PLANT-PARASITIC NEMATODES ASSOCIATED WITH WEEDS IN POTATO (*SOLANUM TUBEROSUM* L.) FIELDS FROM THE NORTHERN AREA OF CARTAGO, COSTA RICA

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ABSTRACT

Núñez Rodríguez, L. A., D. A. Humphreys-Pereira, A. M. Rodríguez-Ruiz, and L. Flores-Chaves. 2022. Plant-parasitic nematodes associated with weeds in potato (*Solanum tuberosum* L.) fields from the northern area of Cartago, Costa Rica. Nematropica 52:33-44.

Potatoes are the main vegetable produced in Costa Rica, however, basic information about the interaction of nematodes and alternative hosts in potato fields is lacking. The objective of this study was to identify the plant-parasitic nematodes associated with weeds in potato fields from the northern area of Cartago, Costa Rica. Weeds from 15 potato fields (3 months after planting) were sampled. To determine the most frequent weed species, 5 sections (approximately 4 m^2) were sampled in each field using a 1 m^2 square. The most frequent weed species (a maximum of five) were selected, and five composite root samples per weed were processed for subsequent nematode identification and quantification. Twenty-seven weed species were identified in the potato fields, with *Brassica campestris*, *Lepidium virginicum*, and *Poa annua* among the six most frequent weed species. Fifteen nematode genera, two families, and a subfamily were identified associated with weed roots. There were statistical differences between endoparasitic nematodes. *Pratylenchus* had the highest frequency of occurrence relative to heteroderids and *Meloidogyne*. *Pratylenchus* also had the highest average population density of the endoparasitic nematodes with 31,056 nematodes/100 g of roots. Our results provide valuable information for the integrated management of nematodes. Alternative hosts such as weeds should be managed after the potato production cycle. Fallow could increase population densities of plant-parasitic nematodes, detrimental to other common crops in the region, such as onions and carrots.

Key words: *Meloidogyne*, *Pratylenchus*, potato, weeds, quantification, roots

RESUMEN

Núñez Rodríguez, L. A., D. A. Humphreys-Pereira, A. M. Rodríguez-Ruiz, and L. Flores-Chaves. 2022. Nematodos fitoparásitos asociados a malezas en el cultivo de papa (*Solanum tuberosum* L.) en la zona norte de Cartago, Costa Rica. Nematropica 52:33-44.

La papa es la principal hortaliza cultivada en Costa Rica, sin embargo, falta información básica sobre la interacción de nematodos con hospederos alternativos en plantaciones de papa. El objetivo de este estudio fue identificar los nematodos fitoparásitos asociados a las principales malezas en plantaciones de papa de la zona norte de Cartago, Costa Rica. Se muestrearon malezas en 15 plantaciones de papa (tres meses de edad). En cada finca se muestrearon cinco puntos (aproximadamente 4m^2) utilizando un marco de 1m^2 para determinar las malezas más frecuentes. Se seleccionaron las especies de malezas más frecuentes (un máximo de cinco) y se recolectaron cinco muestras compuestas por especie para su procesamiento, identificación y cuantificación de nematodos. Se identificaron un total de 27 especies de malezas en las plantaciones de papa, de las cuales, seis especies fueron las más frecuentes, entre ellas *Brassica campestris*, *Lepidium virginicum*, y *Poa annua*. Se identificaron 15 géneros de nematodos, dos familias y una subfamilia. Se observó diferencia estadística significativa entre nematodos endoparásitos, donde *Pratylenchus* fue el más frecuente en comparación a heteroderides y *Meloidogyne*. *Pratylenchus* también tuvo la mayor densidad media poblacional entre los nematodos endoparásitos con 31,056 nematodos en 100 g de raíz. Nuestros resultados muestran información valiosa para el manejo integrado de nematodos. Los hospederos alternativos como las malezas se deberían manejar selectivamente después del ciclo productivo de la papa. El barbecho podría incrementar las densidades de nematodos fitoparásitos, en detrimento de otros cultivos de la región, como cebolla y zanahoria.

Palabras clave: Cuantificación, *Meloidogyne*, *Pratylenchus*, malezas, papas, raíces

INTRODUCTION

Potato (*Solanum tuberosum* L.) is considered the third most important food in the world, only surpassed by wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.) (Juyó *et al.*, 2015). In Costa Rica, there are 3,218 ha of potato, cultivated in Alajuela, Cartago, Heredia and San José Provinces. However, the vast majority of potatoes are grown in Alajuela and Cartago with 867 and 2,553 ha, respectively. Zarcero in Alajuela and the north area in Cartago are the main production areas (SEPSA, 2018).

