Beitr. Ent.	Berlin	ISSN 0005-805X
48 (1998) 1	S. 219-235	31.03.1998

The phytophagous insect fauna of *Tanacetum vulgare* L. (Asteraceae) in Central Europe

With 4 tables

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Summary

A comprehensive description of the Central European phytophagous complex of *Tanacetum vulgare* L., 1753 (Asteraceae) is presented, based on personal observations, data from the literature and information from specialists. The phytophagous complex consists of 143 species, of which 13.3% are monophagous and 44.8% are restricted to Asteraceae. Larval development was recorded for 135 species. Roughly two-thirds of the species feed on the plant tissue while the rest are sap-suckers. Thirty-five percent of the species are endophytic. Twenty-five species are for the first time reported to live on *T. vulgare*, including a new species of *Melanagromyza* (Dipt., Agromyzidae). The identity of a *Liriomyza* species (Agromyzidae) and a *Lasioptera* species (Cecidomyiidae) remained unresolved. The agricultural pest insects, for which *T. vulgare* represents a source of food, are listed. In order to find a suitable agent against *T. vulgare*, which has become a serious, alien pasture weed in some regions of North America, a preliminary selection of herbivores is given, which could be subjected to pre-release studies.

Zusammenfassung

Der mitteleuropäische Phytophagenkomplex von *Tanacetum vulgare* L., 1753 (Asteraceae) wird ausgehend von eigenen Beobachtungen, Literaturhinweisen und Angaben von Spezialisten dargestellt. Dem Komplex gehören 143 Arten an, von denen 13.3% monophag und 44.8% auf Asteraceae beschränkt sind. 135 Arten entwickeln sich als Larven an der Pflanze. Etwa zwei Drittel der Arten befressen Pflanzengewebe, während sich der Rest auf saugende Weise ernährt. Endophytisch leben 35% der Arten. Für 25 Arten wurde *T. vulgare* erstmals als Wirtspflanze festgestellt, darunter eine bisher unbeschriebene *Melanagromyza*-Art (Dipt., Agromyzidae). Auch die Identität einer *Liriomyza*-Art (Agromyzidae) und einer *Lasioptera*-Art (Cecidomyiidae) blieb ungeklärt. Es wird dargestellt, welche in der Landwirtschaft schädlichen Insekten sich von *T. vulgare* ernähren. Um brauchbare Gegenspieler gegen die in Nordamerika eingeführte und als lästiges Weideunkraut bedeutsame Pflanze zu finden, wird eine Auswahl von Phytophagen diskutiert, die für eingehendere biologische Prüfungen in Frage kommen.

Keywords

Tanacetum vulgare L., 1753 - herbivores - phytophagous insect fauna - biological weed control - Central Europe - *Melanagromyza* - guilds - spatial distribution - host specificity - feeding mode.

DOI: 10.21248/contrib.entomol.48.1.219-235

1. Introduction

In Central Europe, tansy *Tanacetum vulgare* L. 1753 (Asteraceae) inhabits naturally disturbed areas along riverbanks and various anthropogenic sites, such as field ridges, wastelands, fallow lands and ruderal meadows (WAGENITZ, 1987). As a characteristic species of the Artemisietea vulgaris Lohm., Prsg. et Tx. in Tx. 50, this perennial herb is an important member of the ruderal vegetation (OBERDORFER, 1979). The Eurasian plant was introduced in North America, Australia, New Zealand (for map see HULTÈN, 1968) and Reunion (WALTER & STRAKA, 1970) during the course of colonization.
As described previously by KLAUSNITZER (1966, 1968a), *T. vulgare* hosts a diverse entomofauna. However, no broadening studies of the phytophagous complex of the plant have since been conducted. Only isolated studies on the biology of the host-specific species of the complex are available. For example, biological data were collected for the following species: *Uroleucon tanaceti* (L.) (Hom., Aphididae) by HOLTFRETER (1977), *Rhopalomyia tanaceticola* KARSCH (Dip., Cecidomyiidae) by KLAUSNITZER (1967a) and HAUS (1991), *Isophrictis striatella* DENIS & SCHIFF. (Lep., Gelechiidae) by HAUS (1991), and *Depressaria emeritella* STT. (Oecophoridae) by KLAUSNITZER (1967b).

This work provides an updated description of the phytophagous complex of *T. vulgare*. This information appears to be of interest for the following reasons:

