work was started on biological, chemical, and cultural control of "early dying". In 1965, trials were also initiated near Othello, Wa. A summary of results are presented herein.

In September 1975, it was observed that most fields of Russet Burbank contained from a few to 5% natural mutation of giant hill plants. These single or double stemmed plants with profuse flowering and very large canopies usually remained green until frost and produced large yields of misshapened tubers. A few of these giant hill plants had very large uniform tubers that appeared to have qualities and disease resistance superior to standard Russet Burbank. Results of subsequent testing of several of these clones are also described herein.

Irradiation studies on Russet Burbank were conducted in an effort to develop mutant strains resistant to Verticillium wilt with uniform tuber shape and high yields.

Pseudomonas fluorescens isolated from potato rhizosphere and antagonistic to V. dahliae in culture plates was studied in greenhouse and field for control of V. dahliae.

Preliminary studies showed that potato production and quality was high following cropping to green peas plus sudan grass (29). Fumigation of such soils did not increase production or quality. Further studies with this rotation were compared to monocropping of Russet Burbank potato for control of V. dahliae and increase in yields.

METHODS AND MATERIALS

Depending upon their volatility, solubility, or special characteristics, the chemicals given in Table 1 were either applied to soil preplant by shanks at 9 inches in depth and 9 inches apart; spread dry or sprayed on soil surface preplant and soil incorporated with a rototiller; dusted on potato seed pieces before planting; sprayed in an 8-inch band over the potato seed at planting; side-dressed to each side of plants in the row; sprayed on foliage during the growing season; applied to bare soil in the water during row irrigation; or drenched preplant in water over the bare soil.

In fall 1980, Vapam was applied to soil previously cropped to potatoes via sprinkler water to six-10 acre pie-shaped plots of a center pivot circle. In 1981, the circle was planted to Russet Burbank and yield and tuber quality were compared in fumigated and control plots.

In irradiation studies on Russet Burbank, "melon balls" (25,000) including eyes were extracted from tubers and were exposed to 7000 RADS of Cobalt 60 radiation at the Reactor Center, Washington State University, Pullman, Wa. Treated eyes that survived were planted with a Lockwood assist feed potato planter. Tubers were saved from resulting plants that appeared resistant to Verticillium wilt and had smooth, large tubers.

Plants from seed pieces of Russet Burbank coated with P. fluorescens isolates were examined for colonization of roots by P. fluorescens, delay of Verticillium wilt, and increases in yield.

All chemical, irradiation treatments and P. fluorescens-coated seed piece treatments, except the Vapam sprinkler applied treatments, were in plots either 9 ft or 12 ft wide by 20 ft long and were completely randomized in blocks using at least three and most often six replications.

In 1980, to further study the beneficial effect of cropping to green peas plus sudan grass, Russet Burbank potatoes were planted in strips, 30 ft in width across a field alternating with strips planted first to green peas and later to sudan grass. In 1981 plots 20 ft long by 12 ft wide were fumigated with Telone C-17 (25 gal/A) in each strip. Russet Burbank potatoes were planted over the entire field, observed for Verticillium wilt and harvested for yield data. All treatments were replicated six times.

During the falls of 1981 and 1982, 112 giant hill plants each with six, uniform, large tubers were selected and hand dug from commercial fields. The next spring the six tubers from each hill were cut lengthwise. One-half of each tuber was saved for seed increase and the other halves were hand planted.

A seed piece of a red variety was alternated with each half to facilitate identification during digging. The six halves of each hill selection were not planted together, but were distributed throughout the trial randomly with all other selections thus providing six replications of single hill plots. A row of standard Russet Burbank (Elite 3 certification) was planted on both sides of each plot row to provide separation and competition. The incidence of Verticillium wilt was recorded and tubers in each hill were hand dug, graded and weighed.

RESULTS

Of the 114 individual chemicals, compounds, or combinations tested from 1963 to 1985, only 18 (DD + chloropicrin, DD-PIC®, EP-197, EP-201, Lanstan, M-2467, M-2467 + chloropicrin, Telone + chloropicrin, Telone C, Telone C-17, Telone PBC®, Terr-o-gel 67®, Terr-o-gas 57-43T®, Terr-o-cide 30, Terr-o-cide 30D, Terr-o-cide 54-45, Vapam and Vorlex) increased yield significantly more than the untreated controls and most of these delayed Verticillium wilt symptoms (see literature citation in Table 1). Of the 18 chemicals, only Lanstan, although very volatile, would not be classified as a fumigant. Of the 17 fumigants, only Vorlex and Vapam were not mixtures of fumigants.

