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Thrips (Thysanoptera) associated with two morphological forms of Andean lupin (*Lupinus mutabilis*)

Michał Hurej[1], Halina Kucharczyk[2], Jacek P. Twardowski[1]* & Andrzej Kotecki[3]

[1]*Department of Plant Protection, Wrocław University of Environmental and Life Sciences, Grunwaldzki 24a, 50-363 Wrocław, Poland; e-mail: jacek.twardowski@up.wroc.pl*
[2]*Department of Zoology, Maria Curie-Skłodowska University in Lublin, Akademicka 19, 20-033 Lublin, Poland*
[3]*Department of Crop Production, Wrocław University of Environmental and Life Sciences, Grunwaldzki 24a, 50-363 Wrocław, Poland*

Abstract: The aim of this study was to determine thrips abundance, species composition, sex ratio and seasonal dynamics of these insects on two morphological forms of Andean lupin (epigonal and semiepigonal). Thrips were studied in the lupine plants sown at two dates at the Experimental Research Station at Pawłowice, near Wrocław, Lower Silesia, Poland, during two growing seasons (2011–2012). The experiment was designed as a split-plot with four replicates for each morphological form and time of sowing. For the determination of thrips species' composition, plants were collected from the central part of each plot when lupin was at the full blooming stage. In the laboratory, plants were shaken over a sheet of white paper. Once in each season thrips were also collected with a sweep net. In the laboratory larvae and adults were identified to species level and separated into males and females. During the whole lupin growing season, insects were also counted weekly on 10 consecutive plants in the middle row of each plot. *Frankliniella intonsa*, *Thrips major* and *Aeolothrips intermedius* were the dominant species in the full blooming stage of both semiepigonal and epigonal forms of Andean lupin. *Thrips tabaci* also occurred in greater numbers. There were no significant differences between numbers of thrips and number of species occurring on semiepigonal and epigonal plants sown at the same time. In the most numerous species, like *F. intonsa* and *T. major*, mainly females occurred in their population. In the population of *A. intermedius* males were abundant. Thrips occurring in *Lupinus mutabilis*, irrespective of the used form of lupin or sowing time, had one peak of abundance, i.e., the last ten days of June and the first ten days of July, when plants were at the blooming stage.

Key words: Andean lupin; *Lupinus mutabilis*; thrips; species composition; sex ratio; abundance

Introduction

Andean lupin (*Lupinus mutabilis* Sweet) originates from South America, where it has been grown for centuries by the indigenous peoples of Ecuador, Peru and Bolivia, and is consumed as a traditional food after debittering. Its grains even become strategic for small and medium farmers in mentioned continent because this crop is adapted to marginal agro-ecological conditions and has high nutritional value (Rivera & Gallegos 2001). Now, *L. mutabilis* is regarded as a potential crop for central European and Mediterranean climates, and more recently for Australia (Hudson et al. 1976; Caligari et al. 2000; Sweetingham et al. 2006). Its seeds have the highest levels of protein (45–50%) and oil (14–24%) of all domesticated lupin species, and the nutritive value of their protein is comparable to that of soybean protein (Petterson 1998; Caligari et al. 2000; Office of the Gene Technology Regulation 2013). The main obstacle to a broader utilization of the Andean lupin in nutrition is its high content of bitter and poisonous quinolizidine alkaloids (Hudson et al. 1976). Now, utilizing different plant breeding methods, it has become possible to obtain a variety of *L. mutabilis* with a negligible percentage of bitter substances, and which meets the requirements, regarding the alkaloid content, for human food and animal feed (Hatzold et al. 1983; Clements et al. 2008).

In yellow tree lupin (*Lupinus arboreus* Sims), an abundant weed in New Zealand, eight thrips species were found. The most abundant was *Thrips obscuratus* (Crawford, 1941), followed by *Thrips tabaci* and *Frankliniella occidentalis* Pergande, 1895 (He et al. 2009). In narrow-leafed lupin (*Lupinus angustifolius* L.) (cv. Graf) grown in mixture with spring triticale (cv. Dublet), 17 species of thrips were identified on plants at the full blooming stage in Poland. *Frankliniella intonsa* and *Aeolothrips intermedius* (predatory species) were the dominant species. *Thrips tabaci* also occurred in greater numbers on lupin plants. In seasonal dynamics, higher numbers of thrips were observed at the full blooming stage of *Lupinus angustifolius* (BBCH 65)

* Corresponding author

Table 1. Species composition of thrips collected by shaking plants in 2011.

Species	13 June					20 June				
	T1 A	%	T1 B	%	Total	T2 A	%	T2 B	%	Total
Frankliniella intonsa (Trybom, 1895)	65	60.6	148	79.6	213	420	81.1	377	82.9	797
Thrips major Uzel, 1895	28	26.5	17	9.2	45	24	4.6	12	2.6	36
Aeolothrips intermedius Bagnall, 1934	6	5.5	9	4.8	15	26	5.0	35	7.7	61
Thrips tabaci Lindemann, 1889	7	6.5	5	2.7	12	24	4.6	15	3.3	39
Thrips fuscipennis Haliday, 1836			5	2.7	5	17	3.3	16	3.5	33
Thrips atratus Haliday, 1836						3	0.6			3
Thrips angusticeps Uzel, 1895	1	0.9	1	0.5	2	1	0.2			1
Thrips flavus Schrank, 1776						2	0.4			2
Thrips physapus L., 1758						1	0.2			1
Aeolothrips fasciatus (L., 1758)			1	0.5	1					
Total	107 b**	100.0	186 b	100.0	293	518 a	100.0	455 a	100.0	973
% larvae	3.7		3.8			0.2		0.4		
Number of species	5		7		7	9		5		9

Explanations: T1 – early-sown plants; T2 – later-sown plants; A – semiepigonal form; B – epigonal form; **values indicated by different letters differ significantly.