1. A survey of the phytophagous insects of *T. vulgare* enables us to expand on current knowledge of the structure of the phytophagous complexes of herbaceous plants. The data seem to be of importance for comparing the utilization of a plant by insects in different distribution areas (c.f. LAWTON 1984), and thus for more accurately assessing the status of the plant in local flora. In the case of *T. vulgare*, it is not completely certain whether the plant is indigenous or archeophytic in Central Europe (LOHMEYER & SUKOPP, 1992).
2. An analysis of the complex would yield essential information for understanding the ecological effects of the plant in (Central European) farmlands. KLAUSNITZER (1968b), and later NENTWIG (1992) and FREI & MANHART (1992), already showed that the plant hosts aphid species which are beneficial in biological control because they represent important alternative hosts for beneficial insects. The role of monophagous aphid species in this context is well documented. On the other hand, it must be considered that the plant is also an important host for agricultural pest species. Thus, this study presents and discusses a list of pest insects found on *T. vulgare*.
3. During the last ten years *T. vulgare* has become a serious pasture weed in some regions of North America where biocontrol programs are being considered. This development began with the cultivation of *T. vulgare* in colonial gardens on the east coast of North America for medicinal use. It migrated from there into the wild and then spread westward through the temperate zones (MITICH, 1992). Today *T. vulgare* is found from Nova Scotia and Ontario across Minnesota to Oregon and Nevada, and south roughly to North Carolina, Missouri and California (BRITTON & BROWN, 1970; MITICH, personal communication, 1996). The species continues to spread in Alberta (Alberta Environmental Centre, 1993), particularly in the southern region of the former boreal mixedwoods (MCCLAY, 1989; STRONG & LEEGGAT, 1981). In addition to roadsides, fallow lands, fence rows and riverbanks, the neophyte also colonizes pastures and meadows in some areas, where it has become an economic factor due to its rejection by livestock (West. Soc. Weed Sci., 1991; cf. DUKE, 1985). *T. vulgare* has become one of the ten most serious pasture weeds in Washington and

DOI: 10.21248/contrib.entomol.48.1.219-235

Idaho (MITICH & KYSER, 1987). Experiments with chemical control methods have met with only partial success up to now, due to the ability of rhizomes to regenerate (LASS et al., 1987; MILLER & CALLIHAN, 1992). Biological control using herbivores appears to be increasingly indicated today (SCHROEDER, personal communication, 1995, STRONG & LEEGGAT, 1981). A description of the Central European complex of phytophagous insects on *T. vulgare* may permit a preliminary selection of species as candidates for use in biological control, which could then be subjected to pre-release studies.

2. Materials and methods

Criteria for the inclusion of a species: The list of phytophagous insects and the following analyses pertain to Central Europe. Central Europe refers to the region from Denmark southward to the main ridge of the Alps inclusive, and from eastern France (east of the Rhône) and the Benelux countries westward to central Poland and the border of the Czech Republic and Slovakia.
Furthermore, this study is limited to arthropods, particularly those which feed on the living tissue or sap of *T. vulgare*. Species which appeared on *T. vulgare* at random are excluded. Proof of reproduction on the plant was not a mandatory requirement.
Data from the literature are included if *T. vulgare* (or "*Chrysanthemum vulgare*") was cited as the host plant. In order to avoid errors, particularly those due to the consideration of out-dated host records, the lists were submitted to specialists for review (see acknowledgments).

Field studies: Data were gathered in field studies conducted between 1992 and 1994 within the framework of a study of the impact of urbanization on the phytophagous insect complexes of *Artemisia vulgaris* L. and *T. vulgare* (SCHMITZ, 1995b, 1996, 1997). In this context, the presence of phytophagous insects was investigated on natural gravel sites around the Ahr river mouth (Rhineland Palatinate, Germany) as "primary habitats" and on ruderal sites in and around the city of Bonn (North Rhine-Westphalia) as anthropogenic sites. The above-ground sections of the plants were searched manually four times in each vegetation period (1992: 37 individual patches, 1993: 99 individual plants on 5 large sites). Flower-bud sections (1992: 10 buds from each of the 37 patches, 1993: 20 buds from each of 84 individual plants on 5 large sites) and rootstocks (1992: 25 individual patches, 1993: 39 individual plants on 5 large sites) were investigated once each year. Stem inhabitants were collected using eclectors (SCHMITZ, 1995a) : (1992: 738 stems from the preceding year from 13 sites, 1993: 973 stems from the preceding year from 25 sites, 1994: 993 stems from the preceding year from 68 individual plants on 5 large sites). Larval morphology was used as the basis for identifying the leaf miners. The "Microlepidoptera" were collected in random samples by rearing them from the plants. The Traminae collected from the roots and several of the Miridae and Curculionidae were forwarded to the appropriate specialists for review (see acknowledgments).

Nomenclature of the herbivores: The nomenclature is based on the following works: Eriophyoidea, DAVIS et al. (1982); Auchenorrhyncha, OSSIANNILSSON (1981, 1983); Aphidinea, EASTOP & HILLE RIS LAMBERS (1976); Psyllinea, OSSIANNILSSON (1992); Heteroptera, GÜNTHER & SCHUSTER (1990); Coleoptera, LUCHT (1987); "Microlepidoptera", LERAUT (1980) and HUEMER & TARMANN (1993); Noctuidae, FIBIGER & HACKER (1990); Geometridae, WOLF (1988); Nymphalidae, EBERT (1991); Cecidomyiidae, SOOS & PAPP (1986); Agromyzidae, SOOS & PAPP (1984) and SPENCER & MARTINEZ (1987); Tephritidae, WHITE (1988).

DOI: 10.21248/contrib.entomol.48.1.219-235

3. Results

3.1. Characterization of the phytophagous complex of *T. vulgare*

3.1.1. Species range

Table 1 contains all of the phytophagous arthropods verified to occur on *T. vulgare* in Central Europe. The table contains data on the phytophagous developmental stage, the infested plant organ, the feeding mode and the host specificity. New host records are included in this context. In addition, frequency categories for the greater Bonn region are indicated.

