CORKY RINGSPOT - WHAT CONTROL MEASURES ARE AVAILABLE?

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INTRODUCTION

Stubby-root nematodes (Paratrichodorus spp. and Trichodorus spp.) are commonly found in ground used for potato production. While they may be damaging to some crops such as onions or corn they are not known to reduce yield of potato. However, when these nematodes become vectors of tobacco rattle virus (TRV) they can introduce the virus into potato plants which causes the disease corky ringspot (CRS) or spraing. Crops with more than 6% culls due to corky ringspot may be rejected by processors.

RELATIONSHIP BETWEEN NEMATODES, VIRUS AND PLANTS

Tobacco rattle virus may exist in many weeds and rotation crops which are also hosts for stubby-root nematodes. Therefore, once the virus is introduced into a field it can be perpetuated almost indefinitely. While many potato production fields are known to contain stubby-root nematodes, it is unknown how many fields are also infested with TRV. Temik is very effective in reducing vector populations and preventing CRS. Use of Temik for control of aphids and Colorado potato beetle has probably prevented the occurrence of this disease in many fields and growers may be unaware that their fields are infested. Since the suspension of Temik, CRS has reoccurred in fields which were known to be infested in the past but have changed ownership so that the new grower may be unaware of the problem. In addition, new infestations of CRS are continually being identified. Unfortunately, there is still no sure way to determine if a population of stubby-root nematodes also carries TRV.

Stubby-root nematodes pick up TRV by feeding on infested plants and ingesting the virus as they feed. The virus particles "stick" to the inside of the nematode buccal cavity and esophagus and are "regurgitated" into a new plant when the nematode feeds again. Each time a nematode molts as it grows the virus is lost and must be reacquired. However, nematodes which overwinter with the virus can infect new plants in the spring. Stubby-root nematodes are often deeply distributed through soil. A recent study in the Klamath Basin observed that 54% of the stubby-root nematode population was below the top foot of soil while only 24% of the Columbia root-knot nematode (Meloidogyne chitwoodi) population was below the top foot of soil.

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SYMPTOMS OF CRS IN POTATO

Foliar symptoms are rarely seen in potato and affected shoots generally die back to be replaced by shoots which show no sign of infection. Infected tubers are occasionally small and misshapen and fall through the digger chain or are purposely discarded back onto the field during harvest. These tubers can grow as volunteers the following season and help perpetuate the virus during rotation. Harvested tubers generally display internal concentric necrotic arcs that are characteristic of CRS. In nonrussetted varieties, these arcs may show through the skin but in russetted varieties the tuber must be peeled or cut to confirm infection. Tubers may also contain diffuse brown spots which can be confused with internal brown spot (IBS). These spots are not limited to the vascular ring but can be found anywhere within the tuber. While some varieties contain arcs almost exclusively, other varieties, such as Russet Burbank usually contain more diffuse spots than arcs. The area of necrotic tissue can be very large in severely infected tubers and encourages rot from other organisms during storage.

RECENT CONTROL STUDIES IN OREGON

The nematology program at Oregon State University has conducted several trials over the last few years to design control options for CRS. This work has been in funded by the Oregon Potato Commission, The Oregon Center for Applied Agricultural Research, Dow Elanco, ICI and Rhone-Poulenc. These studies have proven to be particularly critical since the suspension of Temik and the increase in prevalence of CRS.

COLUMBIA BASIN STUDY - 1992

The first study to be discussed was completed in 1992 in Umatilla Co., Oregon and was in cooperation with Phil Hamm, Hermiston Agricultural Research and Extension Center, Bill Swanson, Puregro, Umatilla, Bob Williams, Dow Elanco and Kurt Volker, ICI. Over 12 other individuals in the cooperators programs were also involved in various stages of data collection or crop management during the study. Efforts by the grower were also instrumental in the success of the study.

The treatments listed in Tables 1 and 2 were applied to plots in a randomized block design with four replications in an irrigated circle with a history of CRS. Telone II and Telone C-17 were applied to appropriate plots on October 25, 1991 by injecting 18 in deep with shanks set on a 15 in spacing. Soil was sealed immediately with a disc and packer which followed behind the fumigator. Vapam was applied with 1 in of water to appropriate plots on November 4 with a portable sprinkler applicator. Mocap 10 G was applied March 18, 1992 by measuring the appropriate amount of material for each plot into a Casoron spreader and making at least two passes over the treated area while dispensing the material. Mocap was incorporated to 6 in with a tractor pulled rototiller. Russet Burbank potato was planted April 14. Temik 15 G was applied on May 22 via a gandy box with lilliston extenders and incorporated with a dammer-diker.

