THE NATURE OF NEMATODES & NEMATICIDES

by
Ross Wright, Nematologist

When one undertakes to discuss nematodes, one is immediately confronted with a maze of variables and contradictions. If there is one statement about nematodes that is factual and unchanging, it is probably this. "Anything one says about nematodes is likely to be true, it is equally likely to be false." Perhaps we should first understand a little about the pest. All nematodes are worms, but not all worms are nematodes. In the scale of life they fall just above the flat worms or flukes, and just below the segmented worms, the Annelids. The largest nematode of which we are aware is 25 feet long, a parasite of the placenta of whales. The smallest is a fraction of a milimeter. There are estimated to be over one hundred thousand species. Circumstantial evidence suggests they were instrumental in the decline and fall of the Mayan civilization in Central America, the Khymers of Indo China, and probably in the decline of the Roman Empire. But since no skeletal remains survive this is speculation, but likely, since these civilizations were largely agricultural.

There is a temptation to wander through the wondrous world of nematodes, and hours could be consumed in this fashion. But for the purpose of this discussion let's confine ourselves to plant parasitic nematodes, and more specifically to those parasitic on potatoes. This, in itself, could consume a long period of time and since brevity is of the essence, we shall just touch briefly on each one. But to consider some features of plant parasitic nematodes. They have no eyes, no brains, no circulatory system, a rudimentary nervous system, an excellent digestive system, and a prolific reproductive system. Most are parthenogenetic, in that the male is not necessary for reproduction, a disturbing thought, if this faculty should ever invade the human race. While they are exceedingly fragile, they are among the most durable of God's creatures. Relatively immobile, they count upon mankind to provide food and transportation, and mankind obliges, to his detriment.

Probably the most severe parasite to infest potatoes in this area is the Root Knot nematode, of which there are 27 known species. In other parts of the world the Golden nematode is considered of greater importance as a parasite. Most nematode are named for how they look, or for what they do. The Root Knot, obviously, because of the knots and galls it causes on the roots of plants. It has, incidentally, over 3,000 known hosts, and is world wide in distribution. As you will see from the pictures I shall show, it causes unmarketable potatoes, and a ruptured root system that devastates yields.

Another widespread parasite is the Root Lesion nematode... named for the lesions it causes on roots and tubers. The most damaging feature of it's attack is the invasion by fungi and bacteria, through these wounds in the root system of plants. There are over 18 species of Root Lesion, but you do not have them all here in Washington, as you do not have all 27 species of Root Knot.

A third predator of importance is the Stubby Root nematode. Here again, the name designates the damage. Stubbed roots that allow entrance of secondary pathogens. They are also carriers, or vectors, of Tobacco Rattle Virus, a significant disease of potatoes.

Two kindred parasites of economic importance to potatoes are of the Genus Ditylenchus.

Ditylenchus Dipsaci, the Stem and Bulb nematode, attacks the aerial parts of the plant. It is an obligate parasite that can feed only on healthy tissue of a host plant. Similar, but again widely different, is the Potato Rot nematode, Ditylenchus Destructor. This parasite attacks the underground parts of the potatoes and causes damage such as I shall show in subsequent pictures. This particular pest has the ability to live not only on plant tissue but on fungi formed on decaying tissue.

There is another nematode parasite of potatoes which thankfully you do not seem to have here, but which exists only a few miles away on Vancouver Island. Hopefully strict quarantine will confine it there. It is among the most difficult of all plant parasitic nematodes to control. It is

