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Thrips and natural enemies through text data mining and visualization

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Abstract: Thrips can cause considerable economic damage. In order to reduce the use of agrochemicals research has also focused on different natural enemies. We used bibliometric mapping and visualization to understand the structure of this field. Articles from Web of Science as well as software Vosviewer were used. Analysis of co-occurrence of terms shows the principal research areas: transmission of viruses, chemical or biological control and new species. A third of articles refer to biological control. Visualizations reveal three major groups of beneficials: entomopathogens, parasitoids, and predators. Recently, attention has shifted mainly to predatory mites as biocontrol agents. Our analysis aims to make such information visually more explanatory with better overview of research directions.

Keywords: pests; Thysanoptera; biocontrol agents; beneficial organisms; mapping; bibliometrics

Thrips, the term employed for the species of the order Thysanoptera, are one of the most economically important insect pests around the world (Wu et al. 2018) and can cause more than 50% yield reduction (Kashkouli et al. 2014). These tiny insects, only few millimeters long, reproduce very fast and can invade a wide range of host plants. They are very mobile, flexible and opportunistic (Mound & Teulon 1995). Some species are extremely difficult to control because of their ability to develop resistance (Bielza 2008). In the order Thysanoptera, about 6 000 species of thrips have been described (Mound & Morris 2007), among which are also harmful herbivorous species; around 1% (Mound 2004; Morse & Hoddle 2006). Some species are beneficial as they are pollinators or predators (Mound & Kibby 1998; Morse & Hoddle 2006). Many different species are difficult to identify (Mehle & Trdan 2012). Such identification requires diagnostic skills of an expert taxonomist. As pests on crops, they can cause significant damage (Moritz 1994). In addition to damage by sucking, thrips can also transmit plant pathogenic viruses, particularly *Tomato spotted wilt virus* (TSWV) and other Tospoviruses which can result in serious plant diseases, and, consequently, crop losses and economic damage (Rotenberg et al. 2015).

Plant protection has for a long time relied on agrochemicals thus ever-new pesticides are needed to sustain effective resistance control strategies (Broughton & Herron 2009). As is evident in Figure 1 the number of published documents on thrips has been growing constantly. This can be attributed to the discovery of new species, new invasions, developing new control techniques and similar. This has been accompanied by documents dealing with environmentally-friendly plant protection (biological control). In order to reduce the use of agrochemicals research has focused on different natural enemies of thrips, for example, pirate bugs (Coll & Ridgway 1995; Elimem et al. 2018), predatory

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thrips (Hoddle et al. 2000; Mautino et al. 2014), predatory mites (van Rijn & Tanigoshi 1999; Khaliq et al. 2018), parasitoids (Murai & Loomans 2001) or different pathogens such as entomopathogenic fungi (Ansari et al. 2008; Liu et al. 2019) or nematodes (Ebssa et al. 2001; Hussein & El-Mahdi 2019).

One of possible ways to investigate the research process in a study area is to focus on a thorough review of scientific literature (De Nardo & Hopper 2004) and related bibliometric methods (San-Blas 2013). Visualization techniques and similar approaches offer a possibility to quantify scientific fields. Bibliometrics as a quantitative analysis by various mathematical and statistical methods was first proposed decades ago by Pritchard (1969). Its history and development are described in detail by Börner et al. (2003). Various approaches can be used to reveal the structure of a research field and to map research trends, depending on the unit of analysis relevant to the question we want to answer; for example: social structure of a scientific field and most prolific authors (also authorship), international dimensions of research with an analysis of co-institutions, co-countries, citation the impact, and similar. Börner et al. (2003) outline the mapping of journals documents, authors, descriptive terms or words. The later are used for the preparation of term (semantic) maps based on co-occurrence of words (co-word analysis) extracted from the text (in general) or from document titles or abstracts. Co-word analysis (Callon et al. 1983, 1991), is usually used in order to better understand the cognitive structure of the areas under analysis (Janssens et al. 2006; Stopar et al. 2020). The method assumes that the co-occurrence of words describes the content of documents.

No such study has directly addressed thrips (Thysanoptera) although a number of articles has applied bibliometric approaches in related topics. San-Blas (2013) investigated the progress in entomopathogenic nematology research and emphasized that an increasing interest in biocontrol organisms will change the ways of farming. Entomopathogenic fungus *Metarhizium anisopliae* (Metschn.) Sorokin, one of the commercially most frequently used natural enemies of pests was analyzed by Hernández-Rosas et al. (2019). Lei et al. (2019) used such approach in forensic entomology, Hu and Cao (2018) on the literature related to planthoppers, Sinha (2012), Rothman and Lester (1985) in a study on insecticides, and similar. Entire journals, for example, the International Journal of Pest Management or Australasian Plant Pathology, have been analyzed by Kolle et al. (2015) and Calver et al. (2012), the later with the purpose of better editorial planning. Some researchers performed bibliometric analysis using programs for mapping and visualization such as Vosviewer or Citespace (Hu & Cao 2018; Hernández-Rosas et al. 2019; Lei et al. 2019). Bibliometric mapping is an increasingly important quantitative approach in the studies of structural and dynamic aspects of scientific fields. Such analyses have grown especially in the more recent period, on account of availability of new software, mapping and visualization tools (Cobo et al. 2011).

