RESEARCH NOTE/NOTA DE INVESTIGACIÓN

NEMATICIDAL ACTIVITY OF WILD PLANT EXTRACTS AGAINST SECOND-STAGE JUVENILES OF *NACOBBUS ABERRANS*

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ABSTRACT

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Nacobbus aberrans affects the production of crops of economic importance such as chili pepper, tomato, and bean. To control this nematode, it is of interest to study environmentally friendly strategies. In this regard, the aim of this work was to evaluate the *in vitro* effect of ethanolic extracts (500 ppm) from 20 wild plants (foliage tissue) against second-stage juveniles of *N. aberrans* . At 24, 48, and 72 hr, the extracts of *Verbesina sphaerocephala*, *Cosmos sulphureus*, and *Senecio salignus* showed the highest immobility effects, respectively ($P \leq 0.05$). At 72 hr, after replacing the extracts with water, *C. sulphureus* had the highest mortality rate (79.45±5.03%). Other extracts with significant nematicidal effects ($P \leq 0.05$) were *Witheringia stramoniifolia* (73.57±8.07%), *Tagetes lunulata* (73.12±7.40%), *S. salignus* (71.25±5.02%), and *Lantana camara* (70.15±11.07%). Since several phenolic compounds have been reported to be nematotoxic, the total phenolic (TPC) and flavonoid (TFC) contents in the plant material were determined. *T. lunalata* and *C. sulphureus* recorded the lowest and highest TPC, respectively ($P \leq 0.05$); in turn, *Dodonaea viscosa* recorded the highest TFC, and the *Ximenia parviflora* recorded the lowest ($P \leq 0.05$). In some cases, the abundance of these compounds resulted in a significant nematicidal effect as it occurred with the *W. stramoniifolia*, *C. sulphureus*, *Asclepias linaria*, and *Nicotiana glauca* extracts. Plant material with significant toxic effects could be assessed at the field level and incorporated into the soil as organic amendments to create suppressive environments against *N. aberrans*.

Key words: ethanolic extracts, false root-knot nematode, *in vitro* screening, phenolic compounds

RESUMEN

Vázquez-Sánchez, M., J. R. Medina-Medrano, H. Cortez-Madrigal, M. V. Angoa-Pérez, C. V. Muñoz-Ruíz, y E. Villar-Luna. 2018. Actvidad nematicida de extractos de plantas silvestres contra juveniles del segundo estadio de *Nacobbus aberrans*. Nematropica 48:136-144.

Nacobbus aberrans afecta la producción de cultivos de importancia económica como chile, jitomate y frijol. Para su control es de interés el estudio de estrategias amigables con el medio ambiente. En este sentido, el objetivo de este trabajo fue evaluar el efecto *in vitro* de extractos etanólicos (500 ppm) de veinte plantas silvestres (follaje) contra juveniles del segundo estadio (J2) de Na. A 24, 48, y 72 hr, los extractos de *Verbesina sphaerocephala*, *Cosmos sulphureus* y *Senecio salignus* tuvieron los más altos efectos de

inmovilidad, respectivamente ($P \leq 0.05$). A 72 hr, después de reemplazar los extractos por agua, *C. sulphureus* exhibió el más alto porcentaje de mortalidad (79.45±5.03%). Otros extractos que tuvieron efectos nematicidas significativos ($P \leq 0.05$) fueron *Witheringia stramoniifolia* (73.57±8.07%), *Tagetes lunulata* (73.12±7.40%), *S. salignus* (71.25±5.02%), y *Lantana camara* (70.15±11.07%). Debido a que varios compuestos fenólicos han sido documentados como nematotóxicos, el contenido de fenólicos (CFeT) y flavonoides totales (CFT) fue determinado en el material vegetal. Los más bajos y altos CFeT fueron registrados en *T. lunalata* and *C. sulphureus*, respectivamente ($P \leq 0.05$), con respecto al CFT, *Dodonaea viscosa* registró el más alto y *Ximenia parviflora* el más bajo ($P \leq 0.05$). Solo en algunos casos, la abundancia de estos compuestos resultó en un efecto nematicida significativo como ocurrió con los extractos de *W. stramoniifolia*, *C. sulphureus*, *Asclepias linaria*, y *Nicotiana glauca*. El material vegetal con efectos tóxicos significativos podría ser evaluado a nivel de campo, incorporándolo en el suelo como enmienda orgánica para crear ambientes supresivos contra *N. aberrans*.