Heterodera Rostochiensis, the Golden Nematode. This genus of which the Sugar Beet nematode, the Soy Bean Cyst nematode, and the Cruciferous Cyst nematode, are members, presents some very real problems in control. They are among the few nematodes that are visible to the naked eye. They appear as small white flecks on the roots of plants. These are the bodies of mature females. They lay a few eggs in the soil, and then fill their bodies with eggs, and then they die, and turn brown, or perhaps it is the other way about. However, they have now passed into the brown cyst stage, in which the eggs are protected by the leathery like body of the dead female. The cyst is composed of Keratin and Chitin, relatively insoluble substances. In this stage they have been known to survive periods of dormancy lasting, in some cases, as long as 20 years. In the absence of a host crop they may last even longer. But here is the weird part of their life cycle. When a host crop is present, and as the roots of the host become established in the soil, and rain or irrigation water contacts them, they exude a stimulus which causes the eggs to hatch. The larvae emerge and attack the host. When enough of them have attacked the host, the plant "turns off the tap", and the stimulus ceases. The rest of the eggs remain dormant awaiting the arrival of another host. Other hosts include tomatoes, eggplant, and perhaps other root crops. There are also weed hosts. This pest originated in Peru, the original home of potatoes. It was transported to Europe by the Spanish Conquistadores, and spread over most of the potato growing area of Europe. Before it was recognized it established several beach heads in North America, at Newfoundland, Long Island, and Vancouver Island. In spite of rigorous quarantines it has now spread to Nova Scotia, and western New York State. I urge a constant alert to the spread of this parasite. While it can be controlled with nematicides, the cost is almost prohibitive due to the large amounts necessary to penetrate the brown cysts, and because the active larvae do not appear until the crop is established. Most of the nematicides available are phyto toxic and cannot be used on living plants.

Now we know something about plant parasitic nematodes, what can we do about them? Significant strides have been made in control by using chemical nematicides. Crop rotation has not been effective because of the wide range of hosts most nematodes have, and due to the fact, that in the egg stage, they are exceedingly durable. Most are resistant to cold. Some can be thawed alive out of ice. They are sensitive to heat, but soil is a poor conductor of heat. I have taken temperatures in the desert at 150 degrees on the surface, but 8 inches down, the temperature is in the 80's.

Most of the nematicides registered for use are volatile liquids. Injected into the soil they form a gas which is absorbed through openings in the nematodes body, and which kills the pest.

Among the first to be developed were Dichloropropane-Dichloropropene .. DD for short, and Ethylene Di Bromide. Later came 1-3 Dichloropropene (Telone). There is another very effective nematicide which does not have the phytotoxicity of the first three, 1-2 Di Bromo 3 Chloropropane, which unfortunately cannot be used on potatoes. It's principal effectiveness is it's long lasting nematicidal activity in the soil, persisting for as long as 13 weeks. There are only four vegetable crops sensitive to this nematicide. They are potatoes, peppers, onions and garlic. There are, on the horizon, attempts to develop systemic nematicides, but there are some serious problems with these, and none are registered as yet, and may not ever be registered for edible crops. Some granular contact nematicides are registered on some crops, but these present a problem in handling. Since they are contact chemicals, they must be brought to the nematode in the root zone, and until equipment is developed to handle them, and they receive wide registration, they are still in the future. Some are exceedingly toxic to warm blooded animals, and with the present attitude in the Environmental Protection Agency, their use may be very restricted.

The proper use of these nematicides is clearly expressed on the labels, and your best insurance of success in their use, is working with an experienced applicator, and ensuring that the soil is properly prepared to receive the chemical. Bear in mind, none of them are any better than the way in which they are used. A final word of caution. In these, as in most chemicals, the cardinal sin is to use too little. The definition of "false economy" was never more pertinent than in the attempt to use too small a rate of nematicides. FOLLOW THE LABEL.

EFFECT OF CONTINUOUS AND DISCONTINUOUS SOIL FUMIGATION WITH VINE BURNING ON CONTROL OF VERTICILLIUM ALBO-ATRUM OF POTATO 1/

by
Gene D. Easton, Michael E. Nagle, and Donald L. Bailey 2/

SUMMARY

Verticillium albo-atrum propagules (microsclerotial type) overwintering in the soil were reduced by annual preharvest vine burning, but not by continuous and discontinuous soil fumigation. Fumigation reduced soil borne propoagules after spring application, but by fall propagule counts were the same in fumigated and non-fumigated plots. Continued fumigation with vine burning, but not fumigation alone, reduced propagules forming in the stems by fall. Propagules were not reduced in stems once fumigation was discontinued.

Either soil fumigation or vine burning controlled V. albo-atrum and increased yield; of the two, fumigation alone was the most effective. A combination treatment did not give greater control of V. albo-atrum.

The beneficial effects of soil fumigation appear to be an annual response, while those of vine burning remain for over one year.

