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Chemotaxonomy of Compositae related to their host suitability for Pratylenchus penetrans

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Abstract

Experimental work and a survey of literature gave data on the effects of 175 Compositae on populations of *Pratylenchus penetrans* in the soil. Nearly 70 Compositae effectively suppress populations of *P. penetrans*. It is shown that a close relationship exists between this suppressing feature and the chemotaxonomy of the Compositae.

Introduction

Research on the host range of *Pratylenchus penetrans* (Oostenbrink et al., 1957; Townshend and Davidson, 1960) and screening of Compositae for their ability to suppress nematode populations, especially of *P. penetrans* (Hijink and Winoto Suatmadji, 1967; Gommers, 1973) gave information on host suitability of about 110 species for this nematode; 40 species suppressed densities of *P. penetrans* to very low levels.

A recent compilation of literature on naturally occurring acetylenes, supplemented with many hitherto unpublished results (Bohlmann et al., 1973) was reason to start an additional screening experiment for Compositae that suppress *P. penetrans*.

Materials and methods

Seeds of Compositae were obtained from a number of Botanical Gardens, through the Department of Plant Taxonomy and Plant Geography, Agricultural University, Wageningen. Experts of Groningen and Wageningen Universities assisted in the correct identification of the plant species. After germination the plants were transplanted to steam-sterilized soil and used about three weeks later in the screening programme. The sandy soil used in the experiment originated from a nursery in Zuidlaren in the North of the Netherlands and contained 210 specimens of *P. penetrans* per 100 ml of soil. Plastic bags in PVC tubes (diameter 5 cm; height 25 cm) were filled with 100 ml of coarse sand and then with approximately 300 ml of infested soil and planted in four replicates with 60 selected Compositae. The suppressor *Tagetes patula* and the host *Anthemis tinctoria* served as controls. After 4 months growth in a glasshouse the numbers of *P. penetrans* in the roots were assessed in a darkened version of the funnel spray method (Oostenbrink, 1960). Plant species with less than 30 nematodes per 10 g of fresh root tissue were considered to be suppressors. Numbers of *P. penetrans* in the soil at the end of the experiment were not counted as small numbers of *P. penetrans* in the roots of Compositae always indicated plant species that suppressed densities of this nematode (Gommers, 1973).

Results

The effects of Compositae on populations of *P. penetrans* in our experiment and the results of Oostenbrink et al. (1957), Townshend and Davidson (1960), Hijink and Winoto Suatmadji (1967) and Gommers (1973) are summarized in Table 1. Plant species are arranged according to the system of Hoffmann (1894). The occurrence of α-terthienyl (column 1) and of 5-(3-buten-1-ynyl)-2,2'-bithienyl (column 2), known natural nematicidal principles (Uhlenbroek and Bijloo, 1958, 1959), is also given. Furthermore the distribution of a group of red-coloured dithio compounds (Bohlmann and Kleine, 1965) (column 3) is indicated. These compounds are suspected to exert nematicidal activity in vitro (Gommers, unpublished).

Suppressing properties of Compositae were already known of all tested species of the genera *Milleria, Iva, Ambrosia, Franseria, Baeria, Schkuhria, Eriophyllum* (except *E. nevinii*), *Helenium* (except *H. hoopesi*), *Gaillardia, Tagetes* and *Echinops*. Certain species of the genera *Melampodium, Silphium, Parthenium, Rudbeckia, Coreopsis* and *Arctotis* also have this suppressing effect.

The present investigations also reveal these properties in the genera *Grindelia, Eclipta, Verbesina, Lasthenia, Chaenactis, Gazania, Berkheya, Didelta* and *Urospermum*. The number of species of the genera *Arctotis* and *Echinops* with this suppressing effect was extended considerably.

Discussion

The similarity between the taxonomic classification of the tested Compositae and their suitability as suppressors of *P. penetrans* is obvious (Table 1). The suppression is particularly marked in the subtribes Ambrosiinae, Heleniinae, Arctotinae, Gorteriinae and Echinopinae. Therefore, the concept of a chemical basis for nematode suppression, as proposed for *Tagetes* species, a *Helenium* hybrid, *Echinops sphaerocephalus* and a few other Compositae (Uhlenbroek and Bijloo, 1958, 1959; Gommers, 1973) probably holds for all Compositae. The two known naturally occurring nematicidal thiophenes are α-terthienyl and 5-(3-buten-1-ynyl)-2,2'-bithienyl. An increase of the energy level of these compounds seems to be necessary for nematicidal activity which in vitro can be obtained by irradiation with light of appropriate wavelengths (Gommers and Geerligs, 1973). The presence of both chemicals in the roots is often accompanied with other bithienyl derivatives (Bohlmann et al., 1973) which also may exert nematicidal activity. According to Uhlenbroek and Bijloo (1960), who synthetized a number of thiophenes and ascertained their nematicidal activity, all active thiophenes can be considered to be derivatives of bithienyl.