(Hurej et al. 2014). The above-mentioned species, together with *Thrips fuscipennis*, were the most abundant and frequently occurred on *Pisum sativum* cultivars in Poland (Pobożniak 2013). *Thrips angusticeps* is mentioned as a pest of *Lupinus albus* L. in the south of England (Ferguson 1994). This species seriously injured the leaves and flower buds of white lupin in April and May. *Odontothrips loti* was sporadically recorded in narrow-leafed lupin in an experiment carried out by Hurej et al. (2014). Although species of the genus *Odontothrips* breed only in the flowers of Fabaceae, according to the literature lupin is not a preferred host plant for this species (Pitkin 1972).

To date, no studies on thrips feeding on *Lupinus mutabilis* plants have been conducted in Europe. In the available world literature there are also no specific data concerning this problem. The aim of this study was to determine thrips abundance, species composition and seasonal dynamics of these insects on two morphological forms of Andean lupin.

Material and methods

The two morphological forms of Andean lupin used in the study have a determined type of growth: epigonal, developing only one main stem, and semiepigonal, developing only the first order of the lateral branches (Stawiński & Rybiński 2001; Sawicka-Sienkiewicz & Augiewicz 2004). Seeds of the epigonal form contain about 18% more alkaloids than the semiepigonal one (Gas 2014). Both forms were sown on two sowing dates, first at the end of March and the second one 14 days later. 90 seeds per 1 m^2 were sown in each treatment.

Thrips in the two forms of Andean lupin and two dates of sowing were studied at the Experimental Research Station at Pawłowice, near Wrocław, Lower Silesia, Poland (51.1776 N, 17.1063 E) during two growing seasons (2011–2012). Plants were grown in plots of 15 m^2 (10 m × 1.5 m) on sandy soil. The 0.3 meters wide space between the experimental plots was maintained mechanically as bare soil, and the plots were weeded regularly. The experiment was designed as a split-plot with four replicates for each morphological form and time of sowing.

For the determination of thrips species composition, ten plants were collected from the central part of each plot (40 plants for treatment), when Andean lupin was at the full blooming stage (BBCH 65). In the laboratory, plants were shaken over a sheet of white paper. Larvae and adults were counted, preserved in 75% ethyl alcohol and then identified. During the whole lupin growing season insects were also counted weekly on ten consecutive plants in the middle row of each plot. Once in each season thrips were collected with a sweep net (40 cm in diameter). A sample consisted of ten 180°-sweeps taken in the middle of each plot on each sampling date. Samples were placed individually into cardboard containers with a paper towel saturated with 95% ethyl acetate. In the laboratory insects were manually separated from plant material and placed into vials containing 75% ethyl alcohol. After counting, both adults and larvae were identified according to the keys of Strassen (2003) and Vierbergen et al. (2010), respectively.

The sex ratio (the percentage of females in a population) was calculated after the standard formula: Sr = f : (m + f) × 100, where Sr – sex ratio, f – number of females, m – number of males (Vasiliu-Oromulu 2002).

Analysis of variance (ANOVA) followed by Tukey's HSD (post-hoc, Honestly Significant Difference) test were used to compare the number of recorded thrips using three different sampling methods in different treatments of the experiment. Statistical significance was evaluated at $P \leq 0.05$. For statistical analysis Statistica 10.0 was chosen.

Results and discussion

Abundance and species composition

In 2011, a total of 1,266 thrips belonging to ten species were collected by the shaking method from all the treatments of Andean lupin plants which were at the full blooming stage (BBCH 65) (Table 1). Plants sown on the first date reached this stage on 13 June. From the semiepigonal form 107 thrips belonging to five species, while from the epigonal form 186 thrips belonging to seven species, were identified. Insects occurred mainly in the adult stage. In each treatment the most numerous species was *Frankliniella intonsa*. This species made up

Table 2. Species composition of thrips collected with entomological net in 2011.

Species	7 July								
	T1 A	%	T1 B	%	T2 A	%	T2 B	%	Total
Frankliniella intonsa (Trybom, 1895)	94	46.3	82	67.8	160	58.8	110	68.7	446
Aeolothrips intermedius Bagnall, 1934	26	12.8	27	22.2	75	27.6	31	19.3	159
Frankliniella tenuicornis (Uzel, 1895)	52	25.6			13	4.8	7	4.4	72
Thrips tabaci Lindemann, 1889	11	5.4	5	4.1	1	0.4			17
Thrips major Uzel, 1895	7	3.4	2	1.7	2	0.7	3	1.9	14
Thrips fuscipennis Haliday, 1836	4	2.0	2	1.7	5	1.8	2	1.3	13
Limothrips denticornis Haliday, 1836	4	2.0			4	1.5	1	0.6	9
Limothrips cerealium Haliday, 1836					5	1.8	2	1.3	7
Thrips physapus L., 1758	1	0.5			3	1.1	2	1.3	6
Thrips atratus Haliday, 1836	2	1	2	1.7			1	0.6	5
Thrips angusticeps Uzel, 1895					3	1.1			3
Haplothrips aculeatus F., 1803	1	0.5	1	0.8	1	0.4			3
Haplothrips leucanthemi (Schrank, 1781)	1	0.5					1	0.6	2
Total	203	100.0	121	100.0	272	100.0	160	100.0	756
% larvae	2.5		35.2				1.3		
Number of species	11		7		11		10		13

Explanations: T1 – early-sown plants; T2 – later-sown plants; A – semiepigonal form; B – epigonal form.