In our effort to produce a Verticillium wilt resistant mutant of Russet Burbank, of the 25,000 eyes irradiated, 20 to 50% of the eyes sprouted and were planted in commercial fields. About 4% of these emerged and 18 plants appeared resistant to Verticillium wilt but had poorly shaped tubers. It was difficult to distinguish the 18 Verticillium wilt resistant plants from giant hill mutations in the non-irradiated Elite III certified seed control. After replanting of the 18 selections the next season, all were discarded because of poor tuber shape or contamination with plant viruses.

In two years of field trials, coating seed pieces with P. fluorescens resulted in root populations of P. fluorescens comparable to those obtained in greenhouse tests, about 10^4 colony forming units/g of root (36,39,40). However, these treatments neither suppressed Verticillium wilt nor increased yield, nor percent U.S. No. 1 tubers.

Previous cropping to green peas + sudan grass did not reduce Verticillium wilt but did reduce by one-half the colonization of potato stems by V. dahliae (29). This rotation also increased yields over 100 cwt/A, the % U.S. No. 1 tubers 10 to 20%, and increased specific gravity 0.002 to 0.008, significantly more than on soil cropped the previous year to potato. Fumigation of soil previously cropped to green peas + sudan grass did not further increase yield or tuber quality.

The 112 giant hill Russet Burbank selections collected from commercial fields in 1981 and 1982 have been compared over a 3-year period with crops grown from Elite III certified seed (Easton, G. D., unpublished). Most selections are resistant to Verticillium wilt and seven produced yields and tuber quality equal to or more than standard Russet Burbank.

DISCUSSION

Most of the 17 fumigants that controlled V. dahliae were either not cleared for use by the Environmental Protection Agency or have been used very little because they either are explosive, too toxic, or too expensive. DD + PIC was removed from use by Shell Chemical Company. In Washington, only Telone C-17 and Vapam are used for control on a wide scale. Lanstan soil treatment controlled V. dahliae one year but not in subsequent trials. No new chemical control agents have appeared in the last 10 years.

In the field, biological control of V. dahliae by coating seed pieces with antagonistic bacteria did not control Verticillium wilt or promote growth, in spite of promising results from earlier studies (34,36,38,39,40). In the greenhouse, under controlled conditions, with higher soil populations of V. dahliae, Verticillium wilt was suppressed. Plant growth was increased and tuber yields often increased when the antagonistic bacteria were present (39,40). In a field near Prosser, Wa., low populations of V. dahliae in soils (100 to 200 V. dahliae propagules/g soil) and stems (10,000 to 50,000 V. dahliae propagules/g of stem) may explain why bacterial antagonist coating of seed showed no beneficial effect. In 1967 in severely infected fields, we reported 2000 to 4000 propagules/g of soil near Prosser, Wa. and 24,000 to 32,000 propagules/g of soil near Othello, Wa. (8,9). Stems from the Othello fields contained 7 to 24.5 million propagules. Bacterial antagonists should be tried in fields such as these. Low populations of V. dahliae may also explain why in fields cropped many years to potatoes, Verticillium wilt appears to be suppressed and does not appear until very late (Easton, G. D., unpublished). Soil fumigation of such fields does not increase yields.

Short rotations to non-host crops of V. dahliae, such as sudan grass may not reduce "early dying" but they do maintain yields and tuber quality (29). Soil fumigation following these non-host crops provides no additional yield response. Fumigation of soil by Vapam following a grain corn crop did not decrease Verticillium wilt or increase tuber quality or yield (28). These crops do, however, reduce wind and water soil erosion.

Selection of a giant hill mutant of Russet Burbank resistant to Verticillium wilt and with yields and tuber quality equal to standard Russet Burbank may be possible. Such a selection should eliminate the need for Verticillium wilt control.

Cultural practices such as week-free crop rotation, adequate fertilization, irrigation practices that reduce nutrient leaching, and tillage that reduces soil erosion all maintain plant and root health and suppress Verticillium wilt. Potato plants may be infected, but due to good plant health and vigor, V. dahliae will cause minimal damage.

There are examples of farms in Washington that have raised 8 to 10 potato crops but because non-Verticillium host crops have been rotated previous to potato there is little V. dahliae in the soil (Easton, G. D., unpublished).

Table 1. Characteristics of chemicals used for control of *Verticillium dahliae* 1963-1985.