In our study we have applied co-word analysis in a set of available documents related to thrips. The aim is to explore the structure of the field and relations among the sub-topics in general, as well as the structure of a more restricted aspect of biological control in this field. Such a spatial display, based on the 'big data' of several tens of thousands of concepts, gives an overview of current research topics, investigates how a scientific domain has developed over time and may thus help researchers to better understand the area of their studies.

MATERIAL AND METHODS

Data source and search strategy. Selection and extraction of data is the first step in mapping process. It is also among the most important. Our analysis involves bibliographic data derived from the Web of Science (WOS) Core Collection citation databases which are frequently used in similar studies. We collected all research articles until the end of 2018. First article in this field was published already in 1912, followed by single-digit annual articles for many decades. In the first analysis we used simple search query (search syntax or search statement) by topics (thrips OR thysanoptera) and retrieved all research articles to this end (for the purposes of consistency we use lower case for all search terms in analysis as the visualization program also employs the same principles). In the beginning of February 2019, the syntax (thrips OR thysanoptera) yielded 4 822 research articles.

For the purposes of further analysis, the content was additionally narrowed to the topics of biological control and natural enemies of the thrips. After some preliminary testing we designed the following search query: ("biological control*" or biocontrol* or "natural enem*" or predator* or parasitoid*

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or entomopathogen* OR beneficial*). These criteria were met in 1 369 articles. Keyword beneficial* returns concepts such as beneficial organisms, beneficial insects, beneficial arthropods, beneficial effects, beneficial predators, parasiting beneficials. Keyword "entomopathogen*" will find concepts entomopathogens, entomopathogenic fungi, entomopathogenic pathogens, and similar (Figure 1).

In addition, we prepared search syntax also for specific groups of natural enemies of thrips (Figure 2). We used a list of natural enemies currently evaluated as biocontrol agents of thrips (Loomans 2003; van Lenteren 2012) to come up with a search query for each group of beneficial organisms. It is difficult to identify all possibly relevant organisms. After some preliminary testing we used the following search queries for each of the specific groups and selected relevant organisms: Predatory mites (*Amblyseius* or *Neoseiulus* or *Iphiseius*)/Predatory thrips (*Aeolothrips* or *Franklinothrips* or *Scolothrips*)/Pirate bugs (*orius* or "anthocoris nemorum")/Pathogens: (steinernema or beauveria or "b bassiana" or *metarhizium* or "m anisopliae" or "*paecilomyces fumosoroseus*" or "p fumosoroseus" or "*verticillium lecanii*" or "v lecanii")/Parasitoids (parasitoid* or ceranisus). Subsequently, we examined 2015–2018 articles in full text. We disregarded some review articles which are very general and such articles which only briefly mentioned representative of individual groups without referring to them in more detail.

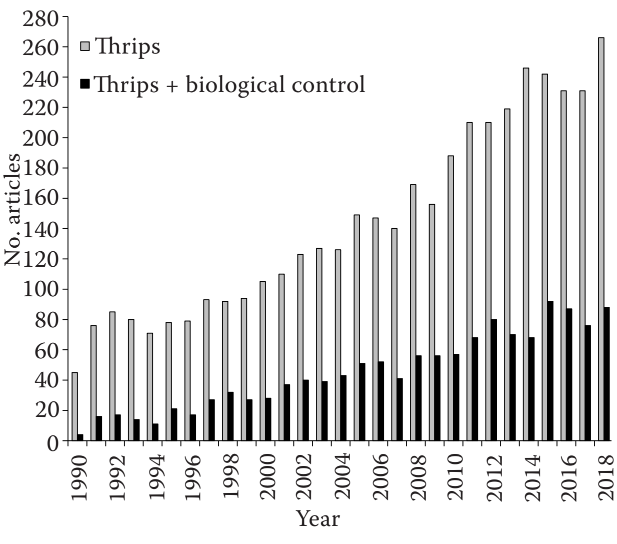

Figure 1. Number of total articles ($n1$ = 4 822) on thrips (Thysanoptera) and articles on thrips in connection with the concepts of biological control ($n2$ = 1 369) published annually between 1990 and 2018