Table 3. Species composition of thrips collected by shaking plants in 2012.

Species	19 June					3 July				
	T1 A	%	T1 B	%	Total	T2 A	%	T2 B	%	Total
Frankliniella intonsa (Trybom, 1895)	86	30.9	116	29.5	202	248	69.3	256	65.1	504
Aeolothrips intermedius Bagnall, 1934	76	27.4	131	33.3	207	63	17.5	77	19.5	140
Thrips major Uzel, 1895	105	37.8	127	32.3	232	20	5.6	17	4.3	37
Thrips tabaci Lindemann, 1889	4	1.4			4	20	5.6	21	5.3	41
Thrips fuscipennis Haliday, 1836	7	2.5	18	4.6	25	2	0.6	12	3.1	14
Thrips flavus Schrank, 1776						3	0.8	7	1.8	10
Thrips atratus Haliday, 1836			1	0.3	1			1	0.3	1
Thrips angusticeps Uzel, 1895						2	0.6			2
Aptinothrips stylifer Trybom, 1894								1	0.3	1
Thrips physapus L., 1758								1	0.3	1
Total	278	100.0	393	100.0	671	358	100.0	393	100.0	751
% larvae						5.3		12.2		
Number of species	5		5		6	7		9		10

Explanations: T1 – early-sown plants; T2 – later-sown plants; A – semiepigonal form; B – epigonal form.

60.6% in the semiepigonal form, and 79.6% in the epigonal form of all identified insects. The second most abundant species, in both treatments, was *Thrips major*. In the semiepigonal form this species made up 26.5% of all insects, and in the epigonal form 9.2%.

In 2011, plants sown on the second date reached the full blooming stage on 20 June. Similar numbers of thrips were found in semiepigonal and epigonal forms, i.e., 518 and 455, respectively (Table 1). They occurred mainly in the adult stage. Only a few larvae were identified in the entomological material. These numbers of thrips were significantly higher in comparison to the first date of sowing ($F = 18.81$, df = 3, $P = 0.00008$). Nine species of Thysanoptera were identified in the collected material from semiepigonal plants and only five species from epigonal ones. *F. intonsa*, as on the first sowing date, was the dominant species in both lupin forms, making up 81.1% and 82.9% of all identified thrips. The second frequently occurring species was *Aeolothrips intermedius*. Single individuals of the following four species were found only in the semiepigonal forms: *Thrips atratus*, *T. angusticeps*, *T. flavus* and *T. physapus*.

In 2011, thrips were collected by entomological net on 7 July, when plants sown on the first date reached BBCH stage 71–73 (10% to 30% pods), and those sown on the second date reached BBCH stage 69–70 (the end of blooming to the first full-grown pods). In the collected material a total of 756 thrips belonging to 13 species were identified from all the treatments (Table 2). In earlier sown plants, from the semiepigonal form 203 thrips belonging to 11 species were identified. Fewer individuals (121) representing seven species occurred on plants of the epigonal form. Adults dominated in the collected samples. In semiepigonal plants three species were numerous: *F. intonsa* (46.3%), *F. tenuicornis* (25.6%) and *Aeolothrips intermedius* (12.8% of all thrips). In epigonal plants *F. in-*

Table 4. Species composition of thrips collected with entomological net in 2012.

Species	19 June					4 July				
	T1 A	%	T1 B	%	Total	T2 A	%	T2 B	%	Total
Frankliniella intonsa (Trybom, 1895)	86	31.6	89	33.9	175	48	71.6	72	68.6	120
Thrips major Uzel, 1895	126	46.1	115	43.9	241	3	4.5	2	1.9	5
Aeolothrips intermedius Bagnall, 1934	29	10.7	27	10.3	56	15	22.4	27	25.8	42
Thrips tabaci Lindemann, 1889	17	6.2	20	7.6	37	1	1.5	2	1.9	3
Thrips flavus Schrank, 1776	8	2.9	3	1.1	11			1	0.9	1
Aeolothrips fasciatus (L., 1758)	5	1.8	1	0.4	6					
Thrips angusticeps Uzel, 1895	2	0.7	2	0.8	4					
Thrips atratus Haliday, 1836			1	0.4	1			1	0.9	1
Thrips fuscipennis Haliday, 1836			2	0.8	2					
Thrips physapus L., 1758			2	0.8	2					
Total	273 a**	100.0	262 a	100.0	535	67 b	100.0	105 b	100.0	172
% larvae	0.4		15.6			16.7		22.8		
Number of species	7		10		10	4		6		10

Explanations: T1 – early-sown plants; T2 – later-sown plants; A – semiepigonal form; B – epigonal form; **values indicated by different letters differ significantly.

tonsa dominated (67.8%), followed by *A. intermedius* (22.2%). Andean lupin was probably a substitute plant for graminicolous *F. tenuicornis*.