Year Tested	Trade or Experimental number	Rate per acre	Type of activity	Method of application	Composition	Source	Control of *Verticillium dahliae*[3]	Literature cited[4]
1963	Vorlex®	15,30,45 gal	FUM	S	methylisothiocyanate + C_3 hydrocarbons	Morton Chem. Co.	+	1
	Picfume®	2,5,7.5 gal	FUM	S	trichloronitromethane	Dow Chem. Co.	-	1
	EP-201	15,30,45 gal	FUM	S	Vorlex + chloropicrin + DD®	Morton Chem. Co.	+	1
	DD®	15,30,45 gal	FUM	S	1,3 dichloropropene & 1,2 dichloropropane	Shell Chem. Co.	-	1
	EP-197	60 gal	FUM	S	Vorlex + methyl bromide + DD®	Morton Chem. Co.	+	1
	DD + chloropicrin	15+5, 30+5 gal	FUM	S	DD + trichloronitromethane	Shell Chem. Co.	+	1
	Telone®	15, 30, 45 gal	FUM	S	1,3-dichloropropene and related chlorinated hydrocarbons	Dow Chem. Co.	-	1
	Telone + Picfume	15+5, 15+2.5,30+5, 30+2.5 gal	FUM	S	Telone + Picfume	Dow Chem. Co.	+	1
	M-2467	30,45 gal	FUM	S	Vidden D (similar to DD®) + propargyl bromide	Dow Chem. Co.	+	1
	M-2467 + Picfume	15+5, 15+2.5,30+5, 30+2.5 gal	FUM	S	M-2467 + Picfume	Dow Chem. Co.	+	1
	Nemagon®	1,5 gal	FUM	S	1,2 dibromo-3-chloropropane + halogenated C_3 compounds	Dow Chem. Co.	-	1
	Vapam®	13,30,45 gal	FUM	S	sodium methyl dithiocarbamate	Stauffer Chem. Co.	-	1
1964	Botran® 5G	30,16 lb	F	F	2,6-dichloro-4-nitroaniline	Upjohn Company	-	3
	Captan® 50D	30,60 lb	F	SI	N-(trichloromethyl)thio-4-cyclohexene-1,2-dicarboximide	Calif. Chem. Co.	-	3
	Chemagro 2635 10D	30,60 lb	F	SI	1,2,4-trichloro-3,5-dinitrobenzene and 1,2,3-trichloro-4, 6-dinitro benzene	Chemagro Corp.	-	3
	D-198-10D	30,60 lb	F	SI	2,5-dimethyl-1,4-benzoquinone	Nagatuck Chem.	-	3
	D-198T-10/10D	30,60 lb	F	SI	2,5-dimethyl-1,4-benzoquinone + tetramethyl thiramdisulfide	Nagatuck Chem.	-	3
	Dexon® 5G	30,60 lb	F	SI	(p-dimethylaminobenzenediazo sodium sulfonate + PCNB)	Chemagro Corp.	-	3
	Dithane A-40® 93 P	30,60 lb	F	SI	disodium ethylene bisdithiocarbamate	Rhom & Haas Co.	-	3
	Dithane M-45® 80 WP	30,60 lb	F	SI	zinc ion and mg ethylene bisdithiocarbamate	Rhom & Haas Co.	-	3
	Dowco 184 98WP	15,145 lb	F	SI	1-(3-chloroally)-3,5,7-triaza-1-axoniaadomantane chloride	Dow Chem. Co.	-	3
	Lanstan® 20G	30,60 lb	F	SI	-1-chloro-2-nitropropane	Niagara Chem. Div.	-	3
	Miller 658 90WP	30,60 lb	F	SI	copper-zinc-chromate complex	Miller Chem. & Fertilizer Corp.	-	3
	NIA 3514 20P	30,60 lb	F	SI	unknown	Niagara Chem. Div.	-	3
	Terraclor® 2EC	10,20,40 lb	F	SI	pentachloronitrobenzene	Squibb Institute	+	3
	Polyram® 10D	30,60 lb	F	SI	zinc polyethylene thiuram disulfide complex	Niagra Chem. Div.	-	3
	TCNA 10WP	30,60 lb	F	SI	2,3,5,6-tetrachloronitroanisole	Pittsburg Plate Glass Company	-	3
	Zinophos® 10G	5,10 lb	F	SI	0,0-diethyl 0-2-pyrazinyl phosphorothioate	Amer. Cyanamid Co.	-	3
	SF 1823 75WP	30,60 lb	F	SI	1,4-dichloro-2,5-dimethoxybenzene	E.I. du Ponte de Nemours & Co.	-	3