As with many other crops, potatoes are affected by different pests, such as plant-parasitic nematodes, which can cause yield losses of about 12.2% (Ravichandra, 2014). Among the most important nematodes associated with potatoes worldwide are *Globodera*, *Meloidogyne*, and *Pratylenchus* (Jones *et al*., 2013; Palomares *et al*., 2014). These genera have been reported in potato fields in Costa Rica (López and Azofeifa, 1981). *Globodera* spp. were described morphologically and molecularly in 2009 (García *et al*., 2009), while there are two *Meloidogyne* spp., *M. incognita* and *M. hapla*, and two *Pratylenchus* species, *P. crenatus* and *P. penetrans*, reported in the country (Montero *et al*., 2007; Sandoval 2015, 2018).

The presence of alternative hosts is a factor that makes plant-parasitic nematode control difficult. Weeds can allow plant-parasitic nematodes to survive with or without the presence of a crop, which provides a constant source of nematode inoculum for future crop cycles (Kaur *et al*., 2007). In the southeastern United States, *Rotylenchulus reniformis* is an important plant-parasitic nematode and its ability to reproduce on different weeds such as *Sida spinosa*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, and *Ipomoea hederacea* has been demonstrated (Lawrence *et al*., 2008). In Florida, *Meloidogyne* spp. can reproduce on weeds such as *Eleusine indica*, *Portulaca oleracea*, *Solanum americanum*, *Amaranthus* spp., and *Lepidium virginicum* (Myers *et al*., 2004) and in the Netherlands on *Senecio vulgaris* and *Capsella bursa-pastoris* (Kutywayo and Been, 2006).

Studies carried out in countries such as Bulgaria and the USA have reported the ability of weeds associated with potato production to host genera such as *Pratylenchus* and *Meloidogyne* (Samaliev and Kalinova, 2013; Smiley *et al*., 2014). In Québec, Canada, weeds frequently associated with potato crops include *A. retroflexus*, *A. artemisiifolia*, *Cyperus rotundus*, *Chenopodium album*, *Polygonum persicaria*, and *Spergula arvensis*, which are hosts of *Pratylenchus penetrans* (Bélair *et al*., 2007). Weeds in the genus *Solanum* have been reported as hosts of *G. pallida* in Idaho, USA (Boydston *et al*., 2010). In Costa Rica, vegetables like carrots, onions, and potatoes are commonly rotated and, in many cases, they are hosts for the same plant-parasitic nematodes. However, studies on the host status of weeds for plant-parasitic nematodes associated with vegetable crops are lacking. López and Salazar (1978) reported *M. hapla* associated with *Sonchus oleraceus*, *Galinsoga parviflora*, *Hipochaeris radicata*, *Iresine celosia*, *Conyza coronapifolia*, *Cirsium mexicanum*, *Rumex acetocella*, *S. americanum,* and *Gnaphalium americanum*. In a nematode survey in the largest vegetable production areas of Costa Rica, *M. hapla* was associated with *Bidens pilosa* and *Cirsium* *subcoriaceum* (López and Azofeifa, 1981). The objective of this study was to identify the plant-parasitic nematodes associated with weeds in potato fields in Cartago, Costa Rica.

MATERIALS AND METHODS

Collection of weed samples

Between August 2016 and March 2017, 15 potato fields (3 and 4 months old, no larger than 1 ha) located in the northern area of Cartago, Costa Rica (Table 1) were sampled for weed identification and nematode analysis. The minimum sampling area was determined according to Fuentes (1986), as follows: a square frame of 1 m^2 PVC frame divided with nylon in 100 squares of 10 cm^2 was randomly placed in a potato field and plant species within the frame were recorded. The initial area was doubled (2 m^2), and new weed species were recorded. This process was repeated until no new species were recorded. For all potato fields, the minimum sampling area was 4 m^2. At each field, five points of 4 m^2 were selected randomly for the weed survey following the quadrant method (Mostacedo and Fredericksen, 2000). The ground cover percentage (total of squares occupied by each weed species) was calculated with the 1 m^2 frame. Weeds were identified based on visible characteristics such as inflorescence, flower structure, leaf features (shape, presence or absence of hairs, margin, venation, and arrangement on the stem). To evaluate weed species composition, frequency of occurrence of weeds (FO%) was calculated for the 15 fields that were sampled (Ntidi *et al*., 2012):

Table 1. Frequency of occurrence of weed species (FO%) sampled in the northern area of Cartago, Costa Rica.