In 2012, 1,422 thrips individuals of ten species were found in entomological material collected by the shaking method from all the treatments of Andean lupin plants which were at the full blooming stage (BBCH 65) (Table 3). Early-sown plants reached this stage on 19 June. From the semiepigonal form 278 thrips of five species were identified. From epigonal plants 393 thrips, also belonging to five species, were found. At this plant's stage no larvae were identified. In each treatment three species were the most numerous: *F. intonsa, A. intermedius* and *T. major*. In the semiepigonal form they made up 30.9%, 27.4%, 37.8%, and in the epigonal form 29.5%, 33.3% and 32.3% of all identified Thysanoptera, respectively. Single specimens of *T. tabaci* occurred only in samples from the semiepigonal plants, while *T. atratus* occurred only in epigonal ones.

In 2012, later-sown plants reached the full blooming stage on 3 July. Similar numbers of thrips were found in semiepigonal and epigonal forms, i.e. 358 and 393, respectively (Table 3). As in the previous samples, they occurred mainly in the adult stage. Seven species of Thysanoptera were identified in the collected material from semiepigonal plants and nine species from epigonal ones. *F. intonsa* was the dominant species in both lupin forms, making up 69.3% and 65.1% of all identified thrips. The second most numerous species, in both lupin forms, was *A. intermedius* (17.5% and 19.5%, respectively). Single individuals of *T. angusticeps* occurred only in the semiepigonal plants, while *T. atratus*, *T. physapus* and *Aptinothrips stylifer* occurred only in epigonal ones.

In 2012, thrips were collected by sweep net from early-sown plants on 19 June. At this date plants were at the full blooming stage. From the semiepigonal form 273 thrips of seven species were identified (Table 4). Almost the same number of insects was found on the epigonal form (262). In this sample ten species of Thysanoptera were identified. In both forms two species dominated (*T. major* and *F. intonsa*). The former made up 46.1% of all collected thrips on the semiepigonal form and 43.9% on the epigonal one. The latter constituted 31.6% and 33.9%, respectively. *A. intermedius* and *T. tabaci* were also numerous in sweep net collection in both forms, but single *T. atratus*, *T. physapus* and *T. fuscipennis* occurred only on the epigonal form. Only a few larvae were found, most of them in samples from epigonal plants.

The second sweep net sample was done 4 July, when plants sown later reached BBCH stage 65. Significantly fewer thrips were collected on this date than on 19 June – 67 (four species) in the semiepigonal form and 105 (six species) in the epigonal one ($F = 3.205$, $df = 3$, $P = 0.038$) (Table 4). In both forms *F. intonsa* was the most abundant species, making up 71.6% and 68.6% of all identified thrips, respectively. The second most numerous species, also in both forms, was *A. intermedius* (22.4% and 25.8%, respectively). *T. atratus* and *T. flavus* were found only in the collected material from the epigonal form.

In the two years of the study using both shaking and sweep net methods a total of 4,151 thrips belonging to 16 species were identified on semiepigonal and epigonal plants of Andean lupin at the full blooming stage. In terms of the feeding group, two species (*A. intermedius* and *A. fasciatus*) were zoophagous, and the rest of the species were phytophagous. In almost all treatments *F. intonsa*, *T. major* and *A. intermedius* were the predominant species. *Thrips tabaci* also occurred in greater numbers. In trials conducted in narrow-leafed lupin in the same location *F. intonsa* and *A. intermedius* were also the most abundant species (Hurej et al. 2014). In recent studies there were no significant differences between numbers of thrips occurring on semiepigonal and epigonal plants sown at the same time. The number of species was changeable, and also not related to specific lupin form or time of sowing.

Table 5. Sex ratio index of the most numerous species.

Shaking method

Species	13 June 2011						20 June 2011					
	T1 A			T1 B			T2 A			T2 B		
	Male	Female	Sr	Male	Female	Sr	Male	Female	Sr	Male	Female	Sr
Frankliniella intonsa	16	47	74.6	19	123	86.6	101	318	75.9	72	304	80.8
Thrips major	4	24	85.7	1	15	93.7	4	20	83.3	4	8	66.6
Aeolothrips intermedius	1	2	66.7	3	6	66.7	13	11	45.8	17	17	50.0

Sweep net method, 7 July 2011

Species	T1 A			T1 B			T2 A			T2 B		
	Male	Female	Sr	Male	Female	Sr	Male	Female	Sr	Male	Female	Sr
Frankliniella intonsa	30	64	68.1	12	33	73.3	2	158	98.7	0	110	100
Frankliniella tenuicornis	0	52	100	0	0	0	0	13	100	0	7	100
Aeolothrips intermedius	19	4	17.4	12	10	45.4	54	21	28.0	21	8	27.6

Shaking method

Species	19 June 2012						3 July 2012					
	T1 A			T1 B			T2 A			T2 B		
	Male	Female	Sr	Male	Female	Sr	Male	Female	Sr	Male	Female	Sr
Frankliniella intonsa	0	86	100	0	116	100	30	212	87.6	36	190	84.1
Thrips major	0	105	100	0	127	100	4	15	78.9	4	12	75.0
Aeolothrips intermedius	45	31	40.8	73	58	44.3	23	28	54.9	32	28	46.7

Sweep net method

Species	19 June 2012						4 July 2012					
	T1 A			T1 B			T2 A			T2 B		
	Male	Female	Sr	Male	Female	Sr	Male	Female	Sr	Male	Female	Sr
Frankliniella intonsa	0	84	100	4	70	94.6	2	44	95.6	16	23	59.0
Thrips major	10	115	92.0	16	98	86.0	0	2	100	0	1	100
Aeolothrips intermedius	13	15	53.6	19	8	30.0	4	9	69.2	12	10	45.4

Explanations: T1 – early-sown plants; T2 – later-sown plants; A – semiepigonal form; B – epigonal form; Sr – sex ratio.