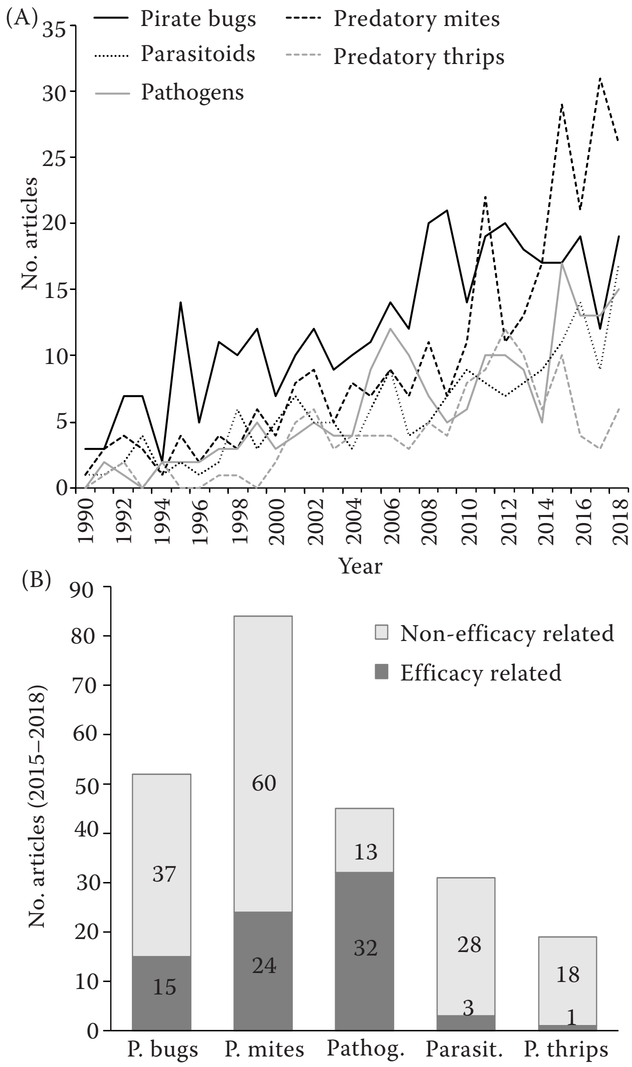

Figure 2. (A) Number of articles ($n1$ = 1 109) for different groups of natural enemies of thrips published annually between 1990 and 2018 and (B) number of relevant articles examined in full ($n2$ = 231) published between 2015–2018 in reference to efficacy of biocontrol

Mapping, clustering, visualization. To answer the questions such as what are the main topics within a selected research area and how do these topics relate to each other we used mapping, clustering and visualization techniques. Our work focused on the relations between key terms/concepts (words or phrases) derived from article titles and abstracts. All terms are harvested from original texts as used by authors, irrespective of possible synonyms, near-synonyms or even less accurate terminology. Two-dimensional term-maps exhibit different concepts in a such a way that the position of concepts in the map provides information on relations and connections. In general, the closer they are to each other,

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the more they are related. Based on clustering algorithms, the concepts are classified into specific groups/clusters. Members of the same cluster are marked with the same color and are related to each other more than to the members in other clusters.

We used computer program VOSviewer (version 1.6.15) (van Eck & Waltman 2010, 2011; van Eck et al. 2010; Waltman et al. 2010) for the purposes of text mining and visualization. The program provides automatic identification of terms i.e. noun-phrases that appear in titles and abstracts of data sets and enables mapping and clustering. For better clarity, only concepts with higher relevance score (calculated based on automated term-identification technique) are shown on the maps. In both analyses we employed the terms occurring at least 10 times in the titles or abstracts of articles. A special thesaurus file was prepared to merge some synonyms into a single term. It is mainly about combining (merging or conflating) concepts that are written in abbreviated form with those that are presented in full (e.g. a barkeri with *Amblyseius barkeri*).

Different types of visualization were conducted in order to address various issues. The label view shows a map in detail. In this view, concepts are marked with labels and circles. The more important the concept the larger the label and the circle. To avoid overlapping, only a limited number of all labels is displayed. Density view shows a more general structure of a map by highlighting the most important areas (described in detail by van Eck & Waltman 2010). In the overlay visualization (Figure 3), the concepts are colored differently (compared with the label visualization). If items have 'scores', for example, average year, the score then determines the color of an item. Color palette, which indicates the average year of publications in which a term occurs, begins with 2006 (dark blue color) and ends with 2012 (red color). Averages also include the data before and after. This average is defined by the program.

RESULTS

Thrips (Thysanoptera) in general. To get the insight into the structure of the field we prepared bibliometric map with the nodes placed in a two-dimensional space and assigned to differently colored clusters. Figure 4 provides label view and density view (smaller map in the lower right corner in Figure 4) of the terms from titles and abstracts of 4 822 articles. 2 022 of the total 66 957 concepts met the threshold (occurring at least 10 times). The most relevant 1 209 concepts are shown on the map (according to default software algorithm). Circles present individual concepts (terms or phrases). The size of the circle represents the number of occurrences of each concept. The larger the label and the bigger the circle, the higher the occurrence