Genus and species	FO%
Brassica campestris	46.7 ay[z]
Bromus carinatus	6.7 c
Calceolaria mexicana	13.3 bc
Capsella bursa-pastoris	6.7 c
Cardamine flaccida	6.7 c
Chenopodium album	6.7 c
Commelina difusa	13.3 bc
Cyperus sculentus	6.7 c
Cyperus sesquiflorus	6.7 c
Cyperus sp.	6.7 c
Eleusine indica	6.7 c
Galinsoga parviflora	6.7 c
Galinsoga quadriradiata	6.7 c
Juncus bufonius	20 b
Lepidum virginicum	46.7 a
Lolium perenne	20 b
Melampodium perfoliatum	13.3 bc
Plantago australis	6.7 c
Poa annua	46.7 a
Polygonum aviculare	13.3 bc
Polygonum persicariodes	40 a
Richardia scabra	13.3 bc
Rumex acetocella	6.7 c
Rumex obtusifolius	40 a
Senecio vulgaris	6.7 c
Sonchus oleraceus	6.7 c
Spergula arvensis	33.3 a

[z]Frequency of occurrence data were analyzed for effects using $\chi 2$ analysis. Values followed by the same letter are not significantly different from each other ($P < 0.05$).

FO% = (Number of potato fields in which the weed species occurred/number of potato fields sampled) × 100. Then, the FO% data were then analyzed using the non-parametric χ2 test for independence for effects of location using R software (R Core Team, 2017).

Extraction and identification of nematodes

The five weed species with the highest ground cover percentage in each potato field were sampled for nematode analysis. Five composite root samples (3 to 5) of each selected weed were collected in a zig-zag pattern (soil surrounding the roots was also collected when immature females of cyst-forming nematodes were observed). Each root system was checked under a stereomicroscope (Nikon SMZ745T; Nikon Instruments Inc., Melville, NY) for galls or cyst-forming nematodes. Nematodes were extracted from roots using the floatation-centrifugation method (Caveness and Jensen, 1955). Plant-parasitic nematodes were identified to the genus level based on morphology. A soil sample of 200 g was processed using the Fenwick method (Shepherd, 1986) in cases where immature females of cyst-forming nematodes were observed attached to the host roots and identified to the genus level based on cyst shape. The frequency of occurrence of plant-parasitic nematodes was calculated according to Barker (1985): (number of samples where a nematode genus was present/total amount of samples) X 100, (number of samples where a nematode genus was present/amount of samples per district) X 100, (number of samples where a nematode genus was present/amount of samples per weed species) X 100 and (number of samples where a nematode genus was present/amount of samples per weed family) X 100. Maximum and mean population densities were also estimated. The frequency of occurrence was analyzed by the χ2 test for independence for effects of districts. Kruskal-Wallis and Mann-Whitney tests were used to analyze effects of districts on population nematode densities.

RESULTS

Weed species identification in potato fields

Fifteen fields distributed in six districts in the northern area of Cartago were sampled; Capellades (altitude ranged between 2,500 and 2,900 m.a.s.l.), Cervantes (1,650 m.a.s.l.), Cot (1,680 and 1,780 m.a.s.l.), Llano Grande (2,100 and 2,190 m.a.s.l.), Pacayas (1,630 and 2,620 m.a.s.l.), and Potrero Cerrado (2,110 and 2,170 m.a.s.l.). Twenty-seven weed species were identified as the most important. *Brassica campestris*, *Lepidum virginicum*, *Poa annua*, *Polygonum persicariodes*, *Rumex obtusifolius*, and *Spergula arvensis* had the highest frequency of occurrence ($P < 0.05$) (Table 1).

Weed species were grouped into 12 botanical families and analyzed based on frequency of occurrence (Table 2). The Brassicaceae were found more frequently in the districts of Capellades and Pacayas ($P < 0.05$). The Polygonaceae were the most frequently encountered family of weeds in the district of Pacayas ($P < 0.05$). Meanwhile, families such as Plantaginaceae and Scrophulariaceae were found only in the district of Capellades ($P < 0.05$) (Table 2). The frequency of occurrence of weed species were analyzed for each district; however, there was no statistical differences between weed species in each district ($P > 0.05$; data not shown).