Frankliniella intonsa was the most abundant species noted on Andean lupin irrespective of form or crop sowing date. It is a highly polyphagous flower-dwelling thrips, infesting many dicotyledonous plants belonging to different orders and families (Bournier 1983; Murai 1988; Raspudič et al. 2009; Wang et al. 2010; Pobożniak & Sobolewska 2011). Feeding of this species causes mechanical damage to flowers and fruits. Moreover, it may be a vector of four plant viruses (GRV, INSV, TCSV, TSWV) (Bournier 1983; Riley et al. 2011). In Poland it is one of the commonest and most abundant thrips species, both in natural plant associations and in crops. It was the third most numerous taxon collected on pea cultivars, although it was the second during the flowering period (Pobożniak 2013). Zawirska (1969) found numerous larvae of this species in the flowers of broad bean, and suggested that both this plant and field bean were host plants for *F. intonsa*. This species is considered to be a serious pest in Asian-Pacific areas and in Turkey, where it is harmful to cotton plantations (Atakan & Özgür 2001; Wang et al. 2010). *A. intermedius* and *T. major* were abundant on Andean lupin. They are regarded, like *F. intonsa*, as flower thrips found in a wide range of species (Kirk 1996). The former species is a facultative predator. Its larvae feed mostly on the preimaginal stages of other arthropods. The high presence of adults during the flowering period suggests that they fed on Andean lupin pollen. The latter species prefers plants with white flowers (Kirk 1984).

Sex ratio of the most numerous species

Taking into account both forms of Andean lupin and both methods of thrips collection, the calculated mean sex ratio of *Frankliniella intonsa* was 86.2%, and ranged from 59.0% to 100%. In four of 16 samples only females were found (Table 5). Similar values of this index were calculated for semiepigonal and epigonal plants. Sex ratio varies on different species of host plants (Koppa 1969). In an alfalfa crop in Romania 90.8% females of *F. intonsa* were found (Barbuceanu & Vasiliu-Oromulu

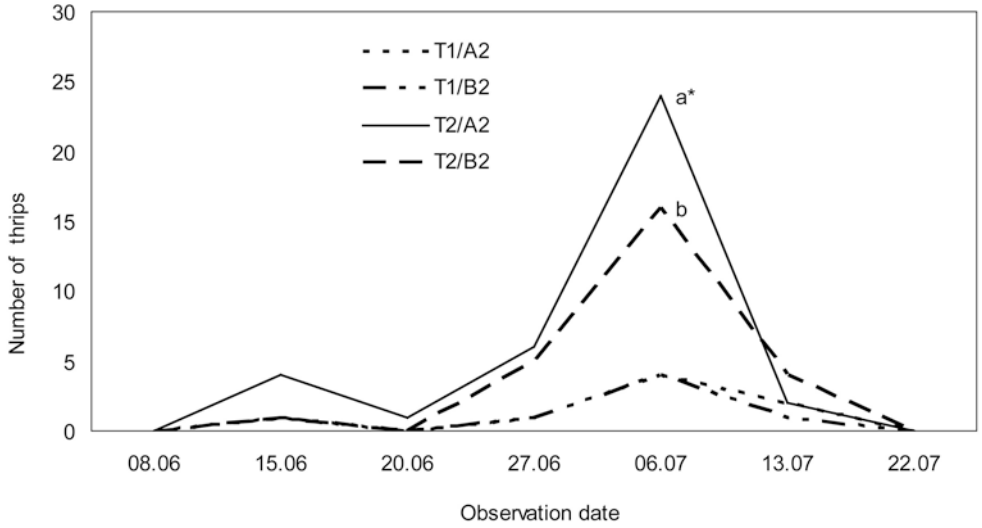

Fig. 1. Seasonal occurrence of thrips recorded on lupin plants in 2011. *Values indicated by different letters differ significantly.

2013). The average sex ratio of this species collected on mountainous meadows by entomological net was 92.4%, and by the shaking method 83.2% (Vasiliu-Oromulu 2002). A lower sex ratio of *F. intonsa* was determined by Šmatas et al. (2013) on winter wheat in Lithuania (60.9%). In the *Thrips major* population mainly females also occurred. The calculated mean sex ratio was 88.4%, and ranged from 66.6% to 100%. In most cases the sex ratio values were similar in both studied forms of Andean lupin. A higher difference in this index was found on 20 June 2011 in plants sown later. In the semiepigonal form the sex ratio reached 83.3%, while in the epigonal one it was 66.6%. Vasiliu-Oromulu (2002) also identified mainly females of *T. major* in collected material from mountainous meadows.