Palabras clave: extractos etanólicos, nematodo falso nodulador, evaluación *in vitro*, compuestos fenólicos

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The false root-knot nematode, *Nacobbus aberrans*, infects plants in tropical and subtropical regions of North (Mexico and USA) and South (Argentina, Chile, Peru, Bolivia, and Ecuador) America (Jones *et al*., 2013). In Mexico, it is one of the plant-parasitic nematodes that limits the production of pepper (*Capsicum* spp.), tomato (*Solanum lycopersicum* L.), and bean (*Phaseolus vulgaris* L.) (Manzanilla-López *et al*., 2002). Like *Meloidogyne* spp., *N. aberrans* induces in its host plants the formation of root galls, root system reduction, chlorosis, dwarfism, and wilting (Manzanilla-López *et al*., 2002; Scurrah *et al*., 2005). In galled roots, the uptake and transport of water and nutrients are severely altered, and, consequently, the crop yields are reduced (Sikora and Fernández, 2005). In this regard, it is important to study strategies for the control of this nematode in the crop fields.

The management of plant-parasitic nematodes often involves the use of synthetic nematicides, products harmful to human health and our ecological environment (Abawi and Widmer, 2000). In order to reduce the excessive use of these products, environmentally healthy strategies for nematode control have been explored based on an integrated approach, such as the use of biological control agents, organic amendments, antagonist plants, plant extracts, and others (Collange *et al*., 2011; Ntalli and Caboni, 2012). The study and use of natural products constitute a promising strategy for pest and disease management, mainly those from wild plants that have the ability to survive in inhospitable conditions. This characteristic is due to the production of secondary metabolites in response to different types of biotic and abiotic stress; these plants may be used as sources to develop natural products, such as herbicides, bactericides, fungicides, and nematicides (Pretorius and Van der Watt, 2011).

Plants produce a wide diversity of secondary metabolites, some of them of pharmaceutical interest and others with antimicrobial properties (e.g., phenylpropanoids, flavonoids, terpenoids, alkaloids, and others), and many of these compounds play a crucial role in the interaction of plants with their environment (Oksman-Caldentey and Inzé, 2004). It is important to note that several phenolic compounds have been found to be toxic for plant-parasitic nematodes, and they are frequently associated with plant resistance to different pathogens (Zhou *et al*., 2012). In this regard, in this study, the *in vitro* nematicidal activity of extracts of 20 native wild plants was tested against second-stage juveniles (J2) of *N. aberrans*, and in addition, the total phenolic and flavonoid contents were determined.

During the period from January to September 2015, the foliage of 20 native wild plants was collected from different localities of the northwest of Michoacán state (Fray Domínguez, Pajacuarán; Zináparo, Zináparo; Chorros del varal, Los Reyes; Jiquilpan de Juárez; and Sahuayo de Morelos). The identity of the plants was determined with the use of taxonomic tools and consultation with a specialist. The plants tested were *Acacia farnesiana* (L.) Willd., *Amelanchier denticulata* (Kunth) K. Koch, *Asclepias linaria* Cav., *Cosmos sulphureus* Cav., *Dodonaea viscosa* (L.) Jacq., *Ipomoea murucoides* Roem. & Schult., *Lantana camara* L., *Mandevilla foliosa* (Müll. Arg.)