Vydate L was foliar applied (1/2 GPA/application) with a backpack sprayer on June 18 and July 16. Potatoes were harvested on October 1 by digging the center row of each plot with a single row digger. All tubers from the center 25 ft of row were collected for yield, grade and disease assessments. A random sample of 25 4-12 oz tubers was cut longitudinally to inspect for symptoms of CRS. If no or only slight symptoms were found, the tubers were further sliced into 1/2 in transverse slices. Only spots or arcs exceeding 1/8 in in diameter were counted. Tubers were placed into categories of "damage" = up to 5% waste (e.g. up to 1 spot or arc per 2 oz of tuber), "serious damage" = 5+% to 10% waste (1-2 spots or arcs per 2 oz of tuber) and "culls" = over 10% waste. Tubers with up to 5% waste may be considered as No. 1's and tubers with 5-10% may be considered No. 2s. Virtually all internal defects present at harvest were symptoms of corky ringspot (CRS). Infection with Meloidogyne chitwoodi was very infrequent and at low levels.

Nematode samples (10 core/plot) from 0-1 ft and 1-2 ft deep were taken from the area in each plot where the two center rows of potatoes would be planted in the spring. Samples were collected before fumigation (October 23, 1991), before planting and Mocap or Temik application (March 17, 1992), midseason (August 18) and at harvest (October 1). Soil samples were sieved, mixed and 250 g extracted by wet sieving-sucrose centrifugation.

All percent damage data were transformed to arcsin square root (x) and examined by analysis of variance (ANOVA). Nematode densities were adjusted for soil moisture and transformed to log (x+1) before analysis (ANOVA). LSD was used to separate means only when ANOVA was significant at $P < 0.05$ unless otherwise stated.

Table 1 gives the nematode densities that were recovered from the different treatments during the course of the study. For brevity, nematode populations from the first and second foot have been combined to illustrate the total number of nematodes which would be found in a 1 in diameter core to a depth of 24 in. (This is approximately equal to 295 cc soil). Stubby-root nematodes (Paratrichodorus allius) were found throughout the plot area before fumigation. Population levels remained relatively unchanged over the winter in the check plots but were reduced to low levels in plots treated with Vapam or Telone C-17. By midseason and harvest, populations in the check plots had declined and were just above limits of detection in most plots treated with Telone C-17 or Vapam. Percent of tuber culls with CRS was not decreased by any rate of Vapam applied (Table 2) and although CRS was significantly decreased by Temik and Telone C-17, the level of infection was still unacceptable. Stubby-root nematode densities were 0 or near 0 in all post fumigation sample dates for all treatments which received Telone II (Table 1). All these treatments controlled CRS to acceptable levels and three treatments had no culls due to CRS (Table 2).

KLAMATH BASIN STUDY - 1990

This study was conducted at the Klamath Experiment Station (KES) in cooperation with Ken Rykbost, Superintendent, KES and Bob Williams, Dow Elanco. This study compared fall fumigation with spring fumigation and nonfumigant nematodes alone or in combination with fumigants. (See treatment list in Table 3). Experimental design and evaluation were similar to that described above. Arc and spot symptoms were analyzed separately and only arc data are presented here.

Midseason populations of stubby-root nematodes (Paratrichodorus teres) were reduced to 0 or near 0 by all fall or spring treatments with Telone II or Telone C-17 (Table 3). By chance, control plots had much fewer stubby-root nematodes than the rest of the plot area. The XRD-429 treatment, which was relatively ineffective, had populations more typical for the rest of the treatments and serves as a better "control" than the nontreated plots. Mocap at either rate had little effect on stubby-root populations. Percentage of tubers with symptoms of CRS was significantly reduced (compared to the XRD-429 treatment) by all treatments except fall fumigation with Telone II at 15 GPA. However, the only acceptable treatments were Telone C-17 and Telone II at 15 GPA (either in the fall or the spring) plus PPI Mocap at 6 lb a.i./A (Table 3).

Since root-knot nematodes are common in potato fields as well as stubby-root nematodes, midseason populations of Meloidogyne chitwoodi and tubers culled by M. chitwoodi are also presented in Table 3. All treatments but XRD-429 and Mocap alone reduced midseason populations of M. chitwoodi to 0. Percent culled tubers were reduced to acceptable levels by all treatments except fall Telone II at 15 GPA and PPI Mocap at 9 lb a.i./A.