Year Tested	Trade or Experimental number	Rate per acre	Type of activity	Method of application	Composition	Source	Control of *Verticillium dahliae*[3]	Literature cited[4]
	TMCB 10G	30,60 lb	F	SI	1,bromo-3-chloropropane	Michigan Chem.Corp.	-	3
	Picfume	5 gal	FUM	S	Given in 1963	Dow Chem. Co.	-	2
	OD	30 gal	FUM	S	Given in 1963	Shell Chem. Co.	-	2
	OD + chloropicrin	20+5, 30+2.5 gal	FUM	S	Given in 1963	Dow Chemical Co.	+	2
	M-2467	30 gal	FUM	S	Given in 1963	Dow Chemical Co.	+	2
	Telone	45 gal	FUM	S	Given in 1963	Dow Chemical Co.	-	2
	Telone + Picfume	30 + 2.5 gal	FUM	S	Given in 1963	Dow Chemical Co.	+	2
	EP-201	45 gal	FUM	S	Given in 1963	Morton Chem. Co.	+	2
1965	DAC-469 8.25 L	20,30 lb ai	F	SI	unknown	Diamond Alkali Co.	-	4
	Di-Syston 10G	3,9 lb ai	I	SI	0,0-diethyl S-[2-(ethylthio)ethyl] phosphoradithioate	Chemagro Corp.	-	4
	Lanstan	30,60 lb ai	F	SI	Given in 1964	Niagara Chem. Div.	+	4
	Polyram 10G	60 lb ai	F	SI	Given in 1964	Niagara Chem. Div.	-	4
	Potassium azide 97.8 P	12,36 lb ai	F	SI	Potassium axide	Pittsburg Plate Glass Co.	-	4
	S.F. 1823 75WP	30,60 lb ai	F	SI	Given in 1964	E.I. du Ponte de Nemours & Co.	-	4
	Terraclor 2EC	30 lb ai	F	SI	Given in 1964	Olin Mathieson Chem. Corp.	-	4
	Terraclor + Terrazole 10+5G	30+15 lb ai	F	SI	Terraclor+5-ethoxy-3-trichloromethyl-1,2,4-thiadiadiazole	Olin Mathieson Chem. Corp.	-	4
1966	Daconil 2787 75WP	40,60 lb ai	F	SI	tetrachloroisophalonitril	Diamond Alkali Co.	-	5
	DiSyston® 10G	6 lb ai	I	SI	Given in 1965	Chemagro Corp.	-	5
	Lanstan 20G	60 lb ai	F	SI	Given in 1964	Niagara Chem. Div.	-	5
	Terraclor EC 2EC	30 lb ai	F	SI	Given in 1964	Olin Mathieson Chemical Co.	-	5
	Tide®, powder	50,150 lb	-	SI	anionic surfactants, complex sodium phosphates, sodium carbonate, sodium sulfate, sodium silicates	Proctor & Gamble	-	5
	Di-Syston	3,6 lb ai	I	S	Given in 1965	Chemagro Corp.	-	6,12
	Temik®	3,6 lb ai	I	S	[2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl) oxime]	Union Carbide	-	6,12
	Lanstan	15,30,60 lb ai	F	SI	Given in 1964	Niagara Chem. Div.	-	6
	Telone	30 gal	FUM	S	Given in 1964	Dow Chemical	-	6
	Telone PBC	30 gal	FUM	S	Telone + propargyl bromide + Picfume	Dow Chemical	+	6,12
	Telone + Picfume	20+5 gal	FUM	S	Given in 1964	Dow Chemical	+	6
1967	Chemagro 4497 50WP	10,20 lb ai	F	SI	bis(1,2,2-trichloroethyl)sulfoxide	Chemagro Corp.	-	7
	Chemagro 6820 1.5EC	10 lb ai	F	SI	Unknown	Chemagro Corp.	-	7

