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Larvae of the Genus *Thrips* – Morphological Features in Taxonomy

H. KUCHARCZYK

Department of Zoology, Maria Curie-Skłodowska University,
Akademicka 19, 20-033 Lublin, Poland, e-mail: hkucharc@biotop.umcs.lublin.pl

Numerical analyses of ten species of larvae of the genus *Thrips (angusticeps, atratus, fuscipennis, major, minutissimus, physapus, tabaci, trehernei, validus, vulgatissimus)* and larvae of *Taeniothrips picipes* were performed using 24 qualitative morphological characters. Classification of OTUs was performed using Cluster Analysis and Correspondence Analysis, which form the measure between particular OTUs. The used analyses have proved that the most important features for distinguishing the taxa are connected with the sclerotisation of the head, thorax and the end of the abdomen as well as the sculpture of body parts.

Keywords: *Thrips,* larvae, morphology, numerical taxonomy.

The genus *Thrips* L. is one of the largest groups of the *Thysanoptera* that apparently evolved in the Old World. Among the approximately 275 known *Thrips* species only 61 are recorded from the New World, and 62 are noted in Europe (Nakahara, 1994; zur Strassen, 1997). As the knowledge about the genus had grown with the discovery of new species and finding new morphological features, the revision of its taxonomy became inevitable. The species of this genus are defined by a significant feature: the presence of the abdominal ctenidia (Mound, 2002). This character was, despite the 8-segment antennae typical of the *Taeniothrips* species, the basis for some revision of the genus *Taeniothrips* and the transfer of some of its species to the genus *Thrips* (zur Strassen, 1997).

While in the adult stages the morphological features are well defined, identifying the larval stages is a more difficult task because the taxonomy of thrips larvae is poorly developed (Nakahara and Vierbergen, 1998). During the faunistic and ecological research very often the preimaginal stages of thrips are collected, sometimes they are more numerous than the adults. Because currently the larvae of only a few species can be identified, the majority of the analyses of the collected material are usually based on adult stages only. So far, the larvae of European *Thrips* and *Taeniothrips* genera can be identified using Speyer and Parr (1941) and Priesner (1964) keys. Some data can be found in the papers of Kirk (1987) and Miyazaki and Kudo (1986).

The aim of starting the studies is to find which morphological qualitative and quantitative characters are the most important in recognising the second instar larvae of the *Thrips* species in Poland, and which features differentiate the two genera *Thrips* and *Taeniothrips.* This paper presents part of the work and contains the analysis of the qualitative features only for a few, but frequently and numerously found polyphagous *Thrips* species *(angusticeps, atratus, fuscipennis, major, minutissimus, physapus, tabaci, trehernei, validus, vulgatissimus)* and, for comparison, the analysis of the larva of *Taeniothrips picipes.*

Material and Methods

The material used in the work has come from I. Zawirska's and my own collections. It consisted of 48 specimens representing the larvae of polyphagous *Thrips* species *(angusticeps, atratus, fuscipennis, major, minutissimus, physapus, tabaci, trehernei, validus, vulgatissimus)* and the larvae of *Taeniothrips picipes.* The specimens were collected in different stations in Poland, as a rule from their host plants, where they were found together with the adults *(Table 1).* All specimens were studied using light microscope Olympus Provis.

Specimens of particular species were treated as operational taxonomic units (OTUs) and each of them was described with the use of 24 morphological characters comprising mostly the sclerotisation and sculpture of body parts. The characters were selected and the terminology was used after Speyer and Parr (1941), Priesner (1964), Nakahara and Vierbergen (1998) and observed by the author. The characters selected include binary characters (7, 19, 22, 23) and multistate discontinuous characters – the rest *(Table 2).*

The following numerical analyses were carried out: Cluster Analysis in which the classification of OTUs was performed using Ward's minimum variance cluster method, based on City block Manhattan *(Fig. 1);* and Correspondence Analysis ordinating the OTUs in a multidimensional space *(Figs 2 and 3).* All numerical calculations were made using the statistical package Statistica 6.0 (StatSoft, Inc., 1984–95).