Table 1: The Central European complex of phytophagous insects of *Tanacetum vulgare* based on personal observations, data from the literature and information from specialists. The symbols in the columns indicate the following:

Developmental stage:	I = imago, L = larva
Plant part:	Plant organs used: L = leaf (incl. buds), F = single flower/fruit, H = flowerbud, I = inflorescence, S = stem, R = rootstocks/rhizomes
Feeding mode:	C = chewer (incl. "grating" types), Lb = local bibitor, Pb = phloem bibitor, Xb = xylem bibitor, G = obligatoric gall inducer, M = leaf miner
Specificity:	Host specificity: m1 = monophagous of 1st degree, i. e. feeds exclusively on one plant species; o = oligophagous, i. e. feeds on plant species of more than one genus within one family, p = polyphagous, i. e. feeds on plant species of more then one family
New host:	New host records: ! = record of primary importance, (!) = record of secondary importance
Bonn area:	Occurrence in the Bonn area: * = rare, ** = moderate, *** = abundant

Notes:
1) *Empoasca decipiens* PL., *E. affinis* NAST, *E. pteridis* DHLB. and *Athysanus argentarius* MTC. are possible polyphagous insects (REMANE, personal communication, 1995); **2)** Frequent on *Achillea* spp., rare on *T. vulgare* (BÖRNER, 1952); **3)** Edge of the "Kottenforst" forest; **4)** Larvae are polyphagous and live ectophytically on the roots (SCHERF, 1964); **5)** According to DIECKMANN (1983); **6)** Larvae are oligophagous and live ectophytically on the roots (SCHERF, 1964); **7)** Oligophagous ? (SCHERF, 1964), monophagous of the 1st degree (DIECKMANN, 1972); **8)** Larvae on *Matricaria* and *Anthemis* (DIECKMANN, 1972); **9)** Gall not described up to now (MEYER personal communication, 1995), see text; **10)** Not described up to now, genus determined by TSCHIRNHAUS, 1995; **11)** Larvae similar to *Liriomyza artemisicola* DE MEIJ.; **12)** Pupa found in flowerbud. **13)** In the Bonn area no distinction was made between the two *Chromatomyia* species which represent the former "*Phytomyza atricornis* MEIGEN".

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Taxa	Devel. stage	Plant part	Feed. mode	Speci-ficity	New host	Bonn area
A C A R I (Eriophyoidea)						
Aceria tuberculata (NAL.)	L,I	I,H	Lb	m1		
C O L L E M B O L A						
Sminthuridae sp.	I	L	C	p	(!)	**
A U C H E N O R R H Y N C H A						
Cercopidae						
Philaenus spumarius (L.)	L,I	S,L	Xb,G	p		**
Aphrophora alni (FALL.)	L,I	S	Xb	p		*
Cercopis vulnerata ROSSI	I	S	Xb	p	(!)	*
Cicadellidae						
Aphrodes cf. *makarovi* ZV.	L,I	S,L	Pb	p	(!)	***
Aphrodes bicinctus (SCHRNK.)	L,I	L,S	Pb	p		
Eupteryx atropunctata (GOEZE)	L,I	S,L	Pb	p		
Cicadellidae sp. [1]	L,I	L	Pb	?		**
S T E R N O R R H Y N C H A						
Lachnidae						
Trama troglodytes VON HEYDEN	L,I	R	Pb	o		**
Protrama flavescens (KOCH)	L,I	R	Pb	o		*
Aphididae						
Macrosiphoniella tanacetaria (KALTENB.)	L,I	L	Pb	ml		**
Macrosiphoniella persequens (WALKER)	L,I	L	Pb	ml		?*
Macrosiphoniella millefolii (DE GEER) [2]	L,I	L	Pb	o		*
Aulacorthum solani (KALTENB.)	L,I	L	Pb	p		*
Macrosiphum euphorbiae (THOMAS)	L,I	L	Pb	p		**
Uroleucon tanaceti (L.)	L,I	L	Pb	ml		**
Metopeurum fuscoviride STROYAN	L,I	S,I,L	Pb	ml		***
Metopeurum enslini (BÖRNER)	L,I	S	Pb	ml		
Aphis fabae SCOPOLI	L,I	S,I	Pb	p		**
Toxopterina vandergooti (BÖRNER)	L,I	R,S	Pb	o		**
Coloradoa tanacetina (WALKER)	L,I	L	Pb	ml		**
Brachycaudus helichrysi (KALTENB.)	L,I	L,S	Pb	p		***
Brachycaudus cardui (L.)	L,I	S	Pb	p		**
Orthezidae						
Orthezia urticae L. [3]	L,I	S	Pb	p	(!)	*