Year Tested	Trade or Experimental number	Rate per acre	Type of activity	Method of application	Composition	Source	Control of *Verticillium dahliae*[3]	Literature cited[4]
	Difolatan 80WP	30,60 lb ai	F	SI	n-(1,1,2,2-tetra chloroethylsulfenyl)cis-4-cyclohexene-1,2 dicarboximide	Chevron Chem. Co.	-	7
	F 849 10D	0.1 lb ai	F	SI	Unknown	United St. Rubber	-	7
	Lanstan 20G	60 lb ai	F	SI	Given in 1964	Niagara Chem. Co.	-	7
	Terraclor 2EC	30 lb ai	F	SI	Given in 1964	Olin Mathieson Chem. Corp.	-	7
	Tide, powder	300,900 lb	-	SI	Given in 1966	Proctor & Gamble	-	7
	TBZ 60WP	30,60 lb ai	F	SI	2-(4-thiazolyl)benzimidazol	Merk Chem. Div.	-	7
	F 849 10D	0.1 lb ai/100 lb seed	F	SP	Unknown	United St. Rubber	-	7
	Vitavax 10D	0.1 lb ai/100 lb seed	F	SP	2,3-dihydro-5-carboxanilido-6-methyl-1,4-oxathiin	United St. Rubber	-	7
1968	Telone + Picfume	20+5 gal	FUM	S	Given in 1964	Dow Chemical	+	10,20
	DD + chloropicrin	20+5 gal	FUM	S	Given in 1964	Shell Chem. Co.	+	10,20
	butyraldehyde + methanol	80+80, 400+400, 800+800 gal	FUM	S	Same as given	Eastman Organic Chem.	-	NP
	Bay 68138 10G	10,20 lb ai	F	SI	ethyl 4-(methylthio)-m-tolyl isopropyl-posphoramidate	Chemagro Corp.	-	9
	Bay 33172 50W	20,40 lb ai	F	SI	2-(2-furyl)-benzimidazole	Chemagro Corp.	-	9
	Chemagro 4497 50W	30 lb ai	F	SI	Given in 1967	Chemagro Corp.	-	9
	Chemagro 4497 50W + Dexon 70W	7.5+7.5,15+7.5 30+7.5 lb ai	F	SI	Given in 1967 and 1964	Chemagro Corp.	-	9
	TBZ 60W	20 lb ai	F	SI	Given in 1967	Merk Chem. Div.	-	9
	TBZ 60W	0.5,1.0 lb ai	F	F	Given in 1967	Merk Chem. Div.	-	9
	Teraclor 2EC	30 lb	F	SI	Given in 1964	Olin Mathieson Chem. Corp.	-	9
1969	Clorine gas	1500,3000,4500,6000, 7500,9000 cu ft.	FUM	S	Clorine	Pennwalt Chem. Corp.	-	NP
	Telone + Picfume	20+5 gal	FUM	S	Given in 1964	Dow Chem. Co.	+	NP
	Vancide F5386 100L	30,60 lb ai	F	SI	2-ethyl-1,3-dimorpholine-2-nitropropane + N(2-nitrobutyl) morpholine	Vanderbilt Co.	-	11
	Bay 78175 40W	10,20 lb ai	F	SI	N,N^1-dipropyl-N,N^1 (dichlorofluoromethylthio) sulfamide	Chemagro Corp.	-	11
	Bay 78175 40W + Bay 68138 3E	10+5, 20+5 lb ai	F	SI	Bay 78175 + ethyl 4-(methylthio)-m-tolyl isopropylphosphor-amidate	Chemagro Corp.	-	11
	Terraclor Super X 2 & .5 EC	2 & 5 gal	F	SI	Terraclor + Terrazole Given in 1965	Olin Mathieson Chem. Corp.	-	11
	Terraclor 2EC	10 lb	F	SI	Given in 1964	Olin Mathieson Chem. Corp.	-	11
	Ferrous sulfate	2 lb	ME	F	Ferrous sulfate	Ciba Geigy Corp.	-	UP

Year Tested	Trade or Experimental number	Rate per acre	Type of activity	Method of application	Composition	Source	Control of *Verticillium dahliae*[3]	Literature cited[4]
	Sequestrene 138 Fe	1.5 lb	ME	F		Ciba Geigy Corp.	-	UP
	Sequestrene 330 Fe	1.0 lb	ME	F		Ciba Geigy Corp.	-	UP
	Telone C	12.5,18.75,25.0, 37.5 gal	FUM	S	Telone + Picfume	Dow Chem. Corp.	+	16
	Telone + Picfume	12.5,18.75,25.0, 37.5 gal	FUM	S	Given in 1963	Dow Chem. Corp.	+	18
	Terr-o-cide 30	12.5,18.75,25.0, 37.5 gal	FUM	S	ethylene dibromide + chloropicrin	Great Lakes Chem.	+	18
	Vorlex	12.5,18.75,25.0, 37.5 gal	FUM	S	Given in 1963	Morton Chem. Co.	+	18
1970	Isobac 20L	6 + 4 oz	F	P&F	Mono-sodium salts of 2,2'-methylenbis(2,4,6-trichlorophenyl)	Nationwide Chem. Co.	-	13
	Mertect 5D	1 lb/100 lb seed	F	SP	Same as TBZ Given in 1967	Merk Chemical Div.	-	13
	Terraclor Super X 2 & .5 EC	2 & 5 gal	F	SI	Given in 1965 and 1969	Olin Mathieson Chemical Corp.		
	DD + chloropicrin (4:1)	12.5,25,37.5,50 gal	FUM	S	Given in 1963	Shell Chem. Co.	+	18
	Telone + Picfume (4:1)	12.5,25,37.5,50 gal	FUM	S	Given in 1963	Dow Chemical Co.	+	18
	Telone C	12.5,25,37.5,50 gal	FUM	S	Given in 1969	Dow Chemical Co.	+	18
	Terr-O-cide 30	12.5,25,37.5.50 gal	FUM	S	Given in 1969	Great Lakes Chem.	+	18
	Terr-O-cide 30D	12.5,25,37.5,50 gal	FUM	S	DD + chloropicrin	Great Lakes Chem.	+	18
	Telone + Picfume	20 + 5 gal	FUM	S	Given in 1963	Dow Chemical Co.	+	15
	DD + chloropicrin	20 + 5 gal	FUM	S	Given in 1963	Shell Chem. Co.	+	15
1971	Citcop 4E	2,4 gal	F	P	copper salts of fatty and rosin acids	Cities Service Co.	-	14
	Terraclor Super X 2 & 0.5 EC	10 gal	F	SI	Given in 1965 and 1969	Olin Mathieson Chem. Corp.	-	14
	DD + chloropicrin	20 + 5 gal	FUM	F	Given in 1963	Shell Chem. Co.	+	20
	Telone + Picfume	20 + 5 gal	FUM	S	Given in 1963	Dow Chem. Co.	+	20
1972	Clorine gas	1000 lb	F	I	clorine	Pennwalt Corp.	-	NP
	Clorine + Ammonia	1000 + 500 lb	F	I	mono and dichloroamine	Pennwalt Corp.	-	NP
	Bravo 75W	10,20 lb ai	F	SI	tetrachloroisophthonitrile	Diamond Shamrock	-	16
	MC 5077 2EC	32 lb ai	F	SI	Unknown	Mobile Chem. Co.	-	16
	MC6536 2EC	18,36 lb ai	F	SI	Unknown	Mobile Chem. Co.	-	16
	Nabac 25 EC	1 qt, 1 gal	F		2,2'-methylenebis (3,4,6-trichlorophenol)	Nationwide Chem. Co.	-	16
	R-24952 50 W	2,5 lb ai	F	SI	Unknown	Stauffer Chemicals	-	16
	Rayplex (powdered Cu, Mg,Mn,Zn,+ Fe	0.1 + 0.25 lb	ME	F	Cu,Mg,Mn,Zn,Fe	Kalo Inoculant Co.	-	16
	S-1805 95EC	0.5+1, .5+3.0 lb ai	ME	P + SD	Unknown	Dow Chemical Co.	-	16
	Sentry 65G	500, 1000 lb ai	ME	SI	Calcium hypochlorite	Pennwalt Chem. Co.	-	16

