EVALUATION OF ETHOPROP AND CADUSAFOS FOR CONTROL OF *MELOIDOGYNE CHITWOODI* ON POTATO[†]

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ABSTRACT

Santo, G. S., and J. H. Wilson. 1990. Evaluation of ethoprop and cadusafos for control of *Meloidogyne chitwoodi* on potato. Nematrópica 20:137–142.

Ethoprop, cadusafos (FMC 67825) and 1,3-D were evaluated for control of *Meloidogyne chitwoodi* on 'Russet Burbank' potato (*Solanum tuberosum*). Based on tuber infection, cadusafos at broadcast rates of 10.1, 13.4, and a split application of 6.7 + 6.7 kg a.i./ha, and a 30-cm-wide band treatment of 6.7 kg a.i./ha were comparable to a commercial treatment of 1,3-D at 176 L a.i./ha. Ethoprop, the nonfumigant nematicide used most frequently on potato for control of root-knot nematodes in the northwestern United States, did not reduce *M. chitwoodi* infection of tubers.

Key words: cadusafos, chemical control, Columbia root-knot nematode, 1,3-D, ethoprop, *Meloidogyne chitwoodi*, nematode control, *Paratrichodorus*, potato, *Pratylenchus neglectus*, *Solanum tuberosum*.

RESUMEN

Santo, G. S., y J. H. Wilson. 1990. Evaluación de ethoprop y cadusafos para el control de *Meloidogyne chitwoodi* en papa. Nematrópica 20:137–142.

Se evaluaron ethoprop, cadusafos (FMC 67825) y 1,3-D para el control de *Meloidogyne chitwoodi* en papa 'Russet Burbank' (*Solanum tuberosum*). El cadusafos a razón de 10.1 y 13.4 aplicado sobre el área total y en una aplicación compartida de 6.7 + 6.7 kg de i.a./ha, redujo los niveles de infección de los tubérculos de manera comparable al tratamiento comercial de 1,3-D de 176 L de i.a./ha. Ethoprop, el nematicida no fumigante más frecuentemente utilizado para controlar los nematodos agalladores en el Noroeste de los E.U.A., no redujo el nivel de infección de los tubérculos por *M. chitwoodi.*

Palabras claves: cadusafos, control químico, 1,3-D, ethoprop, *Meloidogyne chitwoodi* nematodo agallador, *Paratrichodorus*, papa, *Pratylenchus neglectus*, *Solanum tuberosum*.

INTRODUCTION

The Columbia root-knot nematode, *Meloidogyne chitwoodi* Golden, O'Bannon, Santo & Finley is the most important nematode pest of potato (*Solanum tuberosum* L.) in the Pacific Northwest, U.S.A. The

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nematode affects tuber quality and causes severe losses if not properly controlled (9,13). Soil fumigation with either 1,3-D or metham sodium is the most commonly used method to control this nematode on potato (8,12). However, in fields with high *M. chitwoodi* population pressures soil fumigation alone may not be adequate. Under these conditions the most effective treatment for *M. chitwoodi* has been the combination of a soil fumigant and ethoprop (8). Although ethoprop is an excellent nematicide, the lack of downward movement with water severely limits its effectiveness when used alone against *M. chitwoodi* (1,5). Due to their costs, and uncertain future of registered nematicides, there is a continuing need to search for alternative nematicides.

This study reports the comparison of cadusafos (O-ethyl S,S-di-sec-butyl phosphorodithioate [FMC 67825] FMC Corporation, Princeton, NJ, U.S.A.)with ethoprop and 1,3-D for the control of *M. chitwoodi* on 'Russet Burbank' potato.

MATERIALS AND METHODS

This study was conducted from April-November 1986 at the Irrigated Agriculture Research and Extension Center at Prosser, Washington. The texture of the soil in the top 30 cm was a sandy loam (73.3% sand, 23.1% silt, 4.6% clay) with 0.6% organic matter and pH 6.9. The plot area was cropped previously to wheat (*Triticum aestivum* L.) in 1985 and potato in 1984. The infestation of second-stage juveniles (J2) of *M. chitwoodi* race 2 averaged 160/250 cm^3 of soil (6). Numbers of *Pratylenchus neglectus* (Rensch) Filipjev & Schuurmans Stekhoven and *Paratrichodorus* spp. were 10 and 19/250 cm^3 of soil per plot, respectively.