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Taxa	Devel. stage	Plant part	Feed. mode	Speci-ficity	New host	Bonn area
Psyllidae						
Craspedolepta sonchi (FOERSTER)	L,I	S,L	Pb	o		*?
Craspedolepta nervosa (FOERSTER)	L,I	S,L	Pb	o		**
Trioza abdominalis FLOR.	L,I	L,S	Pb	o		
HETEROPTERA						
Miridae						
Phytocoris varipes (BOHEMAN)	I	L,S,I	Lb	p	(!)	**
Adelphocoris lineolatus (GOEZE)	I	L,S,I	Lb	p	(!)	**
Adelphocoris vandalicus (ROSSI)	L,I	L,S,I	Lb	p		
Calocoris roseomaculatus (DE GEER)	L,I	L,S,I	Lb	o		
Calocoris norvegicus (GMELION)	L,I	L,S,I	Lb	p		
Lygocoris lucorum (MEYER-DÜR)	L,I	L,S,I	Lb	p		***
Lygocoris spinolae (MEYER-DÜR)	L,I	L,S,I	Lb	p	(!)	*
Lygus gemellatus (HERRICH-SCHÄFFER)	L,I	L,S,I	Lb	p	(!)	**
Lygus pratensis (L.)	L,I	L,S,I	Lb	p		***
Lygus rugulipennis POPPIUS	L,I	L,S,I	Lb	p		***
Pinalitus cervinus (HERRICH-SCHÄFFER)	L,I	L,S,I	Lb	p		
Orthocephalus mutabilis (FALL.)	L,I	L,S,I	Lb	o		
Oncotylus punctipes REUT.	L,I	L,S,I	Lb	ml		*
Plagiognathus arbustorum (F.)	L,I	S,I	Lb	p		*
Plagiognathus chrysanthemi (WOLFF)	L,I	L,S,I	Lb	p		*
Megalocoleus molliculus (FALL.)	L,I	L,S,I	Lb	o		
Megalocoleus pilosus (SCHRANK)	L,I	I	Lb	ml		**
Berytidae						
Neides tipularis (L.)	L,I	L,S	Lb	p		
Lygaeidae						
Nysius senecionis (SCHILLING)	L,I	I	Lb	o	(!)	***
Nysius ericae (SCHILLING)	L,I	I	Lb	o	(!)	*
Coreidae						
Coreus marginatus (L.)	I	L,S	Lb	p	(!)	**
Alydidae						
Stictopleurus punctatonervosus (GOEZE)	L,I	I	Lb	o		***
Stictopleurus abutilon (ROSSI)	I	I	Lb	o	(!)	*
Pentatomidae						
Palomena prasina (L.)	L,I	L,S	Lb	p	(!)	**
Holcostethus sphacelatus (F.)	I	L,S	Lb	p	(!)	*
Holcostethus vernalis (WOLFF)	I	L,S	Lb	p	(!)	*

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Taxa	Devel. stage	Plant part	Feed. mode	Speci-ficity	New host	Bonn area
Acanthosomatidae						
Elasmostethus interstinctus (L.)	I	L,S	Lb	p	(!)	*
COLEOPTERA						
Phalacridae						
Olibrus bicolor (F.)	L/I	H/L	C	o		***
Mordellidae						
Mordellistena weisei SCHILSKY	L	S	C	o	!	*
Mordellistena bicoloripilosa ERM.	L	S	C	o	!	**
Mordellistena pumila (GYLLH.)	L	S	C	o	!	*
Mordellistena acuticollis SCHILSKY	L	S	C	o	!	**
Cerambycidae						
Phytoecia nigricornis julii MULS.	L	R	C	ml		**
Phytoecia pustulata (SCHRK.)	L	R,S	C	o		
Phytoecia virgula CHARP.	L	R	C	p		
Chrysomelidae						
Chrysolina graminis (L.)	L,I	L	C	p		
Galeruca tanaceti (L.)	L,I	L	C	p		*
Longitarsus succineus (FOURDR.)	L,I	R/L	C	o		
Cassida seladonia GYLLH.	L,I	L	C	o		
Cassida stigmatica SUFFRIAN	L,I	L	C	ml		*
Cassida sanguinosa SUFFRIAN	L,I	L	C	o		
Cassida denticollis SUFFRIAN	L,I	L	C	o		
Curculionidae						
Phyllobius sp. [4]	L/I	R/L	C	p	!	**
Phyllobius brevis GYLLH. [4]	L/I	R/L	C	p		
Strophosoma faber (HERBST) [4]	L/I	R/L	C	p		
Lixus fasciculatus BOHEMAN [4]	I	L	C	p		
Coryssomerus capucinus (BECK) [5]	L/I	R/L	C	o		
Cleonis pigra (SCOPOLI)	L/I	R/L	C,G	o		
Tanymecus palliatus (F.) [4]	L?/I	R/L	C	p		*
Cyphocleonus dealbatus (GMELIN) [6]	L/I	R/L	C,G	o		
Microplontus millefolii (SCHULTZE) [7]	L?/I	S/L	C	ml		
Microplontus rugulosus (WAGNER) [8]	L/I	S,H/L	C	o		
LEPIDOPTERA						
Coleophoridae						
Coleophora ditella ZELLER	L	L	C	o		
Coleophora troglodytella DUPONCHEL	L	L	C,M	o		**
Coleophora bornicensis FUCHS	L	H	C	ml		
Coleophora tanaceti MÜHLIG	L	H	C	ml		**