Frequency and population density of plant-parasitic nematodes

Twenty-seven weed species were sampled for nematode analyses resulting in a total of 338 composite root samples. A total of 18 plant-parasitic nematodes were identified associated with weeds. Although there was no clear differentiation of frequency of occurrence and mean population densities between all plant-parasitic nematodes found in this study, there were significant differences among the two most damaging endoparasites, *Pratylenchus* and *Meloidogyne*, in vegetables in the region. *Pratylenchus* had the highest frequency of occurrence and mean population densities per 100 g of roots ($P < 0.05$) (Table 3).

Heteroderids were found in five of the six sampled districts and the highest mean population density was found in the district of Llano Grande ($P < 0.05$; Table 4). Immature females of Heteroderinae were observed only on roots of *R. obtusifolius* and cysts recovered from soil surrounding the roots were lemon-shaped and had prominent vulval cone characteristic of the genus *Heterodera* (Fig. 1). *Meloidogyne* spp. were found in all six districts and were most frequently found in the districts of Cervantes and Cot. Meanwhile,

Table 2. Frequency of occurrence (FO%) of weed families in six districts of the Northern area of Cartago, Costa Rica.

	District					
	Capellades	Cervantes	Cot	Llano Grande	Pacayas	Potrero Cerrado
Weed family[y]	FO%					
Asteraceae	14 b[z]	0 c	34.5 a	0 c	34.5 a	17 b
Brassicaceae	29.8 a	11.9 b	5.9 b	11.9 b	29.8 a	10.7 b
Cariophyliaceae	60 a	0 c	0 c	0 c	0 c	40 b
Chenopodiaceae	0 b	0 b	0 b	100 a	0 b	0 b
Commelinaceae	0 b	0 b	50 a	0 b	50 a	0 b
Cyperaceae	0 c	0 c	66.7 a	0 c	33.3 b	0 c
Juncaceae	66.7 a	0 c	0 c	0 c	33.3 b	0 c
Plantaginaceae	100 a	0 b	0 b	0 b	0 b	0 b
Poaceae	27.3 a	9.0 b	0 c	27.3 a	27.3 a	9.0 b
Polygonaceae	13.3 bc	6.7 c	13.3 bc	20 b	40 a	6.7 c
Rubiaceae	0 b	50 a	50 a	0 b	0 b	0 b
Scrophulariaceae	100 a	0 b	0 b	0 b	0 b	0 b

[y]Number of observations per weed family = 29 (Asteraceae), 84 (Brassicaceae), 25 (Cariophyliaceae), 5 (Chenopodiaceae), 10 (Commelinaceae), 15 (Cyperaceae), 15 (Juncaceae), 5 (Plantigenaceae), 55 (Poaceae), 75 (Polygonaceae), 10 (Rubiaceae), and 10 (Scrophulariaceae).

[z]Frequency of occurrence data were analyzed for effects using $\chi 2$ analysis. Values followed by the same letter in the same row are not significantly different from each other ($P < 0.05$).

Table 3. Frequency of occurrence (FO%), maximum (max) population density, and mean population density (nematodes/100 g of roots) when present in a sample of plant-parasitic nematodes in the northern area of Cartago, Costa Rica[x].

	Parameter		
Genus/family	FO %	Max	Mean
Aphelenchoides	11.8 defg[y]	160	29 d[z]
Aphelenchus	16.6 cde	880	98 cd
Criconematidae	4.1 efg	80	29 cd
Ditylenchus	8 defg	120	27 d
Gracilacus	0.9 fg	18	13 abcd
Helicotylenchus	46.7 ab	8,520	526 b
Hemicycliophora	15.1 def	105	27 d
Heteroderidae	26 bcd	7,350	293 bc
Hoplolaimus	0.9 fg	20	17 abcd
Longidorus	0.9 fg	10	10 abcd
Meloidogyne	43.2 b	31,120	1,076 b
Paralongidorus	0.3 g	10	10 abcd
Paratylenchus	0.6 fg	10	10 abcd
Pratylenchus	69.5 a	104,720	9,520 a
Trichodoridae	4.4 efg	29	14 d
Tylenchulus	0.9 fg	160	107 abcd
Tylenchus	39.6 bc	240	49 cd
Xiphinema	0.3 g	42	42 abcd

[x]Number of samples included in the analysis was 338.