KLAMATH BASIN STUDY - 1991

This study was conducted in a grower's field near Malin, Oregon and was in cooperation with Ken Rykbost and Chris Olsen, Rhone-Poulenc. Control of CRS with spring fumigation with Telone II at 20 GPA was compared with Mocap, Temik and combinations of Mocap and Temik, Telone II and Mocap and Telone II and Temik.

Nematode densities were very low at midseason (Table 4). Only Mocap plus Temik and Telone II plus Temik had significantly fewer stubby-root nematodes than in nontreated plots and there were no differences between treatments in densities of root-knot nematodes. Distribution of CRS in this field was highly variable with some check plots having high levels of infection and others having very little infection. This variability prevented significant differences between treatments in CRS data. All treatments except Mocap at 9 lb a.i./A reduced CRS to acceptable levels but only Telone II at 20 GPA plus Mocap or Telone II at 20 GPA plus Temik reduced tuber infection by M. chitwoodi to acceptable levels (Table 4).

CONCLUSIONS

Very low densities of stubby-root nematodes can result in high levels of tuber infection with CRS. Thus, as with M. chitwoodi, if even a few nematodes remain after treatment, serious damage may occur. Telone II was very effective at controlling CRS in the Columbia Basin and the Klamath Basin but in the Klamath Basin addition of PPI Mocap was necessary at times to reduce CRS to low levels and reduce root-knot infection to acceptable levels. However, Telone II has very little impact on Verticillium and early dying (see report by Hamm). In fields with a history of yield reduction from Verticillium, combinations of Telone II and Metham Sodium may be the optimum treatment. Combination treatments provided high yields and controlled CRS and Verticillium in the Columbia Basin study. M. chitwoodi was also controlled by double fumigation in this study (data not presented) as well as other studies (see report by Santo). The effectiveness of Vydate for control of CRS needs to be further studied as the two treatments in which it was applied in 1992 had 0 culls. Research is continuing in Oregon to find optimal treatments to control CRS, root-knot nematodes and Verticillium.

Table 1. Effect of fall fumigation with Vapam or Telone alone, in combination or with nonfumigant nematicides on stubby-root nematodes (Paratrichodorus allius), Umatilla, Or. 1992.

	TOTAL NEMATODES IN A 1 IN DIAMETER CORE FROM 0-24 IN			
TREATMENT	BEFORE FUMIGATION	BEFORE PLANTING	MID SEASON	HARVEST
CHECK # 1	24	42 c[1]	3 ab	9 c
CHECK # 2	44	26 c	12 b	16 c
TEMIK @ 3 LB A.I./A	90	71[2]c	2 a	0 a
VAPAM @ 55 GPA	131	3 ab	3 ab	5 ab
VAPAM @ 75 GPA	82	6 b	0 a	1 a
VAPAM @ 100 GPA	53	3 ab	2 a	2 b
TELONE C-17 @ 27.5 GPA	80	0 a	1 a	1 a
TELONE II @ 15 GPA	66	2 a	2 a	0 a
TELONE II @ 20 GPA	52	1 a	0 a	0 a
TELONE II @ 25 GPA	90	0 a	0 a	1 a
TELONE II @ 20 GPA + VAPAM @ 50 GPA	82	0 a	0 a	0 a
TELONE II @ 25 GPA + MOCAP	32	0 a	0 a	0 a
TELONE II @ 25 GPA + TEMIK	126	0 a	0 a	0 a
TELONE II @ 25 GPA + VYDATE	76	0 a	0 a	0 a
TELONE II @ 20 GPA + VAPAM @ 50 GPA + VYDATE	40	1 a	0 a	0 a

[1]Means followed by the same letter are not significantly different.
[2]Samples taken before Temik application

Table 2. Effect of fall fumigation with Vapam or Telone alone, in combination or with nonfumigant nematicides on percent of tuber culls due to corky ringspot disease, Umatilla, Or. 1992.