There are 16 species, distributed over the genera *Eclipta, Gaillardia, Flaveria, Tagetes, Berkheya, Didelta* and *Echinops* which contain α-terthienyl and 15 of them effectively suppress *P. penetrans*. *Flaveria repanda* is the only species of this series on which *P. penetrans* breeds.

Nearly the same holds for the occurrence of 5-(3-buten-1-ynyl)-2,2'-bithienyl. This

Table 1. Host suitability of Compositae for *Pratylenchus penetrans*. Summary of a screening experiment in 1974 (1), the results of Gommers (1973) (2), Hijink and Winoto Suatmadji (1967) (3), Townshend and Davidson (1960) (4) and Oostenbrink et al. (1957) (5). Plant species are arranged according to the system of Hoffmann (1894).
Underlined: plant species that suppress *P. penetrans*.
+ = compound present, − = compound absent, u = presence of compound unknown (Bohlmann et al., 1973).
Column 1: α-terthienyl. Column 2: 5-(3-buten-1-ynyl)-2,2'-bithienyl. Column 3: red-coloured dithio compounds.

			1. 	2. 	3 
EUPATORIEAE	Eupatoriinae	*Ageratum mexicanum* Sims. (3)	−	−	−
		Eupatorium rugosum H.B. et K. (2)	−	−	−
	Kuhniinae	*Liatris spicata* Willd. (3)	−	−	−
ASTEREAE	Solidagininae	*Grindelia robusta* Nutt. (1)	−	−	−
		Grindelia squarrosa Dunal (1)	−	−	−
		Solidago virgaurea L. (1)	−	−	−
		Solidago hybrid (3)	u	u	u
		Solidago hybrid (4)	u	u	u
	Bellidinae	*Brachycome iberidifolia* Benth. (3)	−	−	−
		Bellis perennis L. (3)	−	−	−
	Asterinae	*Callistephus chinensis* Nees (3)	−	−	−
		Erigeron annuus Pers. (4)	−	−	−
		Erigeron canadensis L. (4)	−	−	−
		Erigeron speciosus DC. (3)	−	−	−
		Erigeron strigosus Muhl. (4)	u	u	u
INULEAE	Gnaphaliinae	*Leontopodium alpinum* Cass. (3)	−	−	−
		Gnaphalium uliginosum L. (4)	−	−	−
		Helichrysum bracteatum Andr. (3)	−	−	−
	Athrixiinae	*Podolepis canescens* Cunn. (1)	−	−	−
		Podolepis kendallii Muell. (1)	u	u	u
	Buphthalminae	*Buphthalmum salicifolium* L. (1)	−	−	−
		Telekia speciosa Baumg. (1)	−	−	−
HELIANTHEAE	Coreopsidinae	*Guizotia abyssinica* Cass. (2)	−	−	−
		Coreopsis grandiflora Nutt. (3)	−	−	−
		Coreopsis lanceolata L. (3)	−	−	−
		Coreopsis basalis Blake (3)	−	−	−
		Coreopsis tinctoria Nutt. (3)	−	−	−
		Coreopsis verticillata L. (3)	−	−	−
		Dahlia hybrid (3)	u	u	u
		Bidens dahlioides Wats. (2)	−	−	−
		Cosmos sulphureus Cav. (3)	−	−	−
	Helianthinae	*Siegesbeckia flosculosa* L'Hérit (1)	−	−	−
		Siegesbeckia orientalis L. (1)	−	−	−
		Eclipta prostrata L. (1)	+	+	−
		Rudbeckia bicolor Nutt. (3)	−	−	+
		Rudbeckia laciniata L. (3)	−	−	−
		Rudbeckia serotina Nutt. (3)	u	u	u
		Rudbeckia speciosa Wender. (3)	−	−	+