Results

Cluster analysis

Classification of all the analysed specimens was based on 24 morphological features *(Table 2).* Cluster analysis preliminarily divided all OTUs into two main clusters *(Fig. 1).* The right one includes together three species: *Th. angusticeps, Th. minutissimus* and *Th. validus,* which could suggest their phenetic relationships. The most visible morphological characters in this group of species are the strong chitinisations of the head, thorax and the end of the abdomen.

The left main cluster consists of several subclusters comprising most of the analysed OTUs. The extreme tree is composed of specimens of two species: *Thrips tabaci* – only one among analysed species, deprived of the spiracles on the 2nd abdominal segment, and *Taeniothrips picipes.* For both of those species the presence of the sternal oval brown area on the 11th segment is characteristic. The next subcluster is differentiated according to the sclerotisation and sculpture of the body. In the case of the species belonging to the left tree a characteristic feature is insignificant sclerotisation and body sculpture. The right tree consists of three species: two transferred during the taxonomic revision from the genus

Table 1

List of the specimens used in numerical analyses

Species	No.	Locality	Host	Date of collecting	Collection
Th. validus	1	Warsaw	*Galinsoga parviflora* Cav.	14.08.2000	H. Kucharczyk
Th. validus	2	Augustów	Wet meadow	29.05.1988	I. Zawirska
Th. validus	3	Lublin	*Picris hieracioides* L.	21.06.2002	H. Kucharczyk
Th. validus	4	Lublin	*Hieracium* sp.	01.10.2001	H. Kucharczyk
Th. angusticeps	5	Działdowo	*Triticum aestivum* L.	07.2001	H. Kucharczyk
Th. angusticeps	6	Kościerzyna	*Triticum aestivum* L.	07.2001	H. Kucharczyk
Th. angusticeps	7	Radziejów	*Triticum aestivum* L.	07.2002	H. Kucharczyk
Th. angusticeps	8	Pińczów	*Triticum aestivum* L.	07.2002	H. Kucharczyk
Th. atratus	10	Rowokół	*Dianthus deltoides* L.	26.07.2001	I. Zawirska
Th. atratus	11	Pruszków	*Dianthus* sp.	01.07.1967	I. Zawirska
Th. atratus	12	Puławy	*Linaria vulgaris* Mill.	03.08.1993	I. Zawirska
Th. atratus	9, 13	Lublin	*Melandrium album* (Mill.) Garcke	21.09.2001	H. Kucharczyk
Th. atratus	31	Wojszyn	*Centhaurea scabiosa* L.	31.07.1997	H. Kucharczyk
Th. vulgatissimus	14	Wysowa	*Anthyllis vulneraria* L.	07.07.1995	H. Kucharczyk
Th. vulgatissimus	15	Tatra Mts.	*Phyteuma spicatum* L.	07.07.1994	H. Kucharczyk
Th. vulgatissimus	16, 17	Smołdzino	*Lupinus* sp.	01.07.2001	I. Zawirska
Tae. picipes	18	Tatra Mts.	*Phyteuma spicatum* L.	09.07.1994	H. Kucharczyk
Tae. picipes	19, 20	Smołdzino	*Galium* sp.	29.06.2002	I. Zawirska
Tae. picipes	21, 22	Smołdzino	*Calluna vulgaris* (L.) Hull	29.06.2001	I. Zawirska
Tae. picipes	23	Smołdzino	*Melampyrum* sp.	29.06.2001	I. Zawirska
Th. physapus	24, 25	Skowronno	*Centhaurea stoebe* L.	07.08.1991	I. Zawirska
Th. physapus	26	unknown	*Carex* sp.	23.06.1987	I. Zawirska
Th. physapus	27	Smołdzino	net sample	15.06.2001	I. Zawirska
Th. trehernei	28	Izbica	*Picris hieracioides* L.	15.07.1985	I. Zawirska
Th. trehernei	29, 30	Puławy	*Tragopogon pratensis* L.	22.07.1993	I. Zawirska
Th. fuscipennis	32, 33	Lublin	*Solidago gigantea* Aiton	22.06.2002	H. Kucharczyk
Th. major	34	Hanna	*Sanguisorba officinalis* L.	27.07.2002	H. Kucharczyk
Th. major	35	Dołhobrody	*Galium uliginosum* L.	16.07.2002	H. Kucharczyk
Th. major	36	Księżomierz	*Ranunculus repens* L.	20.05.2000	H. Kucharczyk
Th. major	37	Lublin	*Urtica dioica* L.	17.07.2002	H. Kucharczyk
Th. minutissimus	38, 39	Zawadówka	*Quercus robour* L.	22.05.1998	H. Kucharczyk
Th. minutissimus	40	Żmudź	*Juniperus comunis* L.	30.05.1998	H. Kucharczyk
Th. tabaci	41	Ożarów	*Allium porrum* L.	20.07.1999	H. Kucharczyk
Th. tabaci	42	Sarny	*Nicotiana tabacum* L.	01.07.1976	I. Zawirska
Th. tabaci	43	Izbica	net sample	15.07.1986	I. Zawirska
Th. tabaci	44	Lublin	*Dianthus* sp.	19.08.2002	H. Kucharczyk
Th. brevicornis	45, 46	Iwonicz	*Eupatorium cannabinum* L.	18.08.2000	H. Kucharczyk
Th. flavus	47, 48	Łoiny	net sample	26.05.2001	H. Kucharczyk

