MANAGEMENT OF FIELD MARGIN AIMED AT BENEFITING NATURAL CONTROL OF THRIPS IN STRAWBERRY PLANTS

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Summary: There is some evidence that more diverse agricultural systems may enhance natural control of crop pests. In this paper the interaction crop-weeds is analyzed for the particular case of thrips (Insecta: Thysanoptera) present in the strawberry crop and in the natural vegetation in crop edges. Three types of margins were selected, according to field edge management: 1) ruderal vegetation; 2) natural vegetation with grazing and c) cover crop (*Lupinus luteus* L.). The predators *Aeolothrips* spp. were especially abundant in the crop, followed by the phytophagous *Thrips angusticeps* Uzel. *Lupinus luteus* was found to be a potential source of those predators to the crop. In relation to *T. angusticeps*, specimens were more abundant in the weeds *Andryala integrifolia* L., *Crepis capillaris* (L.) Wallr, and *Ranunculus trilobus* Desf. Considerations about other thrips species/genus presence in the crop and weeds are also presented, aiming a more efficient and sustainable crop protection.

Keywords: Sustainable practices, integrated pest management, ecological based IPM, vegetable crop, biodiversity.

Resumen: ***Gestión de los bordes del cultivo de fresa para beneficiar el control natural de trips***. Es conocido que sistemas agrícolas más diversos pueden mejorar el control natural de las plagas de los cultivos. En este trabajo se analizan las interacciones entre cultivos y malezas para el caso particular de los trips (Insecta: Thysanoptera) presentes en el cultivo de fresa y en la vegetación natural en los bordes del cultivo. Tres tipos de márgenes fueron seleccionados, según la gestión del borde del campo: 1) vegetación ruderal; 2) vegetación natural con pastoreo y

c) cubiertas (*Lupinus luteus* L.). Los depredadores *Aeolothrips* spp. eran especialmente abundantes en el cultivo, seguido por el trips fitófago *T. angusticeps* Uzel. *Lupinus luteus* se encontró como una fuente potencial de aquellos depredadores para el cultivo. En relación con *T. angusticeps*, las muestras fueron más abundantes en las malezas *Andryala integrifolia* L., *Crepis capillaris* (L.) Wallr., y *Ranunculus trilobus* Desf. Consideraciones sobre la presencia de otras especies / género de trips en el cultivo y en las malas hierbas son también presentados, con el objetivo de una protección de los cultivos más eficiente y sostenible.

Palabras clave: Manejo sostenible, control integrado, medidas AgroAmbientales, hortícolas, biodiversidad.

INTRODUCTION

Thysanoptera, also known as thrips, are amongst the insects that cause damages in the strawberry crop, frequently with economic relevance. They are piercing - sucking insects, many of them phytophagous with a particular preference for flowers, owing to pollen and nectar. There is a lack of knowledge about thrips presence and damage in strawberry crop in Portugal with the exception of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), that cause significant losses in this crop. Thrips are more abundant in crops and in the weeds present in their boundaries in late spring, beginning of summer, and may be also very abundant during autumn. Migrations between crops and weeds are frequent (Kirk, 1997; Northfield et al., 2008), especially when plants dry off. There is some evidence that more diverse agricultural systems may enhance natural control of crop pests (Alomar et al., 2008; Dabrowski et al., 2008; Bàrberi et al., 2010; Frank, 2010). In this paper the interaction crop-weeds is analyzed for the particular case of thrips (Insecta: Thysanoptera) present in the strawberry crop and in the natural vegetation in crop boundary.

MATERIAL AND METHODS

Field work was conducted in Amial (N39º09'53,9'' W09º15'20,2''), located about 75 km north from Lisbon, Portugal. Three strawberry fields were selected for sampling weeds and arthropods according to field edge management: B1) ruderal vegetation; B2) natural vegetation with 'grazing' and B3) cover crop (*Lupinus luteus)*. Strawberry plants were at the beginning inside plastic tunnels, and later in open fields (the plastic tunnels were removed during the study). IPM was the control strategy adopted with very few pesticides treatments. Sampling was carried out weekly, from 20 March to 31 July 2013, in a total of 18 sampling dates. In the last three sampling dates, only the crop was sampled, since wild vegetation was mostly dried.