Frankliniella tenuicornis was the only ones found in greater numbers (7 July 2011, sweep net method) and all the collected specimens were females (Tables 2 and 5). This species, feeding mainly on cereals, showed high sex ratio on winter rye (89%) or winter wheat (71.1%) (Šmatas 2009; Šmatas et al. 2013). In the population of *Aeolothrips intermedius* males occurred in greater numbers on both forms of lupin than in the three previously-mentioned species. The average sex ratio of this predatory species was 45.8%, and ranged from 17.4% to 66.7% (Table 5). A similar mean sex ratio of this species (50%) was determined in an alfalfa crop by Barbuceanu & Vasiliu-Oromulu (2013), but it was much higher in mountainous meadows 77.5% (shaking method) and 82.3% (sweep net method) (Vasiliu-Oromulu 2002).

Seasonal changes

In 2011, on early-sown plants only single thrips were observed on both lupin forms. On later-sown plants thrips were more numerous. The first insects were visible in mid June (BBCH 61), but most of them occurred at the end of June and in the first half of July (Fig. 1). The maximum of their population was noticed on 6th July, when plants were at BBCH stage 69–70 (the end of blooming to the first full-grown pods). At the maximum, significantly more thrips were found on semiepigonal plants than on epigonal ones ($F = 5.11$, df = 3, $P = 0.0015$). During this season insects occurred on lupin plants till mid July.

In 2012, the first thrips were found on early-sown lupin at the beginning of the second ten days of June (Fig. 2). They were observed on plants of both forms, mainly at the blooming stage of lupin. As in the previous year, thrips were more numerous on later-sown plants. Their number increased in the second half of June, and reached the maximum at the end of this month (BBCH 65). Significant differences in the number of thrips at the maximum of their population on semiepigonal and on epigonal plants were found. In this season significantly more insects occurred on the epigonal form ($F = 3.09$, df = 3, $P = 0.0258$). In July of this year no thrips were observed on lupin plants.

According to the literature most of the polyphagous species living in temperate climates may complete one or two generations a year (Lewis 1973). The abundance of their populations changed, reaching one or two maxima. The first, lower peak occurs in spring, when the wintering adults colonize plants, and the second, higher peak of abundance is usually recorded in July, which is formed by both the larvae and adults of a new generation (Lewis 1973; Kobro et al. 2000; Hurej & Twardowski 2004; Kucharczyk et al. 2011; Bereś et al. 2013). In our research, thrips occurring in Andean lupin plants, irrespective of the used form of *Lupinus mutabilis*, had one peak of abundance, i.e., the last ten days of June and the first ten days of July. At this time plants were at the blooming stage.

Conclusions

1. *Frankliniella intonsa*, *Thrips major* and the predatory *Aeolothrips intermedius* were the dominant species in the full blooming stage of both semiepigonal and

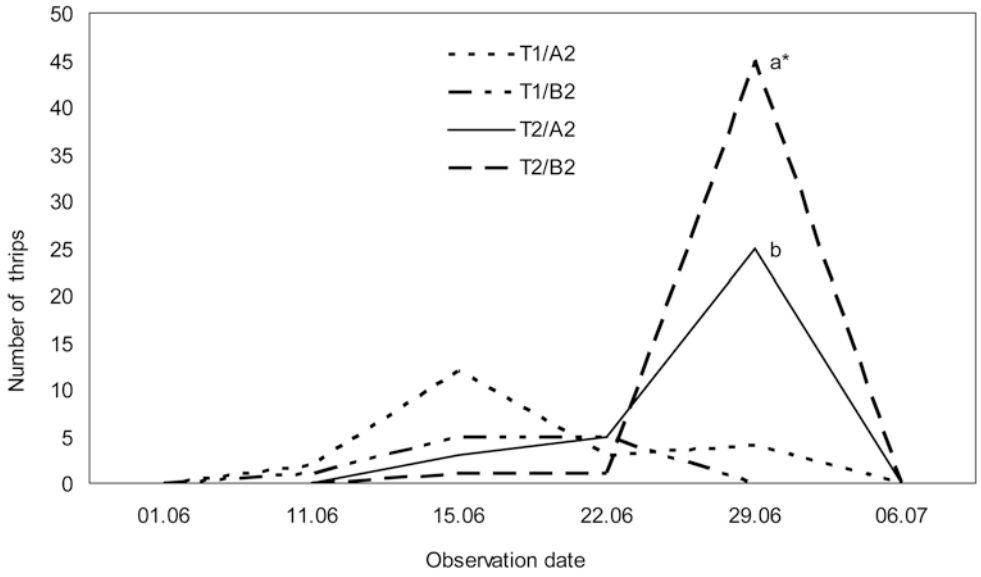

Fig. 2. Seasonal occurrence of thrips recorded on lupin plants in 2012. *Values indicated by different letters differ significantly.

epigonal forms of Andean lupin. *Thrips tabaci* also occurred in greater numbers.

2. There were no significant differences between the numbers of thrips occurring on semiepigonal and epigonal plants sown at the same time. The number of species was changeable, and also not related to specific lupin form or time of sowing.

3. In the most numerous species, like *F. intonsa and T. major*, females mainly occurred in their population. In the population of *A. intermedius* many more males were found, and the mean sex ratio was 45.8%.