INTRODUCTION

Work previously reported on this experiment has shown that annual spring fumigation for 5 consecutive years reduced the populations of V. albo-atrum Reinke and Berth. (microsclerotial type) in field soils, delayed plant infection and wilt symptoms and increased yield of potatoes (2, 3). Annual preharvest burning of potato vines to destroy the microsclerotia in stem tissue increased yields after 2 successive years. Burning, however, did not either reduce soil populations of V. albo-atrum, delay plant infection or wilt symptoms unless performed for 3 consecutive years.

In the 6th year we sought to determine if potatoes could be successfully grown in monoculture following continuous and discontinuous fumigation with and without vine burning.

METHODS AND MATERIALS

The cropping history, cultural methods, plot design, methods of fumigation, preharvest vine burning, soil infestment, stem isolations, and soil propagule assay for V. albo-atrum have been previously reported (2, 3). Telone^R (1, 3-dichloropropene and related hydrocarbons) + Picfume^R (trichloronitromethane) or DD^R (1, 3-dichloropropene, 1, 2 dichloropropane, 3, 3 dichloropropene, 2, 3 dichloropropene and related C_3 chloronated hydrocarbons) + Picfume were applied at rates of 20 gal Telone or DD + 5 gal Picfume per acre. The same plots were fumigated each spring 1966-1972. Starting in 1971, however, one-half of each plot previously fumigated was not fumigated and

1/ This investigation was made possible through grants by the Dow Chemical Company, Shell Chemical Company and the Washington State Potato Commission. Mention of a product used in these studies does not constitue a recommendation of the product by Washington State University over other products.

Information Paper. Project 1709, Agricultural Research Center, College of Agriculture, Washington State University.

2/ Associate Plant Pathologist, Experimental Aide 11, and Technical Farm Laborer. Department of Plant Pathology, Washington State University, Irrigated Agriculture Research and Extension Center, Prosser, Washington 99350

one-half of each plot not previously fumigated was fumigated. Soil temperatures at time of fumigation for 1971 and 1972 were 46 and 50 F. Soil moistures on an oven dry basis were 12.3% and 12.0% for 1971 and 1972. Vine burning was continued on the same plots as in previous years. The experimental field was planted with Solanum tuberosum L. 'Russet Burbank'.

Ten stems were collected from each plot in the fall of 1971 to assay for propagules. The stems were air dried at about 70 F for 3 months then ground and screened to 200 mesh. The screened stem tissue (0.5_g) was diluted 1:50, 1:1000, 1:10,000, and 1:100,000 with sterile tap water and the propagules were estimated by a method reported earlier (1).

RESULTS

Yearly vine burning reduced the over wintering propagules in the soil (tables 1 and 2). Continuous fumigation reduced the propagules in the soil following application, but fumigation alone failed to reduce over wintering soil propagules. Continuous fumigation with vine burning reduced propagules forming in the stems in the fall. Propagules were not reduced in stems once fumigation was discontinued.

The disease incidence (wilted plants) was reduced and the yields were increased by either annual vine burning or annual soil fumigation (tables 1 and 2). Soil fumigation alone was more effective in controlling V. albo-atrum and increasing yield than vine burning alone. A combined treatment did not give greater control of V. albo-atrum.

The beneficial effects of soil fumigation appear to be an annual response, while those of vine burning remain for a longer period. Reduced disease incidence and increased yield occurred after 2 years of discontinued fumigation in previously fumigated plots with vine burning but only 1 year after vine burning was omitted (tables 1 and 2).

Neither fumigation nor vine burning affected % of U.S. No. 1 tubers; therefore, data was not shown.

DISCUSSION

Only the combination treatment of annual vine burning and soil fumigation reduced V. albo-atrum propagules in stem tissue by fall (table 1). Evidently vine burning destroyed the microsclerotia in the stems (99% reduction, G. D. Easton - unpublished data) which reduced the total number of over wintering propagules, and spring fumigation further reduced the surviving microsclerotia in the soil.

Neither annual soil fumigation nor vine burning alone reduced propagules in stem tissue but vine burning alone significantly reduced the propagules over wintering in the soil (table 1). Two to three million propagules per g of stem tissue still remained after fumigation (table 1) while only 2-3000 propagules per g stem tissue remained after stem burning (G. D. Easton unpublished data). Therefore, the vine burning treatment was more efficient in reducing over wintering soil propagules. Weather conditions have been reported also to affect propagule survival (3).