[y]Frequency of occurrence data were analyzed for effects using $\chi 2$ analysis. Values followed by the same letter are not significantly different from each other ($P < 0.05$)

[z]Mean values followed by the same letter are not significantly different ($P < 0.05$) according to Kruskal-Wallis and Mann-Whitney nonparametric statistical tests.

Table 4. Frequency of occurrence (FO%), maximum (max) population density and mean population density (nematodes/100 g of roots) when present in a sample of the endoparasitic nematodes Heteroderidae, *Meloidogyne* and *Pratylenchus* in the northern area of Cartago, Costa Rica[x].

	Heteroderidae			*Meloidogyne*			*Pratylenchus*		
District	FO%	Max	Mean	FO%	Max	Mean	FO%	Max	Mean
Capellades	35.1 a[y]	680	110 a[z]	31.9 a	1,360	142 a	97.9 a	79,280	9,802 a
Cervantes	0 b	0	0	96 b	3,079	646 b	0 b	0	0
Cot	28.9 ac	470	58 c	75.6 b	1,580	170 c	20 c	65	31 b
Llano Grande	13.3 bc	7,350	3,077 d	33.3 a	650	141 acd	80 d	11,420	3,569 c
Pacayas	24.8 ac	570	98 a	39 a	31,120	3,158 bc	76.2 d	104,720	15,009 a
Potrero Cerrado	41.7 a	230	41 c	8.3 c	10	10 d	75 d	1,220	328 d

[x]Number of samples included in the analysis = 94 (Capellades), 25 (Cervantes), 45 (Cot), 45 (Llano Grande),105 (Pacayas), and 24 (Potrero Cerrado).

[y]Frequency of occurrence data were analyzed for effects using χ2 analysis. Values followed by the same letter in the same column are not significantly different from each other ($P < 0.05$)

[z]Mean values followed by the same letter in the same column are not significantly different ($P < 0.05$) according to Kruskal-Wallis and Mann-Whitney nonparametric statistical tests.

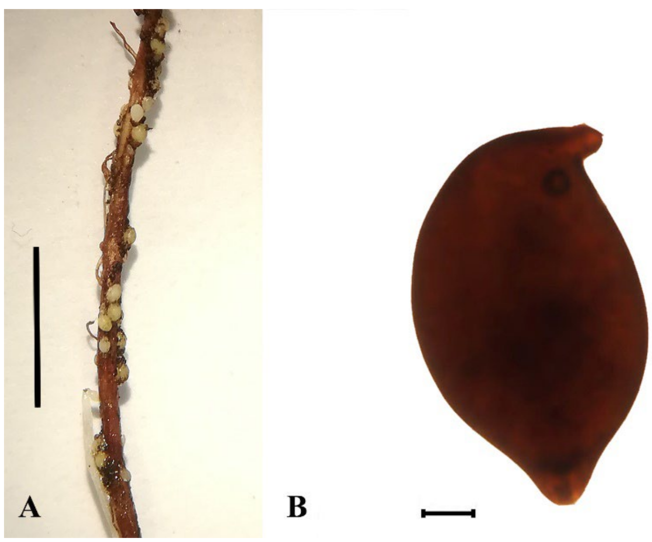

Figure 1. Immature females (A), and cyst (B) of *Heterodera trifolii* in roots of *Rumex obtusifolius*. (Scale bars: A= 5 mm, and B= 100 µm).

Potrero Cerrado had the lowest frequency of occurrence ($P < 0.05$; Table 4). *Pratylenchus* spp. were found in five of the six sampled districts. Capellades and Cot had the highest and lowest frequency of occurrence, respectively ($P < 0.05$; Table 4). From the five districts where *Pratylenchus* spp. were found, Pacayas and Capellades had the highest mean population densites per 100 g of roots ($P < 0.05$; Table 4).

The average population density of *Pratylenchus* spp. was more than 15,000 nematodes/100 g of roots on weeds species such as S. *vulgaris*, *P. annua*, and *Calceolaria mexicana*. The average *Pratylenchus* spp. population density was less than 1,000 nematodes/100 g of roots on *C. bursa-pastoris*, *Galinsoga quadriradiata*, *Melampodium perfoliatum*, and *Richardia scabra*. *Pratylenchus* spp. were not detected in seven weeds (*Cardamine flaccida*, *Commelina difusa*, *Cyperus esculentus*, *C. sesquiflorus*, *Cyperus* sp., *Eleusine indica*, and *Galinsoga parviflora*). Meanwhile, *G. parviflora* had the highest average population density of *Meloidogyne* spp. with more than 20,000 nematodes/100 g roots (Table 5). The frequencies of occurrence and mean population densities of *Meloidogyne* and *Pratylenchus* per weed family and species found per district were not significantly different ($P > 0.05$; data not shown).