Hemsl., *Nicotiana glauca* Graham, *Phytolacca icosandra* L., *Prosopis laevigata* (Willd.) M. C. Johnst, *Senecio salignus* DC., *Serjania racemosa* Schumach., *Solanum ferrugineum* Jacq., *Tagetes lunulata* Ortega, Tecoma stans (L.) Juss. ex Kunth, *Verbesina sphaerocephala* A. Gray, *Witheringia stramoniifolia* Kunth, *Ximenia parviflora* Benth, and *Zanthoxylum fagara* (L.) Sarg.

Each plant's foliage was dried at ~50°C for 5 days. An ethanolic extraction was performed on each sample according to Chaudhary *et al*. (2013) with minor modifications. For this purpose, 30 g of dried tissue was mixed with 600 ml of ethanol and then incubated in the dark for 3 days. The samples were manually stirred every 24 hr. Subsequently, the extracts were filtered (Whatman No. 1) and concentrated to dryness in a rotavapor apparatus (Büchi®) at 40°C. The dry residues were stored at 4°C until use.

The extraction of nematode eggs was performed according to Vrain (1977) from tomato root galls. The eggs were incubated in sterile distilled water (Baermann method) at 25±1°C and freshly hatched J2 were used. To evaluate the nematicidal effect, the plant extracts (dry residues) were redissolved in dimethyl sulfoxide (0.5% DMSO in sterile distilled water) and the concentration was adjusted to 500 ppm. The extracts were placed in glass containers (1 ml) and ~50 *N. aberrans* J2 were added to each container and incubated at 25±1°C. Twenty extracts of wild plants were evaluated and 0.5% DMSO was used as the control. The experimental design was completely randomized, and each treatment had five replicates (glass containers). Under a stereoscopic microscope, at 24, 48, and 72 hr, the number of immobile J2 was recorded. At 72 hr, the extract was replaced with sterile distilled water and the number of dead J2 (those nematodes that did not move when probed with a needle) was recorded 24 hr later. Immobility and mortality data were converted to corrected percent immobility (CPI) according to Abbott's formula (Abbot, 1925). Thus, CPI= [(X-Y)/X]*100, where X is the percent living J2 in the control, and Y is the percent living J2 in the plant extract.

The extraction followed the method of Medina-Medrano *et al*. (2015) with minor modifications. Dry foliage tissue (1 g) was ground, placed in 20 ml of ethanol continuously stirred at 100 rpm at room temperature (RT) in darkness for 24 hr. Extracts were centrifuged (4,800 g) for 5 min at RT and the recovered supernatant was used for quantification of TPC and TFC. TPC was determined by using the methodology of Nurmi *et al*. (1996). Thus, a standard curve of gallic acid (GA, at six concentrations between 40 and 500 µg/ml) was prepared. An aliquot of 250 µl of each solution was mixed with 2.5 ml of distilled water, followed by 125 µl of 1 N Folin-Ciocalteu reagent, and then stirred for 5 min. Finally, 375 µl of a 20% Na_2CO_3 solution was added and left undisturbed in the dark for 2 hr at RT. Absorbance was read at 760 nm with an UV/visible spectrophotometer (Optizen®). To determine the TPC in the wild plant extracts, 250 µl samples were taken and analyzed as described in the standard, each one of them with five replicates. TPC was expressed as gallic acid equivalent (GAE) mg/g dry tissue (DT). Regarding the quantification of TFC, these were estimated by the AlCl3 method (Lamaison and Carnat, 1990). Thus, an ethanolic extract solution (100 µl of extract plus 900 µl of ethanol) was added to 1 ml of 2% $AlCl_3$. Absorbance was measured 10 min later at 430 nm. Each sample was prepared with five replicates. A catechin standard curve treated in the same conditions (CE, at six concentrations between 0.5 and 3 mg/mL) was used. TFC was expressed as catechin equivalent (CE) mg/g DT.

CPI, TPC, and TFC data were subjected to an analysis of variance (ANOVA) and to a Tukey or Duncan's Multiple Range Test (DMRT) ($P \leq 0.05$) measurement comparison test using the SAS version 9.0 software (SAS Institute Inc., 2002). To equalize variances and normalize CPI data, a transformation to arcsine $\sqrt{x}$ prior to the ANOVA was performed.