Plots were three rows (86 cm apart) 10.7 m long, and treatments were arranged in a randomized complete block design with five replications. Chemicals evaluated were cadusafos, ethoprop, and 1,3-D. Untreated plots served as controls. Ammonium sulfate (336 kg N/ha) was broadcast prior to fumigation. 1,3-D at 176 L a.i./ha was applied broadcast with tractor-drawn sweep shanks (two nozzles/shank) 30 cm deep, spaced 23 cm apart prior to planting on 15 April. Immediately after application the fumigated area was sealed with a cultipacker. Soil temperature during fumigation was 15 C at 30 cm, and soil moisture was 68% of field capacity. Ethoprop (6EC) and cadusafos (20G) at 6.7, 10.1, and 13.4 kg a.i./ha were broadcast on the soil surface and incorporated 15 cm deep with a rototiller. Ethoprop was applied with a hand pressurized sprayer and cadusafos was broadcast evenly on the soil surface with a glass jar by hand prior to planting on 7 May. Cadusafos at 6.7 kg a.i./ha also was applied in a 30-cm-wide band on 7 May and rototilled 15 cm deep. Certified 'Russet Burbank' potato seed-pieces were planted and hilled 8 May. The herbicides EPTC at 3.3 kg and trifluralin at 1.1 kg a.i./ha were sprayed and mechanically incorporated prior to plant emergence. Postplant treatments of ethoprop and cadusafos at 6.7 kg a.i./ha were broadcast with a glass jar by hand directly over the plants on 25 June and incorporated with 2.5 cm of water.

Plots were irrigated with solid-set sprinklers and maintained with standard cultural practices (4). The plots received a total of 48 cm of water during the season. Methamidophos, fenvalerate, and carbaryl were applied as needed during the season for insect control. Plots were harvested on 8 October.

Yield, nematode population densities, and tuber infection data were obtained from the middle row (7.6 m) of each plot. Fifteen soil cores (2.5-cm diam. × 30 cm deep) for nematode analyses were taken from each plot before treatment (11 April), after treatment (9 July), and after harvest (12 November). Soil was mixed thoroughly and nematodes were extracted using a semiautomatic elutriator (2) and centrifugal-flotation (3). Twenty tubers from each plot were peeled by hand and examined critically for *M. chitwoodi* infection. Tubers were rated individually for percentage of culls and infection. Tubers with six or more infection sites were graded as culls. Washington State inspectors grade potato lots based on the percentage of culls due to internal defects caused by nematodes or other factors using a scale of 0–5% = US No. 1, 6–10% = No. 2, and 11+% = rejection. An infection index rating of 0–6 also was made for each tuber, where 0 = no nematode infection, 1 = 1–3, 2 = 4–5, 3 = 6–9, 4 = 10+, 5 = 50+, and 6 = 100+ nematodes per tuber. Data were analyzed using analysis of variance, and treatment means were compared by Duncan's multiple-range test. The treatment sum of squares was partitioned into orthogonal contrasts to compare cadusafos vs. ethoprop.

RESULTS AND DISCUSSION

Midseason *M. chitwoodi* second-stage juvenile (J2) population densities were low, and except for ethoprop at 10.1 kg a.i./ha, none of the treated plots differed ($P = 0.05$) from the untreated plots (Table 1). This is consistent with *M. chitwoodi* population dynamic studies on potato which show that the lowest J2 soil population occurs in July (7). Although all of the treated plots had lower J2 counts after harvest than the untreated, only cadusafos at 10.1 kg a.i./ha and the split application of cadusafos differed ($P = 0.05$). Nematode population density after harvest was correlated ($P = 0.01$) with percentage of culls ($r = 0.80$) and with infection index ($r = 0.81$), but not with tuber yields ($r = -0.40$). Except for the postplant application of cadusafos, all of the treatments increased ($P = 0.05$) tuber yields compared with the untreated (Table 1). Yield, however, was not correlated ($P = 0.05$) with *M. chitwoodi* infection based on either percentage of culls ($r = -0.31$) or infection index ($r = -0.42$). There was a high correlation ($r = 0.99$, $P =$

Table 1. Numbers of *Meloidogyne chitwoodi* second-stage juveniles (J2), potato yields, percentage of culls, and tuber infection index from plots treated with 1,3-D, ethroprop, or cadusafos.