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Taxa	Devel. stage	Plant part	Feed. mode	Speci-ficity	New host	Bonn area
Tortricidae						
Cnephasia chrysanthaena DUPONCHEL	L	L	C,M	p		**
Dichrorampha agilana TGSTR.	L	S	C	o		
Dichrorampha sequana HBN.	L	R	C	o		
Dichrorampha alpinana TREITSCHKE	L	R	C	o		
Dichrorampha plumbagana TREITSCHKE	L	R	C	o		?***
Dichrorampha acuminatana LIEN. & ZELL.	L	S	C	o		
Dichrorampha flavidorsana KNAGGS.	L	R	C	o		
Dichrorampha plumbana SCOPOLI	L	R	C	o		
Dichrorampha montanana DUPONCHEL	L	R	C	o		
Periclepsis cinctana DENIS & SCHIFF.	L	L	C	p		
Thiodia citrana (HBN.)	L	I	C	o		
Celypha rufana SCOPOLI.	L	R	C	o		
Cochylidia implicitana WCK.	L	H,S	C	o		
Aethes margaritana HAWORTH	L	H	C	o		
Pyralidae						
Ostrinia nubilalis HBN.	L	S	C	p	!	*
Homoeosoma nimbella DUPONCHEL	L	I	C	p		
Homoeosoma nebulella DENIS & SCHIFF.	L	H	C	o		
Phycitodes carlinella HEINEMANN	L	I,S	C	o		
Phycitodes binaevella HBN.	L	H	C	o		
Phycitodes sp.	L	I	C	o?		*
Gelechiidae						
Isophrictis striatella DENIS & SCHIFF.	L	H,S	C	o		***
Oecophoridae						
Depressaria emeritella STT.	L	L	C	ml		***
Pterophoridae						
Platyptilia ochrodactyla DENIS & SCHIFF.	L	S,L	C,(M)	ml		***
Platyptilia pallidactyla HAWORTH	L	S,L	C	o		
Leioptilus lienigianus Z.	L	L	C	o		
Noctuidae						
Cucullia tanaceti (DENIS & SCHIFF.)	L	L	C	o		
Melanchra persicariae (L.)	L	L	C	p		
Autographa gamma L.	L	L	C	p		*
Phlogophora meticulosa (L.)	L	L	C	p		*

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Taxa	Devel. stage	Plant part	Feed. mode	Speci-ficity	New host	Bonn area
Geometridae						
Thetidia smaragdaria (F.)	L	I,L	C	o		
Thalera fimbrialis (SCOPOLI)	L	L	C	p		*
Rhodostrophia vibicaria (CLERCK)	L	L	C	p		
Eupithecia succenturiata (L.)	L	I,L	C	o		
Eupithecia icterata (DE VILLERS)	L	I,L	C	o		*
Eupithecia absinthiata (CLERCK)	L	I,L	C	p		
Eupithecia subfuscata (HAWORTH)	L	I,L	C	p		
Eupithecia centaureatata (DENIS & SCHIFF.)	L	I,L	C	p		**
Gymnoscelis rufifasciata (HAWORTH)	L	I	C	p		
Chloroclystis v-ata (HAWORTH)	L	I	C	p		
Yezognophos serotinarius (DENIS & SCHIFF.)	L	L	C	p		
DIPTERA						
Cecidomyiidae						
Rhopalomyia tanaceticola (KARSCH)	L	H,S,L	C,G	o		**
Ozirhincus tanaceti (KFFR.)	L	F	C,G	ml		***
Contarinia tanaceti RÜBS.	L	H	C,G	ml		
Lasioptera "sp. n." [9]	L	L	C,G	?	!	**
Tephritidae						
Trypeta zoe MEIGEN	L	L	C,M	o		*
Trypeta artemisiae (F.)	L	L	C,M	o		*
Urophora stigma (LOEW)	L	H	C	o		
Tephritis cf. *tanaceti* (HERING)	L	H	C	o?		
Tephritis neesii (MEIGEN)	L	H	C	o?		
Agromyzidae						
Melanagromyza "sp. n." [10]	L	S	C	ml	!	**
Ophiomyia paramaura PAKALNISKIS	L	S	C	o		*
Liriomyza tanaceti DE MEIJ.	L	L	C,M	o		**
Liriomyza strigata (MEIGEN)	L	L	C,M	p		**
Liriomyza sp. [11]	L	L	C,M	?	!	**
Napomyza cf. *achilleanella* (VON TSCHIRNHAUS) [12]	L	H	C	o		?*
Chromatomyia horticola (GOUREAU) [13]	L	L	C,M	p		?**
Chromatomyia syngenesiae HARDY [13]	L	L	C,M	o		?**
Phytomyza tanaceti HENDEL	L	L	C,M	o		***
Phytomyza pullula ZETTERSTEDT	L	L	C,M	o		

The complex of phytophagous insects in Central Europe encompasses 143 species in 8 orders, 30 families and 88 genera. The Lepidoptera show the strongest representation with 44 species. They are followed by the Heteroptera (27 species), Coleoptera (25), Diptera (19) and Homoptera (19). An average of 1.63 species fall into a single genus. Showing a large number of species are the genera *Dichrorampha* (Lep., Tortricidae) with 8, *Eupithecia* (Lep., Geometridae) with 5, and *Coleophora* (Lep., Coleophoridae), *Cassida* (Col., Crysomelidae), *Mordellistena* (Col., Mordellidae) and *Liriomyza* (Dip., Agromyzidae) each with 4 species.

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3.1.2. Host specificity

The taxa represented in the complex are distributed across the different levels of host specificity as shown in Table 2 (see Table 1 for an explanation of the levels of host specificity):

Table 2. Host specificity (in numbers of species) of different taxa included in the complex of phytophagous insects on *Tanacetum vulgare*. See Table 1 for abbreviation definitions.