For the most part, the extracts had nematostatic and nematicidal effects, and the number of immobilized J2 increased in proportion to the time of exposure. The immobility effects induced by the *V. sphaerocephala*, *C. sulphureus*, and *S. salignus* extracts were 54.85 (24 hr), 47.60 (48 hr), and 27.96% (72 hr) above the average of the other extracts, respectively ($P \leq 0.05$). After replacing the extracts with water, the highest nematicidal effect was shown by the *C. sulphureus* and was 32.37% above the effect exhibited by the other extracts. In this regard, usually the nematicidal effects ranged from 30.12 to 79.45%, where the highest effects were exhibited by *C. sulphureus* (79.45±5.03%), *W. stramoniifolia* (73.57±8.07%), *T. lunulata* (73.12±7.40%), *S.*

salignus (71.25±5.02%), *L. camara* (70.15±11.07%), *A. linaria* (65.83±6.89%), *M. foliosa* (64.64±7.08%), *V. sphaerocephala* (61.94±10.05%), and *N. glauca* (61.49±5.72%) ($P \leq 0.05$). On the other hand, the *I. murucoides*, *V. sphaerocephala*, *T. stans*, and *P. laevigata* extracts showed the highest nematostatic effects, since they had the greatest proportions of reactivated J2 (30.50, 28.22, 26.94, and 26.85%, respectively) (Table 1).

The TPC in the wild plant ethanolic extracts ranged from 0.65±0.03 to 22.46±0.08 mg GAE/g DT, of which *T. lunalata* and *C. sulphureus* had the lowest and the highest content, respectively ($P \leq 0.05$) (Table 2). Regarding the TFC, the levels recorded ranged from 23.53±2.04 to 170.89±1.35 mg CE/g DT. The *D. viscosa* extract had the highest TFC and, in contrast, the lowest levels pertained to *X. parviflora* ($P \leq 0.05$) (Table 2).

In this work, the significant nematicidal effects recorded by some extracts could be associated with the presence of phenolic compounds or other nematotoxic metabolites. Ntalli and Caboni (2012) and Zhou *et al*. (2012) have reviewed the toxicity of several phenolic compounds against various plant-parasitic nematodes. The occurrence of several phenolic compounds in some species of *Cosmos* (Kaisoon *et al*., 2011), *Tagetes* (Xu *et al*., 2012), *Senecio* (Albayrak *et al*., 2014), *Verbesina* (Mora *et al*., 2013), Lantana (Ntalli and Caboni, 2012; Sousa and Costa, 2012), *Asclepias* (Agrawal *et al*., 2009), and Nicotiana (Likić and Rusask, 2014), has been documented. In this sense, we found the highest TPC in *C. sulphureus*, *S. ferrugineum*, *Z. fagara*, *D. viscosa*, and *A. linaria* extracts, whereas the TFC were abundant in *D. viscosa*, *W. stramoniifolia*, *P. icosandra*, *C. sulphureus*, *S. racemosa*, *A. linaria*, *S. ferrugineum*, and *N. glauca*. However, in some cases, the abundance of these compounds resulted in a significant nematicidal effect as it occurred with the *W. stramoniifolia*, *C. sulphureus*, *A. linaria*, and *N. glauca* extracts. In turn, the high TFC levels in extracts of *P. icosandra*, *Z. fagara*, *D. viscosa*, *S. racemosa*, and *S. ferrugineum* are related to the percentages of immobility recorded at 72 hr, with this effect being more nematostatic than nematicidal. The fact that other extracts with abundant TPC and TFC were not significantly toxic for *N. aberrans* may be due to the qualitative and quantitative differences of these compounds in the plants analyzed. Not all phenolic compounds are effective against nematodes. For instance, López-Martínez *et al*. (2011) tested the *in vitro* effect of seven phenolic acids on J2 of *N. aberrans*, of which only the vanillic, trans-cinnamic, coumaric, and syringic acids were highly toxic. In contrast, ferulic and tannic acids had the lowest toxicity rate. In a similar manner, at the *in vitro* level, the J2 mobility of *M. incognita* was inhibited by the flavonols kaempferol, quercetin, myricetin, rutin, and quercitrin. In contrast, *Pratylenchus penetrans* and *Radopholus similis* were not immobilized by these compounds (Wuyts *et al*., 2006).