Treatment	Rate and method[y] (a.i./ha)	J2/250 cm³ of soil April	July	Nov.	Yield (t/ha)	Culls[z] (%)	Infection Index[z]
Untreated		82 a	22 abc	1 000 a	36.1 c	100 a	6.0 a
1,3-D	176 L	76 a	3 cd	375 abc	57.2 a	46 cd	2.3 cd
Ethoprop	6.7 kg	108 a	7 bcd	820 a	46.3 ab	88 ab	4.7 ab
Ethoprop	10.1 kg	108 a	6 bcd	700 a	53.6 ab	92 ab	4.6 ab
Ethoprop	13.4 kg	69 a	1 d	660 a	55.7 a	98 a	5.0 a
Ethoprop	6.7 kg + 6.7 kg (PP)	186 a	3 cd	645 a	55.7 a	98 a	5.4 a
Ethoprop	6.7 kg (PP)	164 a	4 bcd	245 abc	50.9 ab	86 ab	4.5 ab
Cadusafos	6.7 kg	152 a	9 bcd	395 abc	51.4 ab	62 bc	3.2 bc
Cadusafos	10.1 kg	189 a	3 cd	90 bc	49.5 ab	17 d	1.0 d
Cadusafos	13.4 kg	324 a	10 bcd	245 abc	57.9 a	24 d	1.3 d
Cadusafos	6.7 kg + 6.7 kg (PP)	284 a	32 ab	70 c	49.4 ab	14 d	1.1 d
Cadusafos	6.7 kg (PP)	221 a	98 a	480 ab	43.8 bc	100 a	5.7 a
Cadusafos	6.7 kg (30-cm band)	117 a	10 bcd	350 abc	48.7 ab	24 d	1.6 d

Data are means of five replicates. Values in each column not followed by the same letter differ at $P = 0.05$ according to Duncan's multiple-range test. Nematode soil data were transformed to Log (X + 1) and percentage of culls to Arcsin [Sqrt (S)].

[y]PP = applied post-plant on 15 June. All other treatments applied before planting. Except where noted, all treatments applied broadcast. The 6EC and 10G formulations of ethroprop were used before planting and post-plant, respectively. The 20G formulation of cadusafos was used for all treatments receiving this material.

[z]Tubers with six or more infection sites were graded as culls. Infection index: 0 = no nematodes, 1 = 1–3, 2 = 4–5, 3 = 6–9, 4 = 10+, 5 = 50+, and 6 = 100+ infection sites per tuber.

0.01) between percentage of culls and infection index. Although tuber damage was severe in the untreated plots, only 6 of 12 nematicide treatments had less ($P = 0.05$) nematode infection than the untreated. In this trial, 1,3-D applied at the recommended commercial rate of 176 L a.i./ha reduced ($P = 0.05$) tuber infection compared with the control; however, control was not adequate to prevent rejection (> 10% culls). This is contrary to results obtained in other trials where 1,3-D has provided excellent control (10,11). In most instances under commercial field conditions, 1,3-D has provided adequate control of *M. chitwoodi* especially with initial population levels similar to those recovered at the inception of this trial. The reason for the relative high tuber infection in the 1,3-D treated plots at harvest may have been due, in part, to the unusually warm temperatures that occurred in April and May, and the late harvest. These conditions would have optimized the activity and development of *M. chitwoodi*, resulting in an additional generation or more of *M. chitwoodi* (7). More root-knot nematode related complaints were reported in 1986 with 1,3-D and metham sodium as compared to previous years.

Despite this high nematode pressure, results obtained with most of the cadusafos treatments were comparable to 1,3-D. Cadusafos treatments at 10.1, 13.4, 6.7 + 6.7 kg a.i./ha, and the band treatment at 6.7 kg a.i./ha had cullage and tuber infection rates equivalent to the 1,3-D treatment. Orthogonal contrasts showed that cadusafos performed better (P = 0.01) than ethoprop in reducing nematode infection. Cadusafos applied in a band treatment was superior to the comparable preplant broadcast treatment, indicating that better results may be obtained with the higher rate treatments by concentrating cadusafos in a 30-cm-wide band. The rationale for the post-plant treatments was to protect the tubers from second-generation J2 emerging from egg masses that developed on the roots (7). The post-plant treatments of both cadusafos and ethoprop did not protect tubers from *M. chitwoodi*. However, the split application treatment with cadusafos compared with 6.7 kg a.i./ha of cadusafos applied preplant indicated that a post-plant application may be beneficial following a preplant nematicide treatment. The results indicated that applying more than 10.1 kg a.i./ha of cadusafos does not provide added benefits of control.