Taxa	m1	o	p	Status ?	Total
Eriophyoidea	1				1
Collembola			1		1
Auchenorrhyncha			6	1	7
Sternorrhyncha	6	7	6		19
Heteroptera	2	7	18		27
Coleoptera	3	14	8		25
"Microlepidoptera"	4	21	4		29
"Macrolepidoptera"		4	11		15
Nematocera	2	1		1	4
Brachycera	1	10	3	1	15
Total	19	64	57	3	143

The oligophagous insects make up the greatest percentage with 44.8%, followed by the polyphagous insects with 39.9% and the monophagous insects with 13.3%. No second degree monophagous insects ("m2"), i.e. those which infest more than one species within a plant genus, were found within the herbivore spectrum on *T. vulgare*.
The Eriophyoidea and Nematocera (only Cecidomyiidae) demonstrate the greatest degree of host specificity, followed by the Coleoptera, "Microlepidoptera", Brachycera (particularly Agromyzidae) and Sternorrhyncha. The Auchenorrhyncha, Heteroptera and "Macrolepidoptera" prove to be relatively euryphagous.

3.1.3. Phytophagous developmental stage, feeding mode and niche occupation

Larval development on *T. vulgare* was observed for 133 species (93.0%). Seventy of these species feed on the plant exclusively in the larval stage (primarily Holometabola) and 63 as imagines and larvae. Ten species (7.0%) have been found on the plant only as imagines up to now (Heteroptera, Chrysomelidae, Curculionidae).
Roughly two-thirds of the species chew on the plant tissue (Table 3). This group also includes the "grating" Brachycera larvae and Cecidomyiidae larvae. The remaining one-third of the species suck on the plant sap and can, according to KUNKEL (1967), be divided into two main groups: tissue-sucking local bibitors or parenchyma-bibitors and vascular system-sucking types (= phloem and xylem bibitors). Phloem bibitors and local bibitors are represented fairly equally, and together they make up the majority of the sap-sucking insects. In contrast, the xylem bibitors are represented by only a few species (Cercopidae).

DOI: 10.21248/contrib.entomol.48.1.219-235

Table 3. Feeding modes of the phytophagous insects on *Tanacetum vulgare* (in numbers of species).

Feeding mode	No. species	%
Suckers		
Local bibitor (incl. parenchyma bibitor)	28	19.6
Phloem bibitor	23	16.1
Xylem bibitor	3	2.1
Chewers (incl. "grating" insects)	89	62.2

Table 4 shows the spatial and nutritional niche occupation of the phytophagous insects on *T. vulgare*. All organs of the host plant are utilized. Fifty-one species, or 35% of all species, exist on the plant endophytically (excluding species whose larvae mine from the outside, such as the Coleophoridae). The leaves and stems are used by well over half of the species. Twenty-two species of sap-sucking insects are found in the inflorescence or flower buds. A total of twelve species of leaf miners (primarily Agromyzidae) and 7 species of gall-inducers (particularly Cecidomyiidae) are represented.

Table 4. Feeding modes and infested plant organs of the phytophagous insects of *Tanacetum vulgare*.

	Ectophytic			Endophytic*		
	Chewers	Suckers Local bibitors	System bibitors	Mines	Galls	Total
Flower/fruit (excl.)					1	**1**
Flowerbud	2	5		11	2	**20**
Inflorescence	12	21	1			**34**
Leaf and bud	38	22	18	13	2**	**93**
Stem	1	22	16	16	1	**56**
Rootstock/rhizome	7		3	11	2	**23**

* Only chewers, except *Philaenus spumarius*
** Incl. one "open" gall by *Philaenus spumarius*

3.1.4. New host records for *T. vulgare*

A total of 77 species was observed on the host plant in the greater Bonn region. Twenty-five of those were not found in the literature to be feeders on *T. vulgare* ("!" in Table 1). The oligophagous and polyphagous Heteroptera in this group represent the greatest number with 12 species. In this context, particular emphasis is placed on "new" host records of endophytic species, such as stem and leaf miners:
Using a stem eclector method, four species of oligophagous *Mordellistena* (Col., Mordellidae) were collected which have never been cited before for *T. vulgare* (see SCHMITZ, 1995a). *M. bicoloripilosa* is the most frequent species from this genus (42 individuals reared from 986 stems). *M. acuticollis* is found in the stems of *T. vulgare* in rare cases (14 individuals reared). The other two species appear to be random inhabitants in the stems (1 individual of each species). The polyphagous European corn borer *Ostrinia nubilalis* (Lep., Pyralidae) is a similarly rare stem miner on *T. vulgare*. Only one individual was reared from a total of 2704 stems.

DOI: 10.21248/contrib.entomol.48.1.219-235

Several individuals of a totally new species of *Melanagromyza* (Dip., Agromyzidae) (TSCHIRNHAUS, personal communication 1995) were reared from stems collected from the outskirts of the city of Bonn.
Analysis of the leaf mines and their larvae yielded evidence of a *Liriomyza* species (Agromyzidae) whose larval morphology does not agree with that of *L. tanaceti* specified for *T. vulgare* (DE MEIJERE, 1925) and is possibly identical to *Liriomyza artemisicola* DE MEIJERE appearing on *Artemisia vulgaris*. The identity of a gall midge larvae (Dip., Cecidomyiidae) living in small, irregular gall-like leaf mines has also remained unresolved up to now (cf. BUHR 1965). Reared individuals probably belong to a new *Lasioptera* species (MEYER, personal communication, 1997).