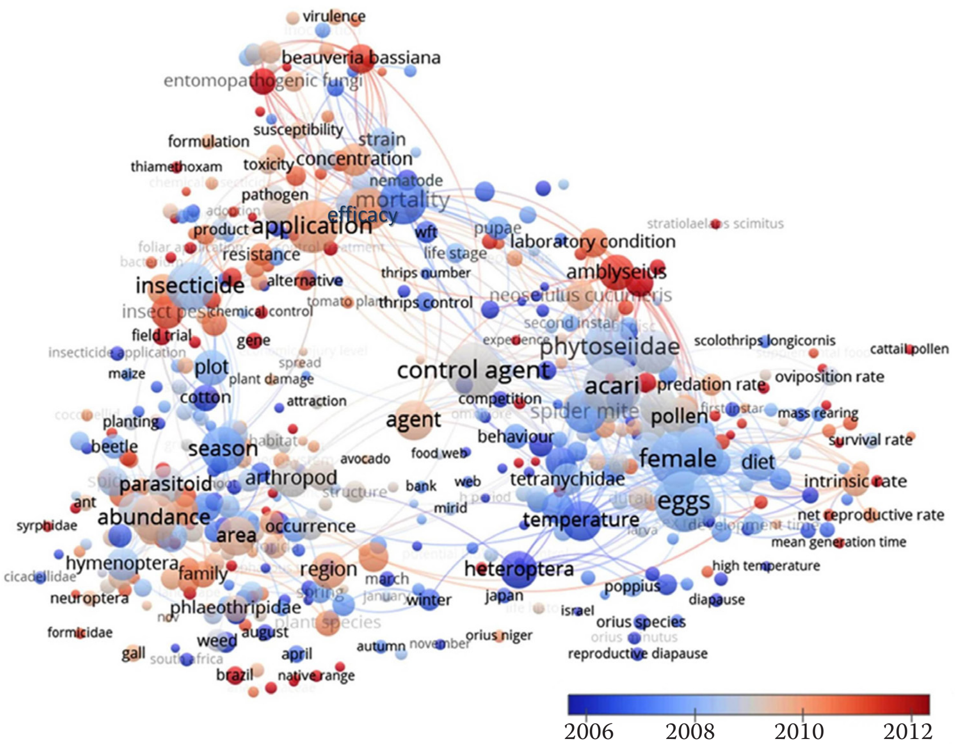

Figure 3. Term-map of articles (n = 1 369) on biological control and natural enemies of thrips (Thysanoptera) based on a period of research. The color of a term indicates the average year of publications in which a term occurs

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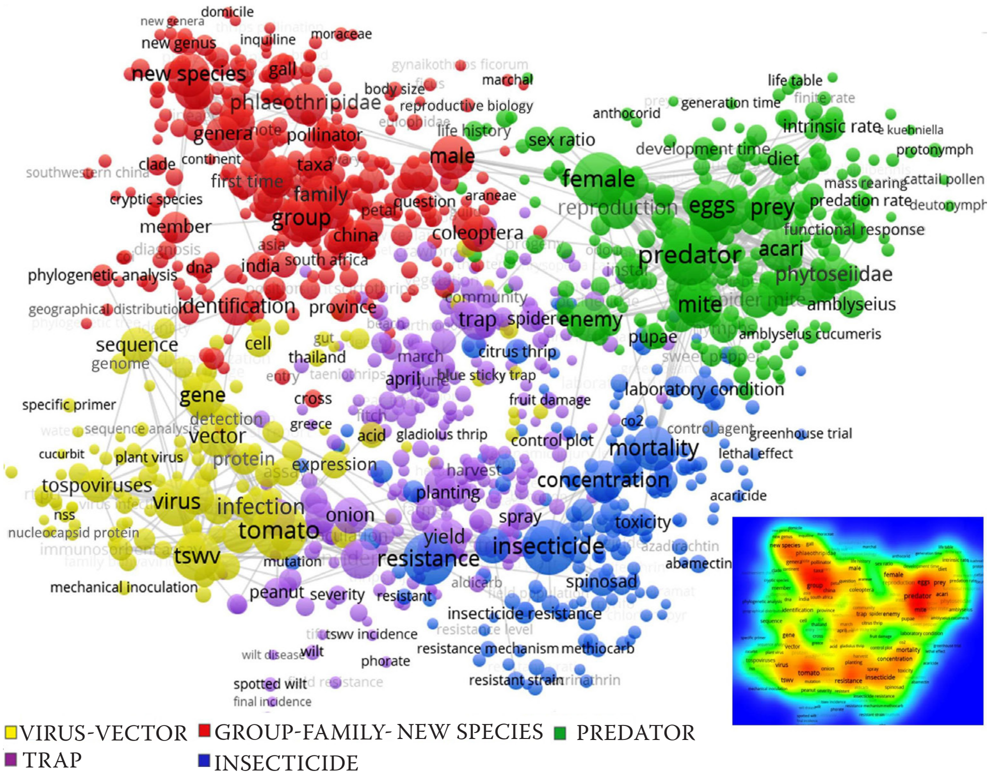

Figure 4. Term-map of articles (n = 4 822) on thrips (Thysanoptera) in general. Small map in the lower right corner represents density view of the same map

of terms. The number of co-occurrence between two individual concepts determines the connections between them. The shorter the distance between the two concepts, the stronger the link.