TREATMENT	PERCENT CRS CULLS
CHECK # 1	81 c[1]
CHECK # 2	74 c
TEMIK @ 3 LB A.I./A	16 b
VAPAM @ 55 GPA	74 c
VAPAM @ 75 GPA	60 c
VAPAM @ 100 GPA	65 c
TELONE C-17 @ 27.5 GPA	12 b
TELONE II @ 15 GPA	5 a
TELONE II @ 20 GPA	1 a
TELONE II @ 25 GPA	3 a
TELONE II @ 20 GPA + VAPAM @ 50 GPA	5 a
TELONE II @ 25 GPA + MOCAP	2 a
TELONE II @ 25 GPA + TEMIK	0 a
TELONE II @ 25 GPA + VYDATE	0 a
TELONE II @ 20 GPA + VAPAM @ 50 GPA + VYDATE	0 a

[1]Means followed by the same letter are not significantly different.

Table 3. Effect of fall and spring fumigation and nonfumigant nematicides on control of stubby-root nematodes (Paratrichodorus teres), root knot nematodes (Meloidogyne chitwoodi) and tuber infection with corky ringspot disease and root-knot nematodes in Klamath Basin, Or., 1990.

TREATMENTS	MID SEASON STUBBY-ROOT[1]	MID SEASON ROOT-KNOT[2]	PERCENT TUBERS WITH ARCS[3]	PERCENT ROOT-KNOT CULLS[4]
NONTREATED CHECK	20 b[5]	65 c	9 a	62 c
FALL TELONE II @ 15 GPA	0 a	0 a	7 a	31 b
FALL TELONE II @ 20 GPA	0 a	0 a	8 a	1 a
FALL TELONE II @ 25 GPA	0 a	0 a	24 a	0 a
FALL TELONE II @ 15 GPA + PPI MOCAP @ 6 LB A.I./A	0 a	0 a	2 a	0 a
FALL TELONE II @ 15 GPA + PPI XRD-429 @ 3 LB A.I./A	1 a	0 a	6 a	1 a
FALL TELONE C-17 @ 27.5 GPA	0 a	0 a	1 a	2 a
PPI XRD-429 @ 3 LB A.I./A	41 b	4 ab	50 c	9 a
PPI MOCAP @ 9 LB A.I./A	28 b	74 c	28 ab	10 a
PPI MOCAP @ 12 LB A.I./A	48 b	28 c	12 ab	3 a
SPRING TELONE II @ 15 GPA	2 a	0 a	27 bc	1 a
SPRING TELONE II @ 15 GPA + PPI MOCAP @ 6 LB A.I./A	1 a	0 a	7 a	0 a

[1]Number of P. teres in a 1 in diameter column to a depth of 24 in (July 10, 1990.)
[2]Number of M. chitwoodi in a 1 in diameter column to a depth of 24 in (July 10, 1990.)
[3]Percent of tubers in which arcs (symptoms of CRS) were detected by transverse slicing of tubers into 1/4 in thick slices.
[4]Percent of tubers with 6+ M. chitwoodi.
[5]Means in the same column followed by the same letter are not significantly different.

Table 4. Effect of spring fumigation and nonfumigant nematicides on control of stubby-root nematodes (Paratrichodorus teres), root knot nematodes (Meloidogyne chitwoodi) and tuber infection with corky ringspot disease and root-knot nematodes in Klamath Basin, Or., 1991.

TREATMENTS	MID SEASON STUBBY-ROOT[1]	MID SEASON ROOT-KNOT[2]	PERCENT TUBERS WITH ARCS[3]	PERCENT ROOT-KNOT CULLS[4]
NONTREATED CHECK	6 bc[5]	0	21	42 bc
MOCAP @ 9 LB A.I./A	1 ab	2	11	45 bc
MOCAP @ 12 LB A.I./A	8 c	9	1	50 bc
TEMIK @ 3 LB A.I./A	5 abc	0	3	73 c
MOCAP @ 9 LB A.I./A + TEMIK @ 3 LB A.I./A	0 a	1	0	33 bc
TELONE II @ 20 GPA	2 abc	0	0	20 ab
TELONE II @ 20 GPA + MOCAP @ 9 LB A.I./A	1 ab	0	1	0 a
TELONE II @ 20 GPA + TEMIK @ 3 LB A.I./A	0 a	0	0	0 a
		NS	NS	

[1]Number of P. teres in a 1 in diameter column to a depth of 12 in (July 10, 1991.)
[2]Number of M. chitwoodi in a 1 in diameter column to a depth of 12 in (July 10, 1991.)
[3]Percent of tubers in which arcs (symptoms of CRS) were detected by transverse slicing of tubers into 1/4 in thick slices.
[4]Percent of tubers with 6+ M. chitwoodi.
[5]Means in the same column followed by the same letter are not significantly different.