Asteraceae is one of the most diverse angiosperm families (Villaseñor and Ortíz, 2014), and many of its members have nematotoxic compounds, such as polythienyls and polyacetylenes (Zhou *et al*., 2012). Therefore, the toxicity against *N. aberrans* shown by *C. sulphureus*, *T. lunulata*, *S. salignus*, and *V. sphaerocephala* extracts could also be associated with these types of compounds. In this regard, at the *in vitro* level, the *C. bipinnatus* extracts were toxic against *M. javanica* (Siddiqui *et al*., 2005). Tsay *et al*. (2004) found from *in vivo* experiments that the root galling induced by *M. incognita* on *Ipomoea reptans* was reduced when associated with *C. bipinnatus*. As far as *T. lunulata* is concerned, the results are consistent with the nematicidal effects found in various *Tagetes* species, which have been related to the high content of polyacetylenes and polythienyls (Ntalli and Caboni, 2012). In addition, the growing of *T. patula*, *T. erecta*, and *T. signata* before tomato, reduced the infection of tomato roots by *M. incognita*, *M. javanica*, *M. arenaria*, and *M. hapla* (Ploeg, 1999). On the other hand, the effect of *S. salignus* on *N. aberrans* could be related to the toxicity of certain metabolites found in other *Senecio* species. For instance, on tomato plants grown on soils amended with *S. bicolor* and inoculated with *M. hapla*, there was reduced root galling related to the content of pyrrolizidine-type alkaloids (Thoden *et al*., 2009). At the *in vitro* level, these alkaloids have also been effective against various nematodes, and they are common in hundreds of plants belonging to the Apocynaceae, Asteraceae, Boraginaceae, and Fabaceae (Thoden *et al*., 2009). The results shown by *V. sphaerocephala* extracts have a connection with those reported in other *Verbesina* species. For

Table 1. Percent immobility of second-stage juveniles of *Nacobbus aberrans* exposed to ethanolic extracts (500 ppm) from wild plants (foliage tissue).

Plant species	Family	Hours of exposure to extracts		
		24	48	72
Asclepias linaria	Apocynaceae	21.14±3.39 bcde[x]	43.86±9.44 efgh	81.05±8.19[y] abc (65.83±6.89 bcd)[z]
Mandevilla foliosa	Apocynaceae	22.34±4.87 bcd	60.54±10.80 bc	73.59±3.93 cde (64.64±7.08 bcde)
Verbesina sphaerocephala	Asteraceae	36.39±5.61 a	58.65±5.84 cd	86.30±7.00 ab (61.94±10.05 bcde)
Senecio salignus	Asteraceae	27.02±2.81 b	51.97±2.28 cde	90.14±9.94 a (71.25±5.02 abc)
Tagetes lunulata	Asteraceae	14.01±1.97 efgh	28.81±7.29 ijk	82.18±6.15 abc (73.12±7.40 abc)
Cosmos sulphureus	Asteraceae	24.84±8.85 bc	77.36±5.10 a	86.39±3.85 ab (79.45±5.03 a)
Tecoma stans	Bignoniaceae	15.81±2.17 defgh	32.63±10.12 hijk	47.42±11.97 hij (34.64±15.75 jk)
Ipomoea murucoides	Convolvulaceae	14.54±6.76 efgh	27.77±11.53 jk	46.65±9.72 hij (32.43±10.55 k)
Acacia farnesiana	Leguminosae	15.14±5.06 defgh	34.69±4.75 fghij	53.87±7.63 ijk (40.72±2.71 ijk)
Prosopis laevigata	Leguminosae	13.07±3.78 fgh	22.49±7.57 k	41.18±5.58 ij (30.12±6.19 k)
Ximenia parviflora	Olacaceae	10.58±4.60 gh	37.80±10.04 fghij	54.58±3.67ghi (44.20±6.75 hij)
Phytolacca icosandra	Phytolaccaceae	24.18±7.01 bc	41.29±2.68 efghi	73.63±17.32 bcde (57.32±12.05 defg)
Amelanchier denticulata	Rosaceae	9.53±4.48 h	23.58±12.00 k	38.37±7.19 j (31.95±2.08 k)
Zanthoxylum fagara	Rutaceae	14.89±8.90 efgh	46.23±11.45 defg	57.88±11.76 fgh (49.62±5.78 fghi)
Dodonaea viscosa	Sapindaceae	12.39±3.59 fgh	22.24±4.38 k	53.11±4.96 ghi (48.79±4.19 ghi)
Serjania racemosa	Sapindaceae	10.99±2.31fgh	47.33±14.39 cdef	65.17±13.19 defg (55.99±12.50 defgh)
Solanum ferrugineum	Solanaceae	14.91±3.73 defgh	28.47±4.10 ijk	62.21±12.10 efg (53.05±8.64 efghi)
Nicotiana glauca	Solanaceae	16.40±5.70 defg	33.54±10.94 ghijk	70.03±5.52 cdef (61.49±5.72 cdef)
Witheringia stramoniifolia	Solanaceae	12.52±4.23 fgh	70.84±10.54 ab	78.32±10.44bcd (73.57±8.07ab)
Lantana camara	Verbenaceae	17.78±3.69 cdef	57.39±11.29 cd	81.93±5.75 abc (70.15±11.07 abc)