		Rudbeckia purpurea L. (3)	u	u	u
		Wyethia elata Hall (2)	u	u	u
		Helianthus annuus L. (3)	–	–	–
		Spilanthes acmella Murr. (1)	–	–	–
		Encelia californica Nutt. (2)	u	u	u
		Encelia virginensis Nelson (2)	u	u	u
		Verbesina alata L. (1)	–	–	+
		Verbesina encelioides Benth. et Hook. (1)	–	–	–
		Verbesina helianthoides H.B. et K. (1)	–	–	–
	Melampodiinae	*Melampodium divaricatum* DC. (2)	–	–	+
		Melampodium perfoliatum H.B. et K. (2)	–	–	–
		Silphium asteriscus L. (2)	–	–	–
		Silphium perfoliatum L. (2)	–	–	–
		Lindheimera texana Gray (2)	–	–	–
		Parthenium argentatum Gray (2)	u	u	u
		Parthenium hysterophorus L. (2)	u	u	u
	Ambrosiinae	*Iva xanthiifolia* Nutt. (2)	–	–	+
		Ambrosia artemisiifolia L. (2)	–	–	+
		Ambrosia chamissonis Greene (2)	u	u	u
		Ambrosia maritima L. (2)	u	u	u
		Ambrosia trifida L. (2)	–	–	+
		Franseria artemisioides Willd. (2)	u	u	u
		Franseria chenopodiifolia Benth. (2)	u	u	u
		Xanthium strumarium L. (2)	–	–	–
	Milleriinae	*Milleria quinqueflora* L. (2)	–	–	+
	Zinniinae	*Zinnia elegans* Jacq. (3)	–	–	–
		Sanvitalia procumbens Lam. (2)	–	–	–
		Heliopsis scabra Dun. (3)	–	–	–
	Galinsoginae	*Tridax trilobata* Hemsl. (1)	–	–	–
		Galinsoga ciliata Blake (1)	–	–	–
		Galinsoga parviflora Cav. (1)	–	–	–
	Madiinae	*Madia anomala* Greene (2)	u	u	u
		Madia elegans Don (2)	–	–	–
		Madia gracilis (Sm.) Keck et Clausen (2)	u	u	u
		Madia sativa Mol. (2)	–	–	–
		Hemizonia corymbosa Torr. et Gray (2)	–	–	–
		Layia elegans Torr. et Gray (2)	–	–	–
		Layia platyglossa Gray (2)	–	–	–
HELENIEAE	Heleniinae	*Baeria californica* (Hook.) Chamb. (2)	–	–	–
		Baeria chrysostoma Fisch. et Mey. (2)	–	–	–
		Baeria minor (DC.) Ferris (2)	–	–	–
		Lasthenia glabrata Lindl. (1)	u	u	u
		Flaveria repanda Lag. (2)	+	+	–
		Schkuhria pinnata (Lam.) Kuntze (2)	–	–	+
		Schkuhria senecioides Nees (2)	–	–	+
		Eriophyllum caespitosum Dougl. (2,3)	–	–	+
		Eriophyllum confertiflorum Gray (2)	u	u	u
		Eriophyllum lanatum Forb. (2)	–	–	+

		Eriophyllum nevinii Gray (2)	u	u	u
		Chaenactis douglasii Hook.et Arn. (1)	u	u	u
		Helenium autumnale L. (2,3)	–	–	–
		Helenium bolanderi Gray (2)	u	u	u
		Helenium flexuosum Rafin. (2)	u	u	u
		Helenium hoopesii Gray (2,3)	–	–	–
		Helenium nudiflorum Nutt. (2)	–	–	–
		Helenium hybrid 'Moerheim Beauty' (2,3)	u	u	u
		Helenium hybrid 'Pumilum' (3)	u	u	u
		Helenium hybrid 'Riverton Gem.' (3)	u	u	u
		Gaillardia amblyodon Gay (2)	–	–	–
		Gaillardia aristata Pursh (2)	–	–	–
		Gaillardia arizonica Gray (2)	u	u	u
		Gaillardia lanceolata Michx. (2)	–	–	–
		Gaillardia lutea Greene (2)	–	–	–
		Gaillardia pulchella Fouger. (2)	+	–	–
		Gaillardia hybrid 'Burgunder' (2,3)	u	u	u
	Tagetinae	*Tagetes erecta* L. (2)	+	+	–
		Tagetes patula L. (2,3,5)	+	+	–
		Tagetes tenuifolia Cav. (2)	+	+	–
ANTHEMIDEAE	Anthemidinae	*Ursinia anthemoides* Gaertn. (1)	–	–	–
		Ursinia calenduliflora Benth. et Hook. (1)	–	–	–
		Ursinia pulchra N.E.Br. (1)	u	u	u
		Ursinia speciosa DC. (1)	–	–	–
		Anthemis cotula L. (4)	–	–	–
		Anthemis nobilis L. (2)	–	–	–
		Anthemis ruthenica Bieb. (2)	–	–	–
		Anthemis tinctoria L. (2)	–	–	–
		Achillea filupendulina Lam. (5)	–	–	–
		Achillea ptarmica L. (2,3)	–	–	–
	Chrysantheminae	*Matricaria matricarioides* Porter (4)	–	–	–
		Matricaria hybrid (3)	u	u	u
		Chrysanthemum carinatum Schousb. (3)	–	–	–
		Chrysanthemum leucanthemum L. (4)	–	–	–
		Chrysanthemum maximum Ramond (3)	–	–	–
		Chrysanthemum parthenium Bernh. (2)	–	–	–
		Chrysanthemum hybrid (3)	u	u	u
		Tanacetum balsamita L. (2)	u	u	u
		Cotula australis Hook. (1)	–	–	–
		Cotula coronopifolia L. (1)	–	–	–
		Artemisia absinthium L. (3)	–	–	–
		Artemisia dracunculus L. (5)	–	–	–
SENECIONEAE	Senecioninae	*Arnica chamissonis* Less. (1)	–	–	–
		Arnica foliosa Nutt. (1)	–	–	–
		Arnica montana L. (1)	–	–	–
		Arnica sachalinensis Gray (1)	–	+	–
		Doronicum caucasicum Bieb. (3)	u	u	u
		Doronicum orientale Hoffm. (5)	u	u	u