Taeniothrips (*atratus* and *vulgatissimus*), and *Th. trehernei.* For all of them, the presence of small chitinised spots on the head and prothorax is characteristic. The specimens of *Th. atratus* and *Th. vulgatissimus* are characterised by rather long processes on the posterior margin of the 9th abdomen segment.

Table 2

Characters, acronyms and character states used in the numerical analyses

No.	Character	Acronym	Character states
1.	head spots	HSPOT	0 – without or very pale; 1 – only 1 long spot on frons; 2 – a spot on frons and small grey spots on cheeks; 3 – a spot on frons and big grey-brownish spots along the cheeks
2.	pronotum spots	PRSPOT	0 – without; 1 – few small spots; 2 – one big and a few small spots; 3 – two large spots along pronotum
3.	mesonotum spots	MSSPOT	0 – without; 1 – one or two pairs of small spots; 2 – one pair of big spots; 3 – two pairs of big distinct spots
4.	metanotum spots	MTSPOT	0 – without; 1 – one pair of small spots; 2 – one pair of distinct spots; 3 – two pairs of distinct spots
5.	sclerotisation of tergite 9	T9SCL	0 – without; 1 – less than half the area; 2 – more than half the area
6.	sclerotisation of tergite 10	T10SCL	0 – without; 1 – less than half the area; 2 – more than half the area
7.	sclerotisation of sternite 11	S11SCL	0 – without; 1 – with 1 small long spot
8.	posteromarginal comb on 9th segment	T9COMB	0 – without; 1 – short, irregular; 2 – short, regular; 3 – long and strong
9.	length of teeth in the posteromarginal comb	LCOMB	1 – < 2.5μm; 2 – 2.5–5 μm; 3 – 5–7.5 μm; 4 – > 7.5 μm
10	range of the comb	WCOMB	0 – only dorsally; 1 – dorsally and partially ventrally; 2 – dorsally and ventrally
11.	pronotum sculpture	PRSCP	0 – without; 1 – on the posterior margin without microtrichia; 2 – on the posterior margin with microtrichia;
12.	mesonotum sculpture	MSSCP	0 – without; 1 – on the anterior margin without microtrichia; 2 – on the anterior margin with microtrichia
13.	metanotum sculpture	MTSCP	0 – without; 1 – plaques without microtrichia; 2 – plaques with microtrichia; 3 – only microtrichia
14.	sculpture of tergites 1–7	T1-7SC	0 – without plaques; only microtrichia; 1 – plaques without microtrichia; 2 – plaques with microtrichia only laterally; 3 – plaques with microtrichia in the anterior part; 4 – plaques with microtrichia in area of the segments
15.	sculpture of sternites 1–7	S1-7SC	0 – without plaques; only microtrichia; 1 – plaques without microtrichia; 2 – plaques with microtrichia only laterally; 3 – plaques with microtrichia in the anterior part; 4 – plaques with microtrichia in area of the segments
16.	sculpture of tergite 8	T8SCP	0 – without plaques; only microtrichia; 1 – plaques without microtrichia; 2 – plaques with microtrichia only laterally; 3 – plaques with microtrichia in the anterior part; 4 – plaques with microtrichia in area of the segments
17.	sculpture of tergite 9	T9SCP	0 – without; 1 – small unclear processes all over the area; 2 – strong distinct processes all over the area
18.	sculpture of tergite 10	T10SCP	0 – without; 1 – small unclear processes all over the area; 2 – strong distinct processes all over the area
19.	trochantin	COXAT	0 – absent; 1 – present; 2 – present; strongly chitinised;
20.	spiracles on 2nd abdominal segment	AT2SP	0 – absent; 1 – present;
21.	number of peritremes in spiracle	NOOFP	0 – 3, 4; 1 – 5, 6; 2 – 7, 8
22.	antennal segment 3 microtrichia	ANS3MT	0 – absent; 1 – only in two rows; 2 – in all rows
23.	shape of the abdominal setae	TSETA	1 – acute at the tip; 2 – blunt at the tip
24.	furca on meso- and metasternum	FURCA	0 – absent; 1 – present