Vosviewer has identified 5 clusters (i.e. subfields). We decided to name each cluster according to the most prominent (typical) concept: VIRUS-VECTOR, INSECTICIDE, PREDATOR, NEW SPECIES-GROUP-FAMILY and TRAP. Cluster VIRUS-VECTOR (yellow color) is focused on thrips as vectors of viruses. Some representative words in this cluster are: tomato, TSWV, virus, vector, infection, gene, transmission, tospoviruses, sequence, detection. Cluster PREDATOR (green color) links biological control and natural enemies, and will be described in more detail further on. In the frame of the cluster INSECTICIDE (blue color) there are, for example, the following terms: insecticide, resistance, mortality, concentration, strain, toxicity. Cluster NEW SPECIES-GROUP-FAMILY (red color) comprises newly described species and related: new species, male, Phlaeothripidae (family of thrips with huge number of genera), family, identification, structure, genera, first time, key, member etc. In the cluster TRAP (purple color), we can observe terms related to traps: trap, sticky trap, blue sticky trap, yellow sticky trap or sticky card. We can also observe different months of the year and terms such as yield, incidence, disease, field trial, insecticide application (not all concepts can be visible due to overlap). The central position of this cluster connects it, to some extent, with other clusters. The reason for that is that traps can be used for thrips control and for different monitoring purposes (Trdan et al. 2005), for example, detecting arrival of vector species (Groves et al. 2003), as well as forecasting spraying time (Piazzol et al. 2010). This is evident in our map, since terms such as wilt disease, spotted wilt, final incidence, tswv incidence or insecticide application, insecticide treatment and similar appear in the purple cluster (some terms are not shown on the map with names because of software characteristics).

While the label view visualization focuses on the details (terms/concepts), the density view (represented with smaller map in the lower right corner of the Figure 4) reveals a more general structure of the same map by highlighting the relative importance of different areas in the map. In this visualization we can identify denser areas in which some points are located close to each other. The red color in this view means that terms located in these areas occur many times together and can be considered as the most important ones (van Eck & Waltman 2010).

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Each of the five clusters has more or less a central zone (density view) around which other terms are distributed. We can detect especially two clusters: one gravitating around taxonomic terms and another, which is associated with predation. Given the well-defined and distinct cluster of predation-related terms we then designed another WOS query which deals specifically with concepts reflecting biological control (described in the methodological section). This analysis is presented in the next section.

Biological control and natural enemies of thrips. We prepared another term-map with a set of data based on 1 369 articles, which address a specialized aspect of biological control and natural enemies of thrips. 808 of the total 25 409 concepts met the threshold of at least 10 occurrences. The most relevant 485 concepts are shown on the map (Figure 5). In this analysis we identified 3 main clusters as follows: entomopathogen (blue cluster), parasitoid (red cluster) and predator (green cluster). In the central part of the Figure 5 we can see the concepts control agent or just agent which describe beneficials as biological control agents against thrips.

Most characteristic concepts in the cluster parasitoid are parasitoid, abundance, season, area, arthropod, region etc. The concept parasitoid forms the strongest links with concepts abundance, hymenoptera, arthropod, eulophidae, spider, group, insecticide and application. The concepts, such as coleoptera, neuroptera, or diptera, however, may also represent various predators in this cluster. Most characteristic concepts in the cluster entomopathogen are application, insecticide, mortality, efficacy, insect pest, concentration, pesticide, soil, *Beauveria bassiana,* strain, entomopathogenic fungi, infection, pest management, pupae, *Metarhizium anisopliae,* resistance, fungus, product, compatibility, conidia, toxicity, isolate, nematode. The phrase entomopathogenic fungi is most commonly used with *Beauveria bassiana*, fungi, *Metarhizium anisopliae* or *M. anisopliae,* izolate, conidia, strain, application, concentration, mortality, efficacy, insect pest. The phrase entomopathogenic nematode, most often occurs with the terms epn, infective juvenile, concentration, nematode, efficacy, mortality and application.

Because of limited space only selected labels can be displayed on the map (Figure 5). Thus, we prepared an additional "zoom" of the right-hand (green) cluster, which relates to various predators (Figure 6).

Figure 6 (green cluster – PREDATOR) exposes several groups of predators, especially predatory mites (upper-left part of the figure) and predatory bugs (bottom). We can also note predatory thrips *Scolothrips longicornis* (towards the upper right).

The period of publication of the articles included in the analysis. We used visualizations also in order to get an insight into the period of research of different topics covered by the documents under