Year Tested	Trade or Experimental number	Rate per acre	Type of activity	Method of application	Composition	Source	Control of *Verticillium dahliae*[3]	Literature cited[4]
	TDMTB + HPMTS 6 + 6D	1 lb/100 lb seed	F	SP	Unknown	Wilbur Ellis Co.	-	16
	TCMTB 30EC	0.5, 1.0 lb ai	F	P	Unknown	Wilbur Ellis Co.	-	16
1973	Ener-jet 20W	25, 50 oz	F	P	dimethyl benzyl ammonium chlorides + dimethyl ethylbenzyl ammonium chlorides	Consan Pacific	-	17
	Ener-jet 20 X 20W	25, 50 oz	F	P	Unknown	Consan Pacific	-	17
	Isobac 20EC	1 qt	F	P	Given in 1970	Nationwide Chem. Co.	-	17
	Nabac 25EC	1 qt	F	P	Given in 1972	Nationwide Chem. Co.	-	17
	R-28 921 50W	2,5 lb ai	F	SI	Unknown	Stauffer Chem. Co.	-	17
	Terraclor 2EC	25 gal	F	SI	Given in 1963	Olin Mathieson Co.	-	17
1974	Telone C	30 gal	FUM	S	Given in 1969	Dow Chem. Cho.	+	19
	Terr-o-gel 67	200, 600 lb	FUM	S	methyl bromide + chloropicrin	Great Lakes Chem.	+	19
	UC 21865 75WP	1.5, 3.0, 6.0 ai	F	P	Unknown	Union Carbide	-	19
	XE-326 95WP	1,2 lb	F	P	Unknown	Chevron Chem. Co.	-	19
1975	EL-222 (.438%D)	1 lb/100 lb seed	F	SP	α-(2-chlorophenyl)-α-(4-chlorophenyl)-5-pyrimidine methanol	Eli Lilly & Co.	-	21
	EL-222 (.875%D)	1 lb/100 lb seed	F	SP	α-(2-chlorophenyl)-α-(4-chlorophenyl)-5-pyrimidine methanol	Eli Lilly & Co.	-	21
	EL-222 12.5% EC	40,80 g	F	F	α-(2-chlorophenyl)-α-(4-chlorophenyl)-5-pyrimidine methanol	Eli Lilly & Co.	-	21
	Telone C	25 gal	FUM	S	Given in 1969	Dow Chem. Co.	+	21
1975	Bas 317 01F 10D	1 lb/100 lb seed	F	SP	2-iodobenzanilide	BASF	-	22
	C-22 1:25 w/water	500 gal solu	F	SI	copper 8-quinolinolate	Chapman Chem. Co.	-	22
	C-22 1:100 w/water	500 gal solu	F	SI	copper 8-quinolinoate	Chapman Chem. Co.	-	22
	Dow General 5E	9 lb ai	H	P	2-sec-butyl-4,6-dinitrophenol	Dow Chem. Co.	-	22
	EL-228 0.1G	60, 120 g	F	SI	α-(2-chlorophenyl)-α-(4Ofluorophenyl)-5-pyrimidine methanol	Eli Lilly & Co.	-	22
	SN 530 (NA055)	25 gal	F	S	Unknown	Nor-am Agr. Products	-	22
	SN 530 (NA060)	25 gal	F	S	Unknown	Nor-am Agr. Products	-	22
	SN 530 (NA061)	16.7 gal	F	S	Unknown	Nor-am Agr. Products	-	22
	Nitro-sul (20%N + 45%S)	800 lbs	FER	P	ammonium polysulfide	Kerley Chem.	-	22
	Polynure 100	30, 60 gal	SC	SI	Unknown	Env. Agr. Products	-	22
	R 2161 3EC	0.5 lb ai	F	SI	Unknown	Rhom Haas Co.	-	22
	Telone C	25 gal	FUM	S	Given in 1969	Dow Chem. Co.	+	22
	Telone C-17	21 gal	FUM	S	1,3-dichloropropene and chloropicrin	Dow Chem. Co.	+	22
	Thio-sul (12%N + 26%S)	800 lbs	FER	P	ammonium thiosulfate	Kerley Chem.	-	22
	Vorlex	25 gal	FUM	S	Given in 1963	Nor-am Agr. Products	-	22
1977	49-010 Agramine	10 gal water:50 gal, 20 gal water:100 gal, 30 gal water:75 gal	FER	SI	Unknown	Reichold Chem., Inc.	-	23
	Telone C-17	10,15,20 gal	FUM	S	Given in 1976	Dow Chemical	-	23
	SN 530 (NA055)	25 gal	F	SI	Unknown	Nor-am Agr. Products	-	23