[x]Means with the same letter in each column are not significantly different (DMRT, $P \leq 0.05$).

.[y]Values represent the corrected percent immobility (mean±standard deviation) according to Abbott's formula (Abbott, 1925).

[z]Values in parentheses are percentages of mortality recorded at 24 hr after the extracts were replaced with sterile distilled water. Each treatment consisted of five replicates.

instance, the nematoxicity of *V. encelioides* extracts has been elucidated, thus, in *in vitro* conditions, aqueous extracts of leaves and stems reduced the viability of J2 of *M. javanica* (Oka, 2012).

The antimicrobial and nematicidal properties of *L. camara* are commonly evidenced (Sousa and Costa, 2012); for instance, at the *in vitro* level, ethanolic extracts of this plant were toxic against juveniles of *M. incognita* and *M. javanica* (Ali *et al*., 2001; Chaudhary *et al*., 2013). In addition, root extracts of *L. camara* reduced the nematode population, as well as root galling in *Vigna radiata* plants inoculated with *M. javanica* (Shaukat *et al*., 2003). It is worth mentioning that phenolic compounds such as p-hydroxybenzoic, vanillic, caffeic, and ferulic acids were found in these extracts. The highest toxicity has been found in the aerial part of *L. camara*, and it has been associated with the lantanilic, camaric, and oleanolic acids (Qamar *et al*., 2005). On the other hand, the evident toxicity of *W. stramoniifolia* (syn. *Brachistus stramoniifolius*) against *N. aberrans* could also be associated with the presence of metabolites other than phenolics. Thus, several compounds such as witanolides, which have antimicrobial and insecticidal properties, have been characterized in several solanaceae, including *B. stramoniifolius*, *Witheringia coccoloboides*, and *W. solanacea* (Misico *et al*., 2011).

In members of the Apocynaceae and Solanaceae, the occurrence of alkaloids capable of inhibiting mobility and causing mortality of certain nematodes is common (Zhou *et al*., 2012). Thus, the nematotoxic activity of some *Asclepias* species has been documented. Harry-O'kuru *et al*. (1999) revealed the *in vitro* and *in vivo* toxicity of

Table 2. Total phenolic and flavonoid contents of ethanolic extracts from the foliage of wild plants.