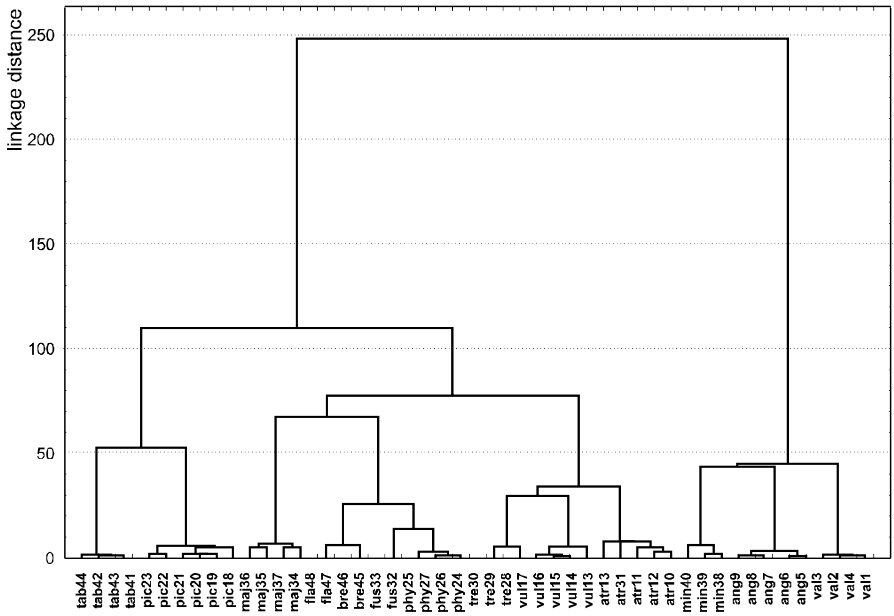

Fig. 1. Cluster analysis of 48 *Thrips* sp. OTUs. Ward's method of classification and City-block distance based on characters listed in *Table 2*

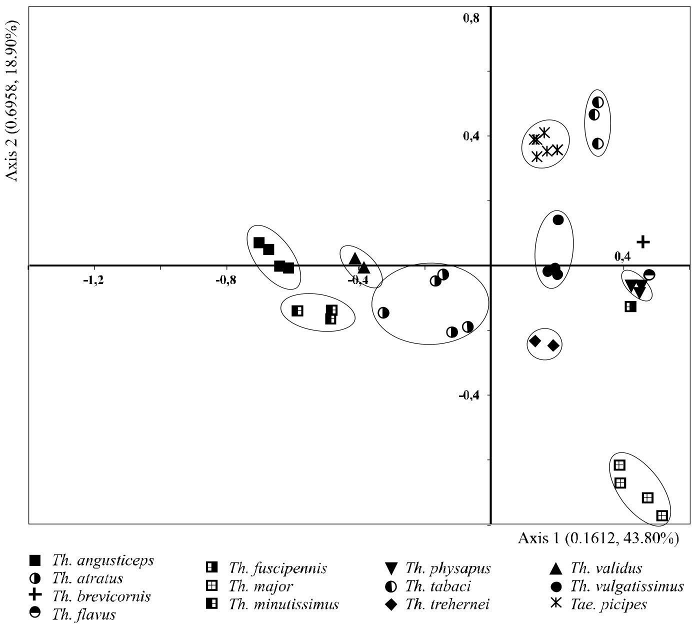

Fig. 2. Correspondence analysis – ordination of *Thrips* genus species as OTUs along first and second axis