4. Thrips occurring in *Lupinus mutabilis*, irrespective of the used form of Andean lupin or time of sowing, had one peak of abundance, i.e. the last ten days of June and the first ten days of July. At this time plants were at the blooming stage.

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References

Atakan E. & Özgür A.F. 2001. Preliminary investigation on damage by *Frankliniella intonsa* to cotton in the Cukurova region in Turkey, Section VII: control strategies, pp. 221–224. In: Marullo R. & Mound L.A. (eds), Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera, 2–7th July, Reggio Calabria, Italy, 390 pp.

Barbuceanu D. & Vasiliu-Oromulu L. 2013. Host associations of Thysanoptera with *Medicago sativa*. Romanian Journal of Biology – Zoology **58 (1):** 19–27.

Bereś P.K., Kucharczyk H. & Kucharczyk M. 2013. Thrips abundance on sweet corn in southeastern Poland and the impact of weather conditions on their populations dynamics. Bulletin of Insectology **66 (1):** 143–152.

Bournier A. 1983. Les thrips. Biologie Importance Agronomique. INRA, Paris, 128 pp. ISBN-10: 2853404641, ISBN-13: 978-2853404648

Caligari P.D.S., Römer P., Rahim M.A., Huyghe C., Neves-Martins J. & Sawicka-Sienkiewicz E.J. 2000. The potential of *Lupinus mutabilis* as a crop, pp. 569–574. In: Knight R. (ed.), Linking Research and Marketing Opportunities for Pulses in the 21st Century, Kluwer Academic Publishers. DOI: 10.1007/978-94-011-4385-1 54

Clements J.C., Sweetingham M.S., Smith L. & Francis G. 2008. Crop improvement in *Lupinus mutabilis* for Australian agriculture – progress and prospects, pp. 244–250. In: Palta J.A. & Berger J.B. (eds), Lupins for Health and Wealth, Proceedings of the 12th International Lupin Conference, Fremantle, Western Australia, 14–18 September, International Lupin Association, Canterbury New Zealand, 551 pp. ISBN: 0-86476-153-8

Ferguson A.W. 1994. Pests and plant injury on lupins in the south of England. Crop Protection **13 (3):** 201–2010. DOI: 10.1016/0261-2194(94)90079-5

Gas M. 2014. Wpływ wybranych czynników agrotechnicznych na rozwój i plonowanie łubinu andyjskiego (*Lupinus mutabilis* Sweet) [The influence of selected agronomic factors on the development and yielding of Andean lupine (*Lupinus mutabilis* Sweet)]. PhD thesis, Wrocław University of Environmental and Life Sciences, 148 pp.

Hatzold T., Elmadfa I., Gross R., Wink M., Hartmann T. & Witte L. 1983. Quinolizidine alkaloids in seeds of *Lupinus mutabilis*. J. Agric. Food Chem. **31 (5):** 934–938. DOI: 10.1021/jf00119a003

He S., Nielsen M.C. & Fagan L.L. 2009. Diversity and seasonal fluctuation of thrips species on yellow tree lupin (*Lupinus arboreus*). New Zealand Plant Protection **62:** 63–68.

Hudson B.J.F., Fleetwood J.G. & Zand-Moghaddan A. 1976. Lupin, an arable food crop for temperate climates. Plant Foods for Man **2 (1/2):** 81–90.

Hurej M., Kucharczyk H., Twardowski J.P. & Kozak M. 2014. Thrips (Thysanoptera) associated with narrow-leafed lupin (*Lupinus angustifolius* L., 1753) intercropped with spring triticale (X *Triticosecale* Wittm. ex A. Camus, 1927). Romanian Agricultural Research **31:** 337–345.

Hurej M. & Twardowski J. 2004. Przylzence (Thysanoptera) wystepujace na pszenzycie jarym uprawianym wspolrzednie z lubinem zoltym [Thrips (Thysanoptera) occurring in spring triticale intercropped with yellow lupine]. Acta Sci. Polon. Agricult. **3 (2):** 263–270.

Kirk W.D.J. 1984. Ecologically selective coloured traps. Ecol. Entomol. **9 (1):** 35–41. DOI: 10.1111/j.1365-2311.1984.tb00696.x

Kirk W.D.J. 1996. Thrips Naturalists' Handbook 25. The Richmond publishing Co. Ltd, 70 pp. ISBN-13: 978-0855463076, ISBN-10: 0855463074

Kobro S., Teksdal A.E. & Andersen A. 2000. Cereals as host plants for thrips (Thysanoptera) in Norway. Norw. J. Entomol. **47 (1):** 1–6.

Koppa P. 1969. The sex index of some species of thrips living on cereals plants. Ann. Entomol. Fenn. **35 (2):** 65–72.

Kucharczyk H., Bereś P.K. & Dąbrowski Z.T. 2011. The species composition and seasonal dynamice of thrips (Thysanoptera) populations on maize (*Zea mays* L.) in southeastern Poland. J. Plant Prot. Res. **51 (3):** 210–216. DOI: 10.2478/v10045-011-0036-6

Lewis T. 1973. Thrips: Their Biology, Ecology and Economic Importance. Academic Press, London, 349 pp. ISBN-10: 0124471609, ISBN-13: 978-0124471603

Murai T. 1988. Studies on the ecology and control of flower thrips, *Frankliniella intonsa* (Trybom). Bull. Shimane Agric. Expt. Stn. **23:** 1–73.