Plant species	Family	Total phenolics (mg GAE/g DT)[x]	Total flavonoids (mg CE/g DT)[x]
Asclepias linaria	Apocynaceae	9.95±0.03 d[y,z]	95.53±1.43 d
Mandevilla foliosa	Apocynaceae	4.63±0.25 jk	39.58±1.43l
Verbesina sphaerocephala	Asteraceae	3.23±0.09l	37.83±0.33l m
Senecio salignus	Asteraceae	6.92±0.27 fgh	52.9±0.03 j
Tagetes lunulata	Asteraceae	0.65±0.03 m	52.06±0.33 j
Cosmos sulphureus	Asteraceae	22.46±0.08 a	100.03±1.06 c
Tecoma stans	Bignoniaceae	5.48±0.26 j	64.08±1.28 h
Ipomoea murucoides	Convolvulaceae	6.32±0.17 hi	35.23±0.08 n
Acacia farnesiana	Leguminosae	5.23±0.22 jk	57.40±1.47 i
Prosopis laevigata	Leguminosae	7.63±0.27 ef	45.03±2.03 k
Ximenia parviflora	Olacaceae	5.37±0.23 j	23.53±2.04 o
Phytolacca icosandra	Phytolaccaceae	8.48±0.20 e	125.02±0.15 b
Amelanchier denticulata	Rosaceae	9.74±0.38 d	36.10±0.49 mn
Zanthoxylum fagara	Rutaceae	11.59±1.16 c	45.64±0.30 k
Dodonaea viscosa	Sapindaceae	10.05±0.16 d	170.90±1.35 a
Serjania racemosa	Sapindaceae	4.38±0.09 k	98.01±1.05 cd
Solanum ferrugineum	Solanaceae	12.94±0.60 b	89.87±1.58 e
Nicotiana glauca	Solanaceae	6.73±0.30 gh	81.93±1.14 g
Witheringia stramoniifolia	Solanaceae	7.35±0.50 fg	122.88±0.38 b
Lantana camara	Verbenaceae	3.48±0.09l	85.76±0.15 f

[x]GAE: gallic acid equivalent. CE: catechin equivalent. DT: dry tissue.
[y]Values represent the mean ± standard deviation (n=5).
[z]Means with the same letter in each column are not significantly different (Tukey, $P \leq 0.05$).

seed extracts from *Asclepias* spp., against *M. chitwoodi*. *Asclepias* species are characterized by their high content of cardenolides (Agrawal *et al*., 2008) and biologically active compounds with nematicidal activity (Zhou *et al*., 2012). On the other hand, the toxicity of *N. glauca* extracts found in this work is similar to that reported by Saeed and Shawkat (2014), where in soils amended with this solanaceous plant, tomato roots infected by *M. incognita* had reduced root galling.

The nematostatic and nematicidal effects of natural products are both important as the immobilization of the nematode is crucial to block their feeding and ability to invade the roots of the host plant. Therefore, the plants whose extracts had significant toxic effects against *N. aberrans* could be tested and used at the field level by incorporating into the soil as organic amendments to create suppressive environments against this plant parasitic nematode. This behavior has been reported in other studies, where the effect of plant extracts *in vitro* and *in vivo* has been evaluated jointly. For instance, at the *in vitro* level, ethanol extracts of *Datura stramonium*, *D. innoxia* and *D. tatula* were lethal against J2 of *M. incognita*. This effect was similar in pot experiments where the galling index of tomato roots was significantly reduced by treatments with these extracts (Babaali *et al*., 2017).

The results obtained in this work reveal the nematicidal potential of *C. sulphureus*, *W. stramoniifolia*, *T. lunulata*, *S. salignus*, *L. camara*, *A. linaria*, *M. foliosa*, *V. sphaerocephala*, and *N. glauca* against *N. aberrans*. Only in some cases was the nematicidal activity of these plants related to the total phenolic and flavonoid content. In the future, it will be necessary to characterize the active compounds and to determine their modes of action. This kind of research opens an opportunity to explore the Mexican wild flora in order to benefit the traditional agriculture.

LITERATURE CITED

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