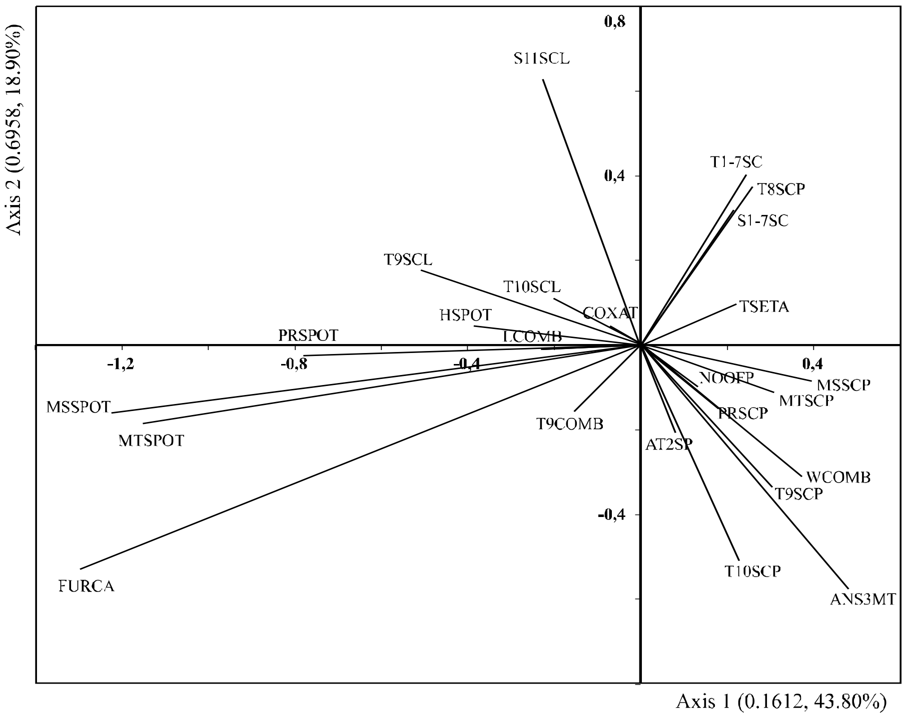

Fig. 3. Correspondence analysis – diagram of qualitative characters along first and second axis

Correspondence analysis

It was used for finding which qualitative characters are the most important for distinguishing the taxa. The first two axes accounted for 62.7% of the total variability of the data *(Fig. 2).* The most reliable qualitative characters were the sclerotised spots on the head and thorax, the sclerotisation of the end segments of the abdomen and the sculpture of the meso- and metanotum. These features conditioned the arrangement of OTUs along the length of axis 1. The features that arrange the specimens along the length of axis 2 are the sculpture of the tergal and sternal parts of the abdomen and the presence of spiracles on the 2nd abdominal segment *(Figs 2* and *3, Table 2).*

The species with stronger sclerotisation *(angusticeps, minutissimus, validus, atratus)* are situated on the left side of axis 2. This group consists of species with relatively long processes on the posterior end of the 9th segment and strong sclerotisation of the 9th and the 10th abdominal segments. Among the analysed *Thrips* species furca (observed on thoracic sternal segments) is characteristic of *Thrips minutissimus* only *(Figs 2* and *3).*

Most of the analysed species are grouped on the right of axis 2 *(Fig. 3).* They are more differentiated, with the sclerotisation in the form of a pale spot on the head only or on the head and prothorax, and a narrow band on the end of abdomen. *Th. major* characterised by minute sculpture with long microtrichia on the body is clearly separated. *Th. tabaci* and *Taeniothrips picipes* are well separated, too. The first is the only one among the analysed species without the spiracles on the 2nd abdominal segment. Both these species are characterised by significant sculpture with microtrichia on tergites and sternites of the abdomen and the presence of chitinised spot on the sternal part of the 11th segment.