Pratylenchus neglectus and *Paratrichodorus* spp. population densities remained low throughout the study. After harvest population densities of *P. neglectus* were suppressed by all the nonfumigant treatments (P = 0.05) compared with the untreated plots and 1,3-D treated plots. Likewise, all of the cadusafos treatments and the split application of ethoprop reduced (P = 0.05) *Paratrichodorus* spp. population densities compared with the untreated plot but did not differ from the other treatments.

In this study, application of ethoprop did not control *M. chitwoodi*. In other studies with ethoprop (10,11), results have been inconsistent whenever ethoprop has been used alone to control *M. chitwoodi* on potato. In certain years, ethoprop has given excellent control (10) and in other years no control (11). The reason for this inconsistency is not clear and is under investigation. Laboratory and greenhouse studies have demonstrated the excellent nematicidal activity of ethoprop against *M. chitwoodi* and *M. hapla* (5). The major limiting factor of ethoprop in the field is its lack of mobility which severely restricts its depth of control (1,5). The most effective use of ethoprop for the control of *M. chitwoodi* has been in combination with 1,3-D (8).

The results obtained with cadusafos were encouraging. However, FMC Corporation has discontinued testing of this nematicide in the U.S.A. At present, cadusafos is registered for nematode control on bananas in the Caribbean region.

LITERATURE CITED

1. BRODIE, B. B. 1971. Differential vertical movement of nonvolatile nematicides in soil. Journal of Nematology 3:292–295.
2. BYRD, D. W., K. R. BARKER, H. FERRIS, C. J. NUSBAUM, W. E. GRIFFIN, R. H. SMALL, and C. A. STONE. 1976. Two semiautomatic elutriators for extracting nematodes and certain fungi from soil. Journal of Nematology 8:206–212.
3. JENKINS, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48:692.
4. KUNKEL, R., and R. E. THORNTON. 1986. Understanding the potato. Scientific Paper No. 7267, College of Agriculture & Home Economics, Washington State University, Pullman, WA, U.S.A.
5. MOJTAHEDI, H., G. S. SANTO, J. N. PINKERTON, and J. H. WILSON. 1988. Effect of ethoprop on *Meloidogyne chitwoodi* and *M. hapla*. Journal of Nematology 20:649.
6. PINKERTON, J. N., H. MOJTAHEDI, and G. S. SANTO. 1987. Reproductive efficiency of Pacific Northwest isolates of *Meloidogyne chitwoodi* on alfalfa. Plant Disease 71:345–348.
7. PINKERTON, J. N., G. S. SANTO, and H. MOJTAHEDI. 1986. Population dynamics of *Meloidogyne chitwoodi* in relation to Russet Burbank potato tuber penetration. Journal of Nematology 18:627.
8. PINKERTON, J. N., G. S. SANTO, R. P. PONTI, and J. H. WILSON. 1986. Control of *Meloidogyne chitwoodi* on commercially grown Russet Burbank potatoes. Plant Disease 70:860–863.
9. SANTO, G. S. 1985. Managing root-knot nematode problems in the Pacific Northwest. Fourth Annual North American Seed Potato Seminar Proceedings 3:9–10.
10. SANTO, G. S., H. MOJTAHEDI, and J. H. WILSON. 1988. Biology and control of root-knot nematodes on potatoes, 1987. Proceedings of the 27th Annual Washington State Potato Conference. Pp. 67–70.
11. SANTO, G. S., H. MOJTAHEDI, J. H. WILSON, and R. E. INGHAM. 1989. Population dynamics and control of the Columbia root-knot nematode on potato. Proceedings of the 28th Annual Washington State Potato Conference. Pp. 111–116.
12. SANTO, G. S., and M. QUALLS. 1984. Control of *Meloidogyne* spp. on Russet Burbank potato by applying metham sodium through center pivot irrigation systems. Journal of Nematology 16:159–161.
13. HAFEZ, S.L., W. HART, H. J. JENSEN, P. A. KOEPSELL, E. L. NIGH, J. PINKERTON, P. A. ROBERTS, G. S. SANTO, and I. J. THOMASON. 1986. Nematodes. Pp. 108–116, *in* Integrated Pest Management for Potatoes in the Western United States. Western Regional Research Publication 011. University of California, Division of Agriculture and Natural Resources Publication 3316. Berkeley, CA, U.S.A.

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