3.2. *T. vulgare* as a host plant for pest insects

The list in Table 1 contains several species which are considered to be pests in agricultural areas (e.g. SORAUER, 1913; FRÖHLICH, 1991): Sminthuridae, *Aphrodes* spp., *Philaenus spumarius*, *Brachycaudus helichrysi*, *Brachycaudus cardui*, *Aulacorthum solani*, *Macrosiphum euphorbiae*, *Aphis fabae*, *Lygocoris* spp., *Lygus* spp., *Galeruca tanaceti*, *Cnephasia chrysanthaena*, *Ostrinia nubilalis*, *Autographa gamma*, *Liriomyza strigata*, *Chromatomyia horticola* and/or *Chromatomyia syngenesiae*.
Some economically problematic species (e.g. *Aulacorthum solani*, *Ostrinia nubilalis*) were only found on *T. vulgare* in rare cases, while there were others which were comparatively common on the plant (*Aphrodes* spp., *Philaemus spumarius*, *Cnephasia chrysanthaena*) but are not considered to be serious pests. The plant-suckers *Brachycaudus helichrysi*, *Macrosiphum euphorbiae*, *Lygocoris* spp. and *Lygus* spp. were found frequently and are also of greater economic relevance.

3.3. Potential candidates for biological weed control in North America

The use of root-eating species has repeatedly proven effective for combating perennial weeds. Unfortunately, the preliminary studies on these insect species are more complicated to conduct than those on leaf-eating species (HARRIS, 1991). The use of fruit-eating species which reduce the number of diaspores would also be conceivable for the control of weeds whose ability to spread is primarily due to non-vegetative mechanisms (cf. JULIEN, 1982).
Additional data on the biology and on the results obtained in this study are provided for several host-specific species from the list of phytophagous insects, which represent possible candidates for programs of biological weed control.

a) *Phytoecia nigricornis julii* (Col., Cerambycidae) lives strictly monophagously in the rootstocks of *T. vulgare* (KOCH, 1992) and consumes the medulla of larger rootstocks. The gallery it bores is closed towards the top, near the surface of the earth, by a plug of accumulated chewing remains which offers protection during hibernation when stems break off and also in the event of flooding. This species showed a relatively high occurrence in the rural areas of the study region, particularly on old and somewhat drier sites.
b) The *Dichrorampha* spp. larvae (Lep., Tortricidae), also found on the rootstocks of *T. vulgare*, were primarily located in the bark and were usually separated from the outside by a thin skin. It was not determined which of the eight species cited for the plant were represented, but larvae were found on many rural and urban sites and, in most cases, there were several individuals in a single rootstock.

DOI: 10.21248/contrib.entomol.48.1.219-235

c) Some of the weevil species specified for *T. vulgare* do feed on the roots as larvae, but they exclusively represent the oligophagous and polyphagous species. *Microplontus millefolii*, whose larvae live in the stem, is the only monophagous species cited (DIECKMANN, 1972). None of the Curculionidae larvae and only a few imagines were found during the study period.

d) *Isophrictis striatella* (Lep., Gelechiidae) lays its eggs in the flowerbuds of *T. vulgare*. The larvae live in the base of the flowerbuds up to the fourth larval instar, and then leave in Autumn in order to bore into the stem further below. They spend the winter as larvae in the stem (HAUS, 1991). The damage the species causes to *T. vulgare* is primarily limited to the base of the flowerbuds, including the achenes. *Isophrictis striatella* was a common species in the study region, inhabiting sunny locations.

e) *Pterophora ochrodactyla* (Lep., Pterophoridae) lives exclusively on *T. vulgare*. The larvae are found in spring in the young shoots and can be located by the black excrement which they push to the outside (cf. SCHÜTZE, 1931). This species inhabited various, preferably dry wastelands in the Bonn region. Some of the patches of *T. vulgare* studied showed a distinct decrease in vitality and, in some cases, complete destruction of the infested shoots.

f) The monophagous *Ozirhincus tanaceti* (Dip., Cecidomyiidae) lives as a gall-inducer in the achenes of *T. vulgare* (BUHR, 1965). This species is very common in the study region and was present at nearly every site.

4. Discussion

4.1. Completeness of the phytophagous complex list

As regards the monophagous species, the species listed in Table 1 probably reflect the complete range of insects. In contrast, however, more expansive study could be expected to reveal additional oligophagous or polyphagous species. For example, "new" species could be found in the following arthropod groups: Tetranychidae, Orthoptera, Auchenorrhyncha (e.g. Cicadellidae), Heteroptera, polyphagous Curculionidae (e.g. Otiorhynchus), Elateridae (e.g. Agriotes), polyphagous Noctuidae (e.g. Agrotinae), Tipulidae (e.g. *Tipula*) and Bibionidae (e.g. *Bibio*). The Thysanoptera species collected from *T. vulgare* up to now are not considered to be phytophagous on this plant (ZUR STRASSEN, personal communication, 1995).