DISCUSSION

The Province of Cartago is recognized as the main vegetable-producing area of Costa Rica. In the northern area of this province, onions, carrots, and potatoes are commonly produced in rotation. Few studies are available on the plant-parasitic nematodes found in these crops or associated with weeds in Costa Rica (García *et al*., 2009; Sandoval *et al*., 2020). Two of the most frequent weed species (*B. campestris* and *P. annua*) associated with potato fields in this study have been reported in horticultural crops, such as carrots and onions in the province of Cartago, Costa Rica (Villalobos, 1999; Araya, 2000; Rodríguez *et al*., 2015). In Guatemala, *B. campestris* is frequently associated with potato fields (Marroquin, 1993), whereas in Colombia, *P. annua*, *S. arvensis*, *S. vulgaris*, *S. oleraceus*, *C. bursa-pastoris*, *Brassica* spp., *Polygonum aviculare*, and *P. segetum* are commonly found in cold weather crops, such as potato (Cárdenas *et al*., 1970; Jamaica and Plaza, 2014).

Weeds can compete with crops for resources such as water, nutrients, and light. Also, weeds have been reported as pest and pathogen reservoirs, mainly for plant-parasitic nematodes (Quénéhervé *et al*., 2011). Potato growers in Cartago commonly leave fields fallow between each production cycle, which allows the development of weeds. In this study, 15 genera of nematodes were found associated with weed roots, among them *Aphelenchoides*, *Aphelenchus*, and *Tylenchus* that might include root feeders and/or fungivores (Hofman and S'Jacob, 1989; Yeates *et al*., 1993).

In some samples, *Ditylenchus* spp. and Trichodorids were found in low frequencies; there are no records of the potential damage to potatoes by these nematodes in Costa Rica. In other countries, these nematodes cause significant crop losses, either by direct impact on the crop or by indirect effects as virus vectors in temperate climates. For example, *D. destructor* and *D. dipsaci* can significantly affect potato production, while species in the genera *Trichodorus* and *Paratrichodorus* are vectors of tobacco rattle virus, the causal agent of corky ringspot on potatoes (Pérez *et al*., 2000; Plowright *et al*., 2002). Further research on the identification of these nematode species should be implemented, which is fundamental to reduce the negative impact of these nematodes on crop production.

Two of the most important plant-parasitic nematodes genera worldwide are *Meloidogyne* and *Pratylenchus* (Jones *et al*., 2013), both of which were found frequently in this study. These genera have been reported to parasitize a large number of weeds (Myers *et al*., 2004; Kaur *et al*., 2007; Brito *et al*., 2008). *Pratylenchus* is a major nematode problem on potato, where species such as *P. penetrans* can cause up to 50% of yield loss (Holgado *et al*., 2009; Esteves *et al*., 2015). *Pratylenchus penetrans* was found at high population densities on *P. annua*, *S. oleraceus* and *S. vulgaris* (Bendixen, 1988; Kutywayo and Been, 2006; Bélair and Simard, 2008).

Meloidogyne can parasitize more than 2,000 plant species (Agrios 2005; Jones *et al*., 2013). *Meloidogyne* spp. were found at high population densities on *G. parviflora*, which coincides with several studies in United States, Argentina, Costa Rica and Hungary (Lopez and Salazar, 1978; Doucet, 1993; Kutywayo and Been, 2006). Also, two species, *M. chitwoodi* and *M. hapla,* have been associated with *G. parviflora* (Lopez and Salazar, 1978; Kutywayo and Been, 2006), both of which can affect potato tuber quality. There were some weed species with low *Meloidogyne* spp. population densities that can potentially be used for management of this genus. For example, in Costa Rica, *L. virginicum* has been reported as a non-host for *M. incognita* (López and Quesada, 1997), a nematode that causes a reduction in the marketability of the potato tuber due to galling (Montero *et al*., 2007).