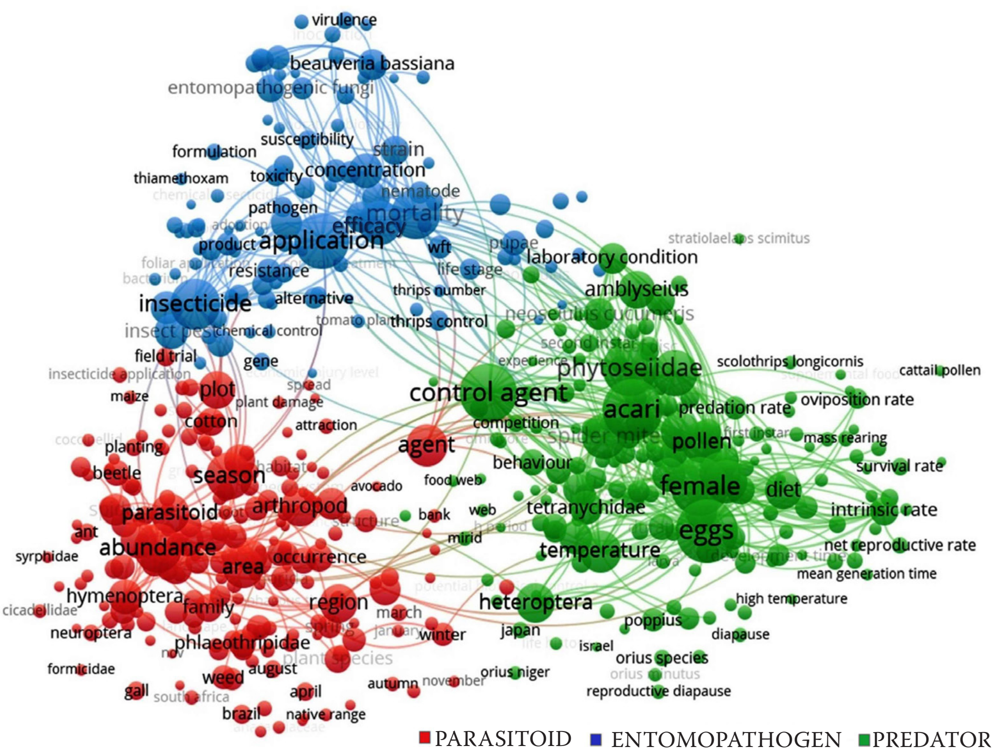

Figure 5. Term-map of articles (n = 1 369) on biological control and natural enemies of thrips (Thysanoptera)

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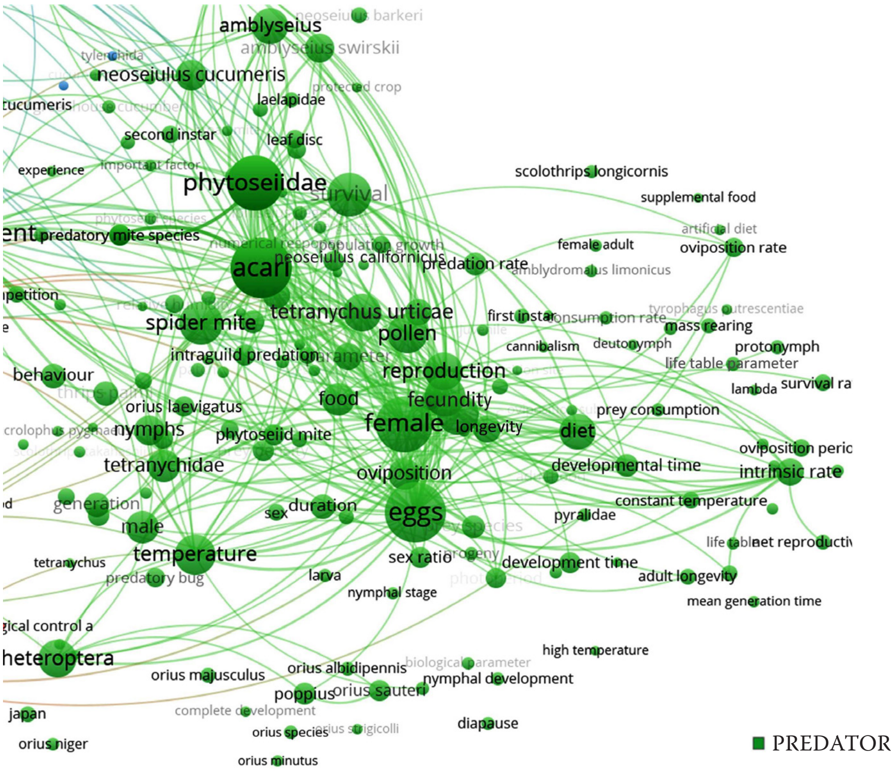

Figure 6. Zoom into the right zone (cluster PREDATOR) of the text map presented in Figure 5 (n = 1 369)

analysis. The subsequent map (Figure 3) is based on the same data and the same concepts as the previous maps. Compared with the term-map presented in Figure 5 (where colors corresponded to thematic clusters), colors in Figure 3 now indicate average publication years. Blue colors specify earlier research, while red indicate more recent subjects of interest. According to Figure 3, research has in recent years progressed slightly more towards predatory mites studies. In addition, in recent years some interesting topics on entomopathogenic fungi have developed, in particular related to fungus *Beauveria bassiana*.

However, if the topic is displayed in blue, this does not necessarily mean that there is now no further research in this field. It may have been investigated before but now more attention has been placed on other topics. This is evident from the analysis of individual groups of natural enemies (Figure 2; the search procedure is described in the methodological section). The growth rate of articles by year shows that pirate bugs are the most represented in terms of total number of articles, but the growth in this group has more recently stagnated. On the other hand, the group of predatory mites has gained more attention in the last decade.