Neither fumigation nor vine burning is a cure since by fall propagule levels in the soil had increased and showed no difference between treatments.

Fumigation provides an annual response which reduces surviving over wintering propagules, delays infection, delays wilt and increases yields (3); vine burning, it seems, is a practice which enhances the overall response of fumigation by reducing over wintering stem inoculum. To maintain high yields in a soil infested with V. albo-atrum it would seem necessary to fumigate and burn vines annually. Fumigation, but not vine burning, could probably be omitted for one season if the field had received both fumigation and vine burning for several years.

Table 1. Effect of annual soil fumigation and preharvest vine burning on <u>Verticillium</u> <u>albo-atrum</u> (microsclerotial type) and potato production in 1971.

Treatments[1/]	Verticillium propagules per g oven-dried soil [2/]			Number wilted plants [4/]	Verticillium propagules per g stem tissue [5/] (x 10^6)	Yield cwt/a
	Apr. 7[3/]	Apr. 22[3/]	Aug. 18[3/]	Aug. 30	Oct. 13	
A. Vines burned annually						
Never fumigated	63 a[9/]	76 b	80 a	16 b	9.68 c	605 b
Discontinuous fumigation [6/]	29 a	38 b	52 a	3 a	7.81 c	745 a
Continuous fumigation [7/]	25 a	0 a	92 a	0 a	0.98 a	740 a
Fumigated 1 yr only[8/]	84 a	4 a	153 a	0 a	1.88 a	721 a
B. Vines not burned						
Never fumigated	207 b	218 c	438 a	30 c	3.28 b	484 c
Discontinuous fumigation	317 b	267 c	602 a	28 c	9.24 c	573 b
Continuous fumigation	129 b	28 a	37 a	0 a	3.04 b	726 a
Fumigated 1 yr only	232 b	21 a	117 a	1 a	2.38 b	726 a

1/ Results for DD + Picfume or Telone + Picfume at 20 + 5 gal/a applied each spring were statistically equal so data was combined. Experimental plot planted continuously to potatoes 1966-1971.

2/ Average number of propagules as determined by counts made on 54 assay plates per treatment.

3/ Soil fumigated on Apr. 8; planted Apr. 30.

4/ Values given based on an examination of 34 plants per treatment.

5/ Average number of propagules as determined by counts of 36 assay plates per treatment from potato stems collected before vine burning and harvest on Nov. 8.

6/ Fumigated 1966-70, but not in 1971.

7/ Fumigated 1966-71.

8/ Fumigated 1971, only.

9/ Means followed by the same letter are not significantly different at the 5% level according to the individual degrees of freedom test and Duncan's multiple range test.

Table 2. Effect of annual soil fumigation and preharvest vine burning on *Verticillium albo-atrum* (microsclerotial type) and potato production in 1972.

Treatments 1/	Verticillium propagules per g oven-dry soil 2/ March 29 3/	Apr. 11 3/	Oct. 6 3/	Number wilted plants 4/ Sept. 12	Yield cwt/a
A. Vines burned annually					
Never fumigated	29 a 8/	72 b	291 a	26 c	542 b
Discontinuous fumigation 5/	60 a	46 b	331 a	28 c	516 b
Continuous fumigation 6/	45 a	27 a	716 a	2 a	605 a
Fumigated 2 yr only 7/	22 a	29 a	767 a	7 a	537 b
B. Vines not burned					
Never fumigated	504 b	286 c	341 a	31 d	450 c
Discontinuous fumigation	152 b	194 c	501 a	34 d	426 c
Continuous fumigation	337 b	16 a	1380 a	10 b	571 a
Fumigated 2 yr only	145 b	10 a	804 a	12 b	561 b

1/ Results for DD + Picfume or Telone + Picfume at 20 + 5 gal/a applied each spring were statistically equal so data was combined. Experimental plot planted continuously to potatoes 1966-1972.

2/ Average number of propagules as determined by counts made on 54 assay plates per treatment.

3/ Soil fumigated Mar. 31; planted on April 14.

4/ Values given based on an examination of 34 plants per treatment.

5/ Fumigated 1966-70, but not in 1971-72.

6/ Fumigated 1966-72.

7/ Fumigated 1971-72, only.

8/ Means followed by the same letter are not significantly different at the 5% level according to the individual degrees of freedom test and Duncan's multiple range test.

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