		Cineraria candidacans J. et C.Presl (3)	u	u	u
		Senecio aquaticus Hill (2)	-	-	-
		Senecio viscosus L. (2)	-	-	-
		Senecio vulgaris L. (3,4)	u	u	u
CALENDULEAE		*Calendula officinalis* L. (2,3)	-	-	-
ARCTOTEAE	Arctotinae	*Arctotis acaulis* L. (1)	-	-	-
		Arctotis fastuosa Jacq. (1)	-	-	-
		Arctotis grandis Thunb. (1)	-	-	-
		Arctotis stoechadifolia Berg. (1)	-	-	-
		Arctotis hybrid (3)	u	u	u
	Gorteriinae	*Gazania lichtensteinii* Less. (1)	-	-	-
		Gazania splendens Hort.Angl. (1)	-	-	-
		Gazania hybrid (1)	u	u	u
		Berkheya adlamii Hook. (1)	+	+	-
		Berkheya macrocephala Wood (1)	+	+	-
		Didelta carnosa Ait. (1)	+	+	-
CARDUEAE	Carduinae	*Arctium minus* Bernh. (4)	-	-	-
		Cirsium arvense Scop. (4)	-	-	-
		Onopordon acanthium L. (4)	-	-	-
		Silybum marianum Gaertn. (1)	-	-	-
		Saussurea albescens Hook.f. et Thoms. (2)	-	-	-
	Centaureinae	*Centaurea cyanus* L. (3)	-	-	-
	Echinopinae	*Echinops bannaticus* Rochel (1)	+	+	-
		Echinops champtavicus (1)	+	+	-
		Echinops exaltatus Schrad. (1)	+	+	-
		Echinops horridus Desf. (1)	+	+	-
		Echinops macrophyllus Boiss. et Haussk. (1)	u	u	u
		Echinops ritro L. (2,3)	+	+	-
		Echinops sphaerocephalus L. (2)	+	+	-
CICHORIEAE	Cichoriinae	*Cichorium endivia* L. (3,5)	u	u	u
		Cichorium intybus L. (3,4,5)	u	u	u
	Scorzonerinae	*Tragopogon dubius* Scop. (1)	u	u	u
		Tragopogon pratensis L. (1)	u	u	u
		Scorzonera hispanica L. (5)	u	u	u
	Crepidinae	*Sonchus arvensis* L. (4)	-	-	-
		Sonchus oleraceus L. (4)	u	u	u
		Hieracium pratense Tausch (4)	u	u	u
		Urospermum dalechampii Schmidt (1)	-	-	-
		Lactuca sativa L. (3,5)	-	-	-
		Lactuca scariola L. (4)	-	-	-
		Taraxacum officinale Web. (4,5)	-	-	-