Nematodes of the subfamily Heteroderinae were found in *R. obtusifolius* and identified to genus level as *Heterodera* using morphological characters like shape of the cyst and the presence of the vulval cone (Mulvey, 1974), thus discarding the presence of *Globodera* females or cysts (spherical shape and without vulval cone) (Skantar *et al*., 2011). Recently, this species was identified using both morphological and molecular approaches as *H. trifolii* (Núñez *et al*., 2021). *Globodera* was not found in weeds associated with potato in the northern area of Cartago.

Table 5. Population density of plant-parasitic nematodes associated with the predominant weeds in potato fields in Cartago, Costa Rica. Data are expressed as number of nematodes per 100 g of roots and in the form of mean (minimun-maximun).

Weed species	*Ditylenchus*	*Helicotylenchus*	*Heteroderides*	*Meloidogyne*	*Pratylenchus*	*Trichodoridae*
Brassica campestris	17 (10-30)	193 (10-1,040)	17 (10-30)	158 (10-420)	1,226 (40-3,590)	10
Bromus carinatus	0	0	0	160 (20-380)	4,964 (3,840-5,780)	0
Calceolaria mexicana	0	41 (32-50)	160 (80-240)	295 (73-516)	15,706 (5,360-30,560)	0
Capsella bursa pastoris	0	0	10	0	10	0
Cardamine flaccida	24	1,556 (120-5595)	0	1,918 (620-3,079)	0	0
Chenopodium album	0	0	0	90 (20-160)	1,890 (420-3,640)	0
Commelina diffusa	20	456 (360-930)	0	1403 (30-3,350)	0	0
Cyperus esculentus	60 (20-80)	188 (60-480)	0	10 (10-10)	0	0
Cyperus sesquiflorus	20	710 (40-1,380)	0	284 (10-720)	0	0
Cyperus sp.	90 (60-120)	5100 (1,260-8,520)	0	120 (120-120)	0	0
Eleusine indica	0	692 (300-1,270)	0	295 (20-950)	0	10
Galinsoga parviflora	0	280 (80-480)	0	22,656 (9,440-31,120)	0	0
Galinsoga quadriradiata	10	0	20	10	636 (260-1,220)	10
Juncus bufonius	0	70 (27-160)	0	32 (10-80)	7,949 (10-21,120)	13 (10-20)
Lepidium virginicum	13 (10-18)	59 (10-263)	21 (10-70)	29 (10-80)	5375 (12-18,000)	0
Lollium perenne	0	80	0	0	14,897 (20-26,400)	0

Table 5. Continued.

Weed species	*Ditylenchus*	*Helicotylenchus*	*Heteroderides*	*Meloidogyne*	*Pratylenchus*	*Trichodoridae*
Melampodium perfoliatum	10 (10-10)	82 (20-210)	23 (10-40)	62 (20-130)	18 (10-30)	10 (10-10)
Poa annua	10 (10-10)	81 (20-240)	91 (10-230)	48 (10-160)	28016 (20-104,720)	10
Plantago australis	0	144 (80-160)	0	512 (80-1360)	13904 (6,560-20,720)	0
Polygonum aviculare	0	10 (10-10)	10 (10-10)	45 (10-80)	1634 (100-5,800)	0
Polygonum segetum	10 (10-10)	1322 (30-6,620)	128 (10-470)	283 (10-1450)	2829 (10-6,450)	15 (10-20)
Richardia scabra	0	226 (40-583)	31 (19-43)	105 (20-324)	50 (19-65)	29 (28-29)
Rumex acetocella	0	17 (10-20)	0	0	3058 (670-6,380)	0
Rumex obtusifolius	0	19 (10-50)	929 (20-7350)	94 (10-240)	9309 (20-32,720)	10 (10-10)
Senecio vulgaris	0	80	0	80	31,056 (20,080-40,160)	0
Sonchus oleraceus	0	0	0	0	7,040 (1,480-19,680)	0
Spergula arvensis	37 (20-53)	13 (10-20)	86 (10-211)	26 (10-39)	2,094 (60-6,382)	0

Further studies, such as the identification of plant-parasitic nematodes on weeds at the species level and pathogenicity assays to assess the ability for these nematodes to reproduce on weeds are valuable for an integrated nematode management. Potential non-host species may be used to reduce the nematode population densities based on our data. Caution must be taken when other hosts like onions and carrots are planted after fallow, which are common crops in the northern area of Cartago.

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