4.2. Characterization of the phytophagous complex

The phytophagous complex of *T. vulgare* appears to be relatively diverse with 143 species. Although it must be taken into consideration that the total numbers of species indicated in the literature for specific plant species are based on different calculation methods and study areas, it is clear that the figures cited here for *T. vulgare* fall in the high range for perennial herbs: SCHMITZ (1996): 181 species on *Artemisia vulgaris*, ZWÖLFER (1965): 139 species on *Cirsium arvense*, BATRA et al. (1987): 120 species on *Lythrum salicaria*; DAVIS (1983): 81 species on *Urtica dioica*, DREYER & KIRSCH (1987): 63 species on *Filipendula ulmaria*; KOCK (1966): 32 species on *Linaria vulgaris*. The number of species on *T. vulgare* thus clearly approaches that of many shrubs or trees (KENNEDY & SOUTHWOOD 1984: e.g. 141 species on *Alnus glutinosa* in Great Britain).

The absence of species which also occur on other *Tanacetum* species in addition to *T. vulgare* may be explained by the fact that the two other indigenous species, *T. alpinum* (L.) Schulz-Bip. and *T. corymbosum* (L.) Schulz-Bip., have a limited range and have therefore hardly been

DOI: 10.21248/contrib.entomol.48.1.219-235

studied with regard to their phytophagous insects. In an analysis of these plant species, some arthropod species which were previously considered to be first degree monophagous herbivores would possibly be categorized as second degree monophagous herbivores.
If it is assumed that the percentage of 13.3% strictly monophagous species determined here reflects real conditions (even after further studies on other *Tanacetum* species), then this figure would be comparable to that of other hemicryptophytes indicated to be indigenous to Central Europe. For example, ZWÖLFER (1965) showed 6.5% for *Cirsium arvense*, BATRA et al. (1986) 11.3% for *Lythrum salicaria*, SCHMITZ (1996) 14.9% for *Artemisia vulgaris*, KOCK (1966) 18.8% for *Linaria vulgaris*, DREYER & KIRSCH (1987) 31.7% for *Filipendula ulmaria*, and DAVIS (1983) 38.3% for *Urtica dioica*. Due to the fact that it has not yet been definitively resolved whether *T. vulgare* is indigenous or archeophytic (LOHMEYER & SUKOPP, 1992), the high number of species and the high percentage of monophagous species as shown by KENNEDY & SOUTHWOOD (1984) and ZWÖLFER (1982) may indicate that *T. vulgare* is indigenous to Central Europe, or at least that there was probably a contiguous link to the original distribution areas in eastern Europe and in Asia.

4.3. *T. vulgare* as a host for insect pests

Of the species living on *T. vulgare*, some of the polyphagous insects are known as agricultural pests, but only a few of them are both abundant on *T. vulgare* and included among the more serious pests. The positive effects which the presence of *T. vulgare* on field ridges has on agricultural production may be expected to outweigh the negative effects. Thus, *Tanacetum* stands on field ridges should continue to be preserved.

4.4. Candidates for the biological control of *T. vulgare* in North America

Several species of the phytophagous complex should be subjected to more in-depth studies of host specificity, feeding location and effectiveness, life cycle and dependence on climatic conditions.
Of the root inhabitants, primarily the genus *Dichrorampha* should be analyzed for suitable candidates. It may be assumed that the peripheral feeding pattern in the rootstocks is more damaging than the feeding of the Cerambycid beetle, *Phytoecia nigricornis julii*, whose larvae live in the medulla.
The *Dichrorampha* group is restricted to the Anthemideae (BRADLEY et al. 1979). Further study of the host range of this Tortricoid-genus, including Eastern Europe, is indicated.
The question as to whether the stem-mining, strictly monophagous weevil *Microplontus millefolii* is suitable for biological control must also be investigated. The species was not observed in the Bonn region in this study.
Observations in the Bonn region showed that although the highly present and abundant species *Isophrictis striatella* and *Ozirhincus tanaceti* are hardly capable of reducing the vitality of the plants, they do reduce the number of diaspores because they inhabit the flowerbuds and achenes. However, the question as to whether this reduction has an effect on the spreading of the plant must be thoroughly investigated.
According to observations to date, *Pterophora ochrodactyla* (Pterophoridae) is probably the most suitable candidate, due to the fact that feeding is already evident in the fresh shoots early in the year, which leads to a distinct weakening of the plant. Therefore, detailed study of the life style and habitat dependence of the species is strongly recommended.

DOI: 10.21248/contrib.entomol.48.1.219-235

Acknowledgments

I am indebted to the following specialists for their work in reviewing the species list, in which particular emphasis was placed on the biological data: H. BECK (Mainz): "Macrolepidoptera"; L. BEHNE (Eberswalde): Curculionidae; W. BIESENBAUM (Velbert-Langenberg): "Microlepidoptera"; H. JÜNGLING (Esslingen): "Macrolepidoptera"; Prof. B. KLAUSNITZER (Dresden): Coleoptera; Prof. G. LAMPEL (Freiburg/Switzerland): Aphidina; Dr. H. MEYER (Kiel): Cecidomyiidae; Dr. S. MEYER-ARNDT (Heidenrod-Dickschied) and Prof. R. REMANE (Marburg): Auchenorrhyncha; Dr. J. SCHIESSKE (Hamburg): Eriophyoidea; W. STEINHAUSEN (Munich): Chrysomelidae; Dr. M. v. TSCHIRNHAUS (Bielefeld): Agromyzidae; Dr. E. WOLFRAM (Mainaschaff): Heteroptera. I would also like to thank M. ONOFRIETTO (Warren, NJ) for her assistance with the translation.

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DOI: 10.21248/contrib.entomol.48.1.219-235