Tabel 1. Geschiktheid van Composieten als waardplant voor Pratylenchus penetrans. Samenvatting van de resultaten van eigen onderzoek (1) en van de gegevens van Gommers (1973) (2), Hijink en Winoto Suatmadji (1967) (3), Townshend en Davidson (1960) (4) en Oostenbrink et al. (1957) (5). Plantesoorten zijn gerangschikt volgens het systeem van Hoffmann (1894).
Onderstreept: soorten, die de bevolkingsdichtheid van P. penetrans verlagen.
+ = verbinding aanwezig, — = verbinding niet aanwezig, u = aanwezigheid van verbinding niet bekend (Bohlmann et al. 1973).
Kolom 1: α-terthienyl. Kolom 2: 5-(3-buteen-1-ynyl)-2,2'-bithienyl. Kolom 3: rode dithio-acetyleen-verbindingen.

is logical, for the biogenesis of α-terthienyl and of the bithienyl derivative partly follows a common pathway (Bohlmann et al., 1973).

In attempts to isolate nematicidal principles from roots of *Milleria quinqueflora, Iva xanthiifolia, Ambrosia artemisiifolia, A. trifida, Schkuhria pinnata* and *Eriophyllum caespitosum* red-coloured fractions were obtained with strong nematicidal activity in vitro. These unstable sulphur-containing compounds could not be obtained sufficiently pure to allow identification. Because of their spectra with maxima near 340-350 nm and weaker absorption near 490-500 nm they are very probably acetylenic dithio compounds (Bohlmann and Kleine, 1965).

The occurrence of these compounds also coincides with nematode-suppressing properties in a number of Compositae. There are 12 plant species with acetylenic dithio derivatives (Table 1); 11 of them belonging to the genera *Milleria, Melampodium, Iva, Ambrosia, Rudbeckia, Verbesina, Schkuhria* and *Eriophyllum* suppress populations of *P. penetrans*. *Rudbeckia speciosa* must be considered as a host plant but roots nevertheless contain these dithio compounds. On the other hand roots of *R. laciniata* do not contain these compounds, but nevertheless populations of *P. penetrans* are suppressed effectively.

A nematicidal constituent of *Asparagus* roots, 1,2-dithiolane-4-carboxy acid (Takasugi et al., 1975), possesses, like the acetylenic dithio compounds, an -S-S- bond which may be important for nematicidal activity. From roots of the *Helenium* hybrid 'Moerheim Beauty' (Gommers, 1971), *H. nudiflorum, H. puberolum* and *H. mexicanum* (Bohlmann et al., 1969) the nematicide 2-hydroxy-3-methylene-6-methylbenzofuran was isolated. Therefore, clearly different nematicidal principles occur in the Compositae. It is also possible that genera like *Grindelia, Arctotis, Gazania* and *Urospermum* contain other nematicides.

Samenvatting

Chemotaxonomie van Composieten in relatie met hun geschiktheid als waardplant voor Pratylenchus penetrans

Eigen onderzoek aangevuld met gegevens uit de literatuur gaf informatie over de invloed van 175 Composieten op populaties van *Pratylenchus penetrans* in de grond. Bijna 70 soorten verlaagden deze dichtheden (Tabel 1). Het betreft soorten van de geslachten *Grindelia, Solidago, Coreopsis, Eclipta, Rudbeckia, Verbesina, Melampodium, Parthenium, Iva, Ambrosia, Milleria, Baeria, Schkuhria, Eriophyllum, Chaenactis, Helenium, Gaillardia, Tagetes, Arctotis, Gazania, Berkheya, Didelta, Echinops* en *Urospermum*. Er is een duidelijk verband tussen de taxonomische indeling van Composieten en deze eigenschap. Bijna alle getoetste soorten van de subtribus Ambrosiinae, Heleniinae, Arctotinae, Gorteriinae en Echinopinae reduceerden populaties van *P. penetrans*. In sommige geslachten zoals *Solidago, Coreopsis, Rudbeckia* en *Melampodium* veroorzaakten slechts een of enkele getoetste soorten dit effect.

Van de 16 Composieten, waarvan bekend is dat zij α-terthienyl in hun wortels bevatten, verlaagden er 15 dichtheden van *Pratylenchus*. Vrijwel hetzelfde geldt voor Composieten met 5-(3-buteen-1-ynyl)-2,2'-bithienyl in hun wortels (Tabel 1). Ook de aanwezigheid in een aantal andere Composieten van een groep rode dithio-acetyleenverbindingen met waarschijnlijk nematicide eigenschappen in vitro, komt goed overeen met de eigenschap om dichtheden van *P. penetrans* in de grond te verminderen.

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