Discussion

Most contemporarily published papers both in botany and zoology use numerical analyses for finding the phylogenetic relationships among different taxa. This kind of research is possible in well-known groups, and more often is based on the morphological, molecular, genetic, and behavioural features of the adult stages (Arambarri, 2000; Chiapella, 2000; Miranda-Esquivel, 2001; Morris et al., 2001, 2002; Mound, 2002). *Thrips,* especially their preimaginal instars, are rather poorly known. The aim of using the common numerical analyses in the presented preliminary research on the larvae of the genus *Thrips* was to find the distinct morphological features which help identify the 2nd instar larvae collected during faunistic and ecological research. The analyses were based on the qualitative features only.

The Speyer and Parr key (1941) is useful for determining 12 species of the genus *Thrips,* 9 of them are the same as the species analysed in the presented paper. The authors use the qualitative and quantitative characters, in the first kind of features most them are the same as in the presented paper, e.g. sclerotisation and sculpture of body parts, length of processes on the 9th abdominal segment, shape of setae, the other class of features consists of the length of abdominal setae. The first step in determining *Thrips* species in using the Speyer and Parr key is the sclerotisation of the 9th and 10th segments. The same characters are used by Nakahara and Vierbergen (1998) in their key for *Frankliniella* species and by Kirk (1987) for determining common Australian flower thrips.

Using the Priesner's key (1964) we can determine 24 *Thrips* species. The first step for differentiating the species is the kind of the comb on the posterior part of the 9th segment of the abdomen. Only *Th. calcaratus* was classified to the group with a very long and irregular comb similar to that of *Taeniothrips inconsequens* and some of *Odontothrips* species. The other species of the genus *Thrips* are classified to the group without a comb or with a comb consisting of short processes. The next step is the character of body sculpture; only *Th. major* and *Th. albopilosus* were classified to the species without visible sculpture. For the other species the main distinctive feature is meso- and metanotum sclerotisation and the next steps are connected with features of body colour, sculpture and the quantitative features, e.g. the length of antenna and its segments, the length of the thorax and abdominal setae, and the width of the head.

In the presented paper only qualitative features were used for differentiating the chosen *Thrips* species. On *Fig. 2,* which illustrates the results of correspondence analysis we can see that the features of head and thorax sclerotisation receive a higher value than the sclerotisation of the end of the abdomen. It seems that these features are the most important in distinguishing the analysed species. In cluster analysis these characters divided the analysed species into two main clusters: one containing species with strong and extent sclerotisation of the head and thorax *(angusticeps, minutisimus, validus)* and the other without or with pale sclerotisation (rest of the species) *(Fig. 1).* In order to obtain results, the next step in distinguishing the species is to compare the sculpture of their integument (second main cluster). The other features chosen in these analyses may be used afterwards.

In studying the larvae of the genus *Thrips* I have found features not used before in the existing keys for *Thrips* larvae, e.g. furca on the sternites of thorax, the number of rows of microtrichia on the 3rd segment of the antenna and the presence of oval spot on the sternal part of the 11th segment. The last feature is present in species from different genera, it was used in the key for *Frankliniella* species (Nakahara and Vierbergen, 1998) and in my observations was characteristic of a few *Thrips* species: *angusticeps, validus, tabaci, trehernei* and the specimens of *Taeniothrips picipes.* For that reason it may play a minor role in differentiating the species within the same genus but a major one among various genera.

The presented results of preliminary research on the larvae of the genus *Thrips* confirmed the role of selected qualitative morphological characters in their taxonomy. They make it possible to classify the specimens into several main groups of species. But inside the groups, e.g. in the case of *Th. atratus,* whose specimens are different among themselves and in the group of *Th. brevicornis, Th. flavus, Th. fuscipennis* and *Th. physapus,* an additional analysis of the quantitative features is necessary.

Research on the qualitative and quantitative morphological characters and their role in genus *Thrips* taxonomy will be continued.

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