DISCUSSION

The aim of this study was to detect and shed light on patterns and trends in the scientific literature on thrips, which represent a significant group of plant pests. According to the co-occurrence analysis of terms the main areas of research are concerned with the transmission of viruses, chemical or biological control, and the identification of new species. Although pest control is generally based on agrochemicals, an increasing number of studies are advocating more environmentally friendlier methods (van Lenteren 2012; San-Blas 2013) partly because of the resistance to insecticides (Jensen 2000). In fact, various plant protection products may also harm beneficial organisms (Bohinc et al. 2018). Our results show that about a third of all articles deal with beneficial organisms and resulting biological control.

In our study, the articles on biological-control were analyzed in more detail. Clustering of terms and visualizations revealed three major groups of beneficials which are used as biological control agents against thrips: parasitoids, entomopathogens, and predators. Within the group of predators, which was analyzed in more detail, articles

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refer to pirate bugs and predatory mites, followed by predatory thrips. Given the size of the circles and labels in Figure 6, we assume that many articles address the problems associated with Phytoseiidae (the family of predatory mites) and related Phytoseiid species, predatory mite species or genera of *Amblyseius*, *Neoseiulus*, which feed on thrips and various harmful mite species. Phytoseiid mites are well studied predators investigated in biological control of a wide range of harmful pests (Negloh et al. 2008).

The concept acari (subclass – a taxon of arachnids) is positioned between pest mites and predatory mites. Concepts spider mite and *Tetranychus urticae* (shown to the right of spider mite) represent harmful organisms that come about on the plants along with thrips. The concept intraguild predation, the consequences of which are still very much unexplored according to Lang (2003), describes predation/competition processes, in which both species are dependent on the same prey and also benefit from preying upon each other. In this sense, Xu et al. (2006) studied the effectiveness of pirate bugs *Orius insidiosus* in the biocontrol of either thrips *Frankliniella occidentalis* or the spider mite *Tetranychus urticae* individually, or both species together.

Orius species – representatives of the pirate bugs – are numerous predators around the world. Funderburk et al. (2000) studied predation of thrips *Frankliniella occidentalis* by *Orius insidiosus* and concluded that natural enemies, in general "may play a more important role in regulating populations of thrips than previously believed". As can be seen in Figure 6 some other *Orius* species are visible on the map such as *O. niger*, *O. minutus*, *O. strigicolli*, *O. sauteri, O. albipennis, O. majusculus* and *O. laevigatus* (most concepts are positioned in the lower part of the map).

On the upper-right side of the map we can see the concept *Scolothrips longicornis*, a representative of the third predatory group (predatory thrips). This group of thrips represents beneficial insects. Several species of the *Scolothrips* genus predate on spider mites, such as *Tetranychus urticae*, as mentioned, for example, by Pakyari and Enkegaard (2012). The behavior of cannibalism, the concept that appears on the map near the group of mites, is an important factor in biological control. Search in the database WOS itself shows that the term cannibalism comes about most often in connection with predatory spider mite *Tetranychus urticae* (about half of all hits within the subclass Acari or family Phytoseiidae). Cannibalism can affect the structure and dynamics of the populations of predators used in biological control programs. Farazmand et al. (2014), for example, investigated cannibalism by adult females of the specialist predatory thrips, *Scolothrips longicornis* and the generalist predatory mites *Neoseiulus californicus* and *Typhlodromus bagdasarjani* and concluded that cannibalism could also be triggered by absence of spider mite (*Tetranychus urticae*) as usual prey.

Concepts such as developmental time, survival, longevity, oviposition rate, fecundity, reproduction, and the like refer to research on the various biological functions of predatory insects, for example, on a selected diet (Kiman & Yeargan 1985). Given the size of the circles and labels (Figure 6), we assume that many articles deal with this particular topic. The concepts that describe biological functions occur most frequently with terms (according to lines between circles on the map) such as pollen, eggs, temperature, food, diet, male, female, sex ratio etc. A study by van Rijn et al. (2002) showed that pollen supply can significantly improve the control of thrips with predatory mites in greenhouses. van Rijn and Tanigoshi (1999) summarized that all known phytoseiide mites, although they are usually known as predators, can also effectively feed and reproduce on pollen, increasing their chances of survival in times when natural prey is lacking. Song et al. (2019) tested various artificial diets as an alternative food source for rearing predatory mite *Neoseiulus californicus* and concluded that artificial diet could contribute to a more cost-effective rearing of phytoseiid mites and other biocontrol organisms. In Figure 6, the concepts such as mass rearing, life table and life table parameters are shown on the right side of the map and co-occur most often with concepts such as survival, female, eggs and degrees C. *Ephestia kuehniella* eggs, for example, can be important part of artificial diet used in mass rearing of *N. californicus* as indicated also by Song et al. (2019).