Year Tested	Trade or Experimental number	Rate per acre	Type of activity	Method of application	Composition	Source	Control of *Verticillium dahliae*[3]	Literature cited[4]
	SN 530 (NA087)	25 gal	F	SI	Unknown	Nor-am Agr. Products	-	23
	Vorlex	25 gal	FUM	S	Given in 1963	Nor-am Agr. Products	-	23
	Terr-o-cide 54-45	3.5,5.0,6.5,8.0 gal	FUM	S	ethylene dibromide and chloropicrin	Great Lakes Chem.	-	23
1978	48-010 Agramine	7.5 gal	FER	P	Unknown	Reichold Chem., Inc.	-	24
	CG 64251 .846EC	1.0 lb ai	F	P,F	Unknown	Ciba-Geigy	-	24
	LS 74-783 80WP	4 lb ai	F	P	Unknown	Rhodia, Inc.	-	24
	RP 26019 50W	2 lb ai	F	F	3-(3,5-dichlorophenyl-N-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboxamide	Rhodia, Inc.	-	24
	Telone C-17	25 gal	FUM	S	Given in 1976	Dow Chem. Co.	-	24
	Terr-o-cide 54-45	5.0, 6.5, 8.0 gal	FUM	S	Given in 1977	Great Lakes Chem.	-	24
	Benlate 50W	4 lb	F	P	methyl-1(butyl carbamoyl)-2-benzimidazolecarbamate	E.I.duPonte de Nemours	-	UP
1979	Telone C-17	25, 50 gal	FUM	S	Given in 1976	Dow Chem. Co.	-	25
	Terr-o-cide 54-45	8, 12, 24 gal	FUM	S	Given in 1977	Great Lakes Chem.	-	25
	Telone C	25,50 gal	FUM	S	Given in 1969	Dow Chem. Co.	-	25
	MC-33	960 lb	FUM	T	methyl bromide + chloropicrin	Dow Chem. Co.	-	25
	Circo 79-1	20 lb	F	SI	Unknown	Cities Service Co.	-	25
	53-345 8.6 DC	50 lb ai	F	SI	Unknown	Shell Chem. Co.	-	25
	CGA 64250 3.6EC	0.5+0.5+0.5 lb ai	F	P,SD	Unknown	Ciba Geigy	-	25
1980	DD + chloropicrin	25, 35 gal	FUM	S	Given in 1963	Shell Chem. Co.	+	26
	Terr-o-gas 57-43T	20 gal	FUM	S	chloropicrin and DD	Great Lakes Chem.	+	26
	Prochloraz 40 EC	40 oz	F	P	N-[2-(2,4,6-trichlorophenyloxy)ethyl]-N-propyl-1H-imidazole-1-carboxamide	Boots Co.	-	26
	Prochloraz 40 EC	40 + 40 oz	F	P+SD	N-[2-(2,4,6-trichlorophenyloxy)ethyl]-N-propyl-1H-imidazole-1-carboxamide	Boots Co.	-	26
	Prochloraz 40 EC	40 + 5x40 oz=240 oz	F	P+5F	N-[2-(2,4,6-trichlorophenyloxy)ethyl]-N-propyl-1H-imidazole-1-carboxamide	Boots Co.	-	26
1981	Prochloraz 40 EC	40+40+40+40+40 oz	F	5F	Given in 1980	Boots Co.	-	27
	Prochloraz 40 EC	40+40+40 oz	F	3F	Given in 1980	Boots Co.	-	27
	Telone C	27.5 gal	FUM	S	Given in 1969	Dow Chem. Co.	+	27
	Terr-o-cide 54-45	9, 12 gal	FUM	S	Given in 1977	Great Lakes Chem.	+	27
	Vapam	50 gal	FUM	I	Given in 1963	Stauffer Chem. Co.	+	28
	DD-PIC	30 gal	FUM	S	DD and chloropicrin	Shell Chem. Co.	+	28
	Telone C-17	27.5 gal	FUM	S	Given in 1976	Dow Chem. Co.	+	28
1982	S-45 antagonists	1 lb/100 lb seed	BACT	SP	*Streptomyces* spp	Wash. State Univ.	-	30
	Telone C-17	27.5 gal	FUM	S	Given in 1976	Dow Chem. Co.	-	30
	Telone C-17	12,20,27.5 gal	FUM	S	Given in 1976	Dow Chem. Co.	-	30