Office of the Gene Technology Regulation 2013. The Biology of *Lupinus* L. (lupin or lupine). Australian Government, Department of Health and Ageing, 64 pp. http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/biologylupin2013-toc/$FILE/biologylupin2013-2.pdf (accessed 01.02.2015)

Petterson D.S. 1998. Composition and food uses of lupins, pp. 353–384. In: Gladstones J.S., Atkins C.A. & Hamblin J. (eds), Lupins as Crop Plants: Biology, Production and Utilization, CAB International Wallingford, UK, 544 pp. ISBN-13: 978-0851992242, ISBN-10: 0851992242

Pitkin B.R. 1972. A revision of the flower-living genus *Odontothrips* Amyot & Serville (Thysanoptera: Thripidae). Bull. Brit. Mus. (Nat. Hist.) Entomol. **26 (9):** 371–402.

Pobożniak M. 2013. The species composition, harmfulness and selected aspects of the occurrence and feeding preference of thrips (Thysanoptera) on pea (*Pisum sativum* L.) cultivars. Zeszyty Naukowe Uniwersytetu Rolniczego im. Hugona Kołłątaja w Krakowie: Rozprawy **514 (391),** 153 pp.

Pobożniak M. & Sobolewska M. 2011. Biodiversity of thrips species (Thysanoptera) on flowering herbs in Cracow, Poland. J. Plant Prot. Res. **51 (4):** 393–398. DOI: 10.2478/v10045-011-0064-2,

Raspudić E., Ivezić M., Brmež M. & Trdan S. 2009. Distribution of Thysanoptera species and their host plants in Croatia. Acta Agricult. Sloven. **93 (3):** 275–283. DOI: 10.2478/v10014-009-0016-y

Riley D.G., Joseph S.V., Srinivasan R. & Diffie S. 2011. Thrips vectors of tospoviruses. J. Integr. Pest Manage. **1 (2):** 1–9. DOI: 10.1603/IPM10020

Rivera M. & Gallegos P. 2001. Plagas del chocho, Capitulo IV. pp. 31–35. In: Caicedo C. & Peralta E. (eds), El cultivo de chocho *Lupinus mutabilis* Sweet: fitonutrición, enfermedades y plagas, en el Ecuador, Boletín Técnico 103, INIAP/FUNDACYT, Quito, Ecuador, 67 pp.

Sawicka-Sienkiewicz E. & Augiewicz J. 2004. Cytogenetics studies of Andean lupin, pp. 79–85. In: van Santen E. & Hill G.D. (eds), Wild and Cultivated Lupins from the Tropics to the Poles, Proc. 10th Int. Lupin Conf., 19–24 June 2002, Laugarvatn, Iceland, 382 pp. ISBN: 0864761236

Stawiński S. & Rybiński W. 2001. Domestication of Andean lupine by means of mutation. 4th European Conference on Grain Legumes, AEP, Kraków, Poland, 223 pp. ISBN: 2950949142

Strassen R. 2003. Die Terebranten Thysanopteren Europas und des Mittelmeer-Gebietes. In: Dahl F. (ed.), Die Tierwelt Deutschlands und der angrenzenden Meeresteile 74, Goecke and Evers, Keltern, 277 pp. ISBN: 3931374580, 9783931374587

Sweetingham M.W., Clements J., Buirchell B.J., Sipsas S., Thomas G., Quealy J., Jones R., Francis C. & Smith C.G. 2006. Preliminary breeding and development of Andean lupin for Australian agriculture, pp. 32–34. In: van Santen E. & Hill G.D. (eds), México, where Old and New World Lupins Meet, Proceedings of the 11th International Lupin Conference. Guadalajara, Jalisco, Mexico, 4–9 May 2005. International Lupin Association, Canterbury, New Zealand, 433 pp. ISBN: 0-86476-165-1

Šmatas R. 2009. Species structure and sex ratio of thrips (Thysanoptera) on winter rye (*Secale cereale*). Zemdirbyste-Agriculture **96 (4):** 260–267.

Šmatas R., Tamosiunas K. & Danyte V. 2013. Diversity and sex ratio of thrips (Thysanoptera) species in winter wheat in Lithuania. Zemdirbyste-Agriculture **100 (3):** 289–292. DOI: 10.13080/z-a.2013.100.037

Vasiliu-Oromulu L. 2002. The dynamics of the sex ratio index of thrips populations in mountainous meadows, pp. 315–324. In: Marullo R. & Mound L.A. (eds), Thrips, Plants, Tospoviruses: The Millennial Review, 2–7th July 2001, Reggio Calabria, Italy, 390 pp. ISBN: 0975020609

Vierbergen G., Kucharczyk H. & Kirk W.D.J. 2010. A key to the second instar larvae of the Thripidae of the Western Palearctic region. Tijdschr. Entomol. **153:** 99–160. DOI: 10.1163/22119434-900000294

Wang C.L., Lin F.C., Chiu Y.C. & Shih H.T. 2010. Species of *Frankliniella* Trybom (Thysanoptera: Thripidae) from the Asian-Pacific Area. Zool. Stud. **49 (6):** 824–838.

Zawirska I. 1969. Fauna of Thysanoptera in flower soft leguminous plants in Poland. Prace Naukowe, Instytut Ochrony Roślin **11 (2):** 41–79.

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