At present, natural enemies are mass-reared in so-called bio-factories in order to release them in large numbers and use them immediately for pest control (van Lenteren 2012). Among the various natural enemies used in augmentative biological control, 26 species are commercially available worldwide to control thrips. Four of them are ranked among the most important (according to the number of countries in where this is used): *Amblyseius swirskii*, *Neoseiulus cucumeris* (= *Amblyseius cucumeris*),

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Neoseiulus californicus (= *Amblyseius californicus*) and *Orius laevigatus*. All these species are represented on the map as well (Figure 6).

These topics were also confirmed in our a more detailed examination of articles in full. This examination focused on the period of 2015–2018 whereby we wished above all to ascertain how many articles were explicitly centered on experimental results in terms of efficiency: biological control experiments conducted under laboratory, greenhouse or field conditions (Figure 2). Most such articles involved pathogens and predatory mites. In the articles relating to pathogens (the same applies to predatory mites and pirate bugs) around two-thirds included greenhouse or field conditions. An increase in the field- or greenhouse-based experiments, compared with previous periods, is also reported in literature (San-Blas 2013). High proportion of efficacy-related articles at pathogens and predators is consistent with the visualization. The concept efficacy occurs with a relatively high incidence in the cluster entomopathogen, and is strongly associated (most co-occurrences) with the concepts such as entomopathogenic fungi, *Beauveria bassiana* as well as with predatory mites; in connection with the genera *Amblyseius* and *Neoseiulus*. The group of predatory bugs occurs with many low-incidence species, which is the reason why we do not mention them in this context.

For the purposes of improving the sustainability thrips control in connection with pathogens, literature reffers to efficacy of spray applications of entomopathogenic fungi against thrips under different moisture/temperature conditions, compatibility with different fungicides, interference between biological agents when combining beneficials and similar. Combination of entomopathogenic fungi or nematodes in the soil and predatory mites or pirate bugs (for example, *O. laevigatus*) in the canopy reduced thrips more efficiently (Pozzebon et al. 2015; Otieno et al. 2017; Wu et al. 2017). On the map, these groups of beneficials are also positioned relatively close to each other (Figure 5). In the case of parasitoids, some articles do not directly relate to parasitoid-research. About a third of the articles obtained in the query were very general and referred to parasitoids only briefly. The articles under analysis nevertheless describe results of monitoring, seasonal occurrence of both key pests and beneficial insects, their response to different-colored sticky traps, side-effects of insecticides, as well as screening flowering plant species for attractiveness to natural enemies and herbivores. Vaello et al. (2018), for example, report that parasitism alters plant defence responses, Bouagga et al. (2018a), however, report that some mirid predators are able to induce plant defences by release of volatile organic compounds which repell thrips and attract parasitoids. Attraction of natural enemies to herbivore-induced plant volatiles, alone or in combination with accompanying plants, has also been studied in conjunction with predatory thrips (Salamanca et al. 2018). In addition, articles from this group refer to some other contents such as side effects of different pesticides, different qualitative and quantitative studies and records of thrips species.

Articles on pirate bugs and predatory mites refer to response of predatory insects to different ecological and biological factors (temperature, humidity, spectral wavelength, biochemistry, mating behavior, landscape factors, seasonal/populational dynamics, spatial distribution, alternative food and similar). The influence of this factors on various biological functions (stages of development, survival, reproduction and predation of diaper insects) is also indicated by the concepts shown in Figure 6. Results reported by Oveja et al. (2016), for example, suggest that the addition of supplemental food in the patch where predators are released result in a better thrips control as predator populations increase quicker when supplemental food is provided. Christiansen et al. (2016) report that efficacy of *A. swirskii* in biological control can be enhanced by priming young predators on a specific prey early in life. Another group of articles involves relationships with other organisms, reflected as predator-pray interactions, cannibalism (Christiansen & Schausberger 2017), intarguild predation (Choh et al. 2015), prey preference, combined releases of biological control agents (Bouagga et al. 2018b), plants as attractans which increase available resources for natural enemies and help reduce thrips (Zhao et al. 2017), side-effect of pesticides on predation (Herrick & Cloyd 2017), and similar.

Recently, attention has shifted mainly to predatory mites. This group is widely known to researchers to be the most effective natural enemies. Many species of predatory mites are therefore also commercially available (van Lenteren 2012) which is certainly one of the more important reasons for the increasing number of scientific articles dealing with this predatory group. They are easily accessible to researchers; unlike, for example, parasitoids which are

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not commercially available. Also, they are less effective, have not been so intensely investigated, and are not used in agricultural practice.

Scientific fields increasingly cross boundaries between the traditional research fields. Experts thus need a good overview of research directions. To this end, bibliometric maps offer an additional visual perspective. The current analysis is the first attempt at bibliometric evaluation of this particular area. The limitation is the representation of mainly the more represented areas. A future follow-up analysis of this kind can perhaps focus on individual groups of beneficials, by also employing additional bibliometric parameters (authors, citations, etc.). We recommend attention on those natural enemies of thrips which, despite a still low number of publications, have proven their usefulness and should thus be studied more thoroughly.

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