Year Tested	Trade or Experimental number	Rate per acre	Type of activity[1]	Method of application[2]	Composition	Source	Control of *Verticillium dahliae*[3]	Literature cited[4]
	DD-PIC	21,27 gal	FUM	S	Given in 1981	Shell Chemical Co.	-	30
1983	Telone C-17	27.5	FUM	S	Given in 1976	Dow Chem. Co.	-	31
1984	Aliette® 80W	7.5 lb	F	D	aluminum tris (-O-ethylphosphonate	Rhone Poulenc, Inc.	-	32
	Ridomil® 2E	1.5, 3.0 gal	F	D	N-(2,6-dimethylphenyl-N-(methoxyacetyl) alanine methyl ester	Ciba Geigy Corp.	-	32
	Ronilan® 50W	4 lb	F	D	3-(3,5-dichlorophenyl)-5-methyl-5-vinyl-1,3 oxazolidine-2, 4-dione	BASF	-	32
	Rovral® 50W	4 lb	F	D	1-isopropylcarbamoyl-3-(3,5-dichlorophenyl) hydantoin	Rhone Poulenc, Inc.	-	32
	Vapam	50 gal	FUM	D	Given in 1963	Stauffer Chem. Co.	-	32
1985	Aliette 80W	7.5, 15 lb	F	D	Given in 1984	Rhone Poulenc, Inc.	-	UP
	Benlate 50WP	12, 24 lb	F	D	Given in 1978	E.I.duPonte du Nemours	-	UP
	Ridomil 2E	3, 6 gal	F	D	Given in 1984	Ciba Geigy Corp.	-	UP
	Ronilan 50W	12, 24 lb	F	D	Given in 1984	BASF	-	UP
	Rovral 50WP	12, 24 lb	F	D	Given in 1984	Rhone Poulenc, Inc.	-	UP
	Topsin M 70WP	8.6, 17.2 lb	F	D	dimethyl-4-1,4-O-phenylenebis-3-thioallophanate	Pennwalt Corp.	-	UP
	Topsin M 5g	20, 40 lb	F	P	See above	Pennwalt Corp.	-	UP
	Vapam	50, 100 gal	FUM	D	Given in 1963	Stauffer Chem. Co.	-	UP
	CGA-449 50WP	4 lb	F	SI	Unknown	Ciba Geigy Corp.	-	UP

[1] FUM = fumigant; F = fungicide; I = insecticide; ME = minor element; H = herbicide, FER = fertilizer; SC = soil conditioner; BACT = bacteria.

[2] S = soil shank fumigated; SI = soil incorporated with rototiller; SP = seed piece treatment; F = sprayed on foliage; P = sprayed over potato seed piece in furrow at planting; I = applied during row or sprinkler irrigation; T = injected to soil under plastic tarp; SD = side dressed plant in row; D =soil drenched.

[3] + = following treatment plants had less Verticillium wilt and yielded significantly more then the untreated; - = treatment had no affect on plant wilt or yields.

[4] Number refers to number of literature cited where results of test was published; UP = test results unpublished.

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