Thrips were captured in strawberry plants (applying the beating technique on two flowers per m^2, along 12 crop rows 8 m long), and in weeds (three plant specimens of each species, collected along a 3 m width strip on the borders, were carried into the lab, where the beating technique was applied).

To determine the distribution of thrips on plant species among the three margin types, multivariate procedure, i.e., Principal Component Analysis (CAP) was used, with 62 plant species and three variables according to field edge management.

RESULTS

Flora margins comprised a total of 98 species distributed among 24 botanical families. The most representative were Poaceae (26 %); Fabaceae (15 %) and Asteraceae (14 %) - Table 1. Other relevant families were Geraniaceae (6 %), Polygonaceae (5 %) Caryophyllaceae (4 %) and Plantaginaceae (4 %).

Table 1. Number of plant species distributed among botanical families and type of margin.

Margin	Asteraceae	Fabaceae	Poaceae
B1	7	8	12
B2	11	11	13
B3	8	10	20
Total	26	28	45

Field edge management: B1) ruderal vegetation; B2) natural vegetation with 'grazing' and B3) cover crop.

The border type B3 had higher species richness, followed by border type B2. Border type B1 had lesser floristic diversity because B2 and B3 were both enriched with a plant mixture with Poaceae and Fabaceae. There was no difference in diversity (Shanon index H') among different borders. However the Eveness index (E) was lower in border type B2 indicating that, albeit high species richness it was dominated by some plant species – Table 2.

Table 2. Floristic diversity in different boundaries.

Biodiversity Indices	B1	B2	B3
S – Species richness	55	61	66
D – Simpson's index	0,03	0,02	0,02
H – Shanon-Wiever index	3,75	3,23	3,91
E – Eveness	0,94	0,79	0,93

Field edge management: B1) ruderal vegetation; B2) natural vegetation with 'grazing' and B3) cover crop.

The relative abundance of thrips (adults) both in the crop and in weeds is registered in Table 3. A total of 761 and 401 thrips were detected, respectively, in the weeds and in the strawberry crop, during the sampling period.

The thrips detected in the strawberry crop included the following taxa: *Anaphothrips sp., Ceratothrips sp., Frankliniella intonsa, F. occidentalis, F. tenuicornis*, *Isoneurothrips australis., Limothrips angulicornis; L. cerealium, Limothrips sp., Melanthrips* sp., *Neohydatothrips* sp., *Tenothrips frici, , T. discolor, Thrips angusticeps, T. atratus, T. flavus, T. major,* and *T. tabaci*; *Aeolothrips tenuicornis* Bagnall; *A. andalusiacus* zur Strassen; *A. citricinctus* Bagnall; *A. intermedius* Bagnall; *A. melici* Bagnall and Tubulifera– Table 4.

Table 3. Thrips abundance in crop and boundary in different strawberry plots.

Thrips genera	Plot 1		Plot 2		Plot 3	
	crop	boundary	crop	boundary	crop	boundary
***Anaphothrips* sp.**	0	0	0	0	0	1
***Aptinothrips* sp.**	0	0	0	3	0	0
Chirothrips manicatus	0	0	0	0	0	2
Chirothrips aculeatus	0	1	0	4	0	3
***Ceratothrips* sp.**	0	0	0	0	1	1
***Frankliniella* sp.**	2	62	3	74	6	43
Isoneurothrips australis	1	1	1	0	0	1
Limothrips angulicornis	0	5	0	19	0	2
Limothrips cerealium	1	0	1	9	3	1
***Megalurothrips* sp.**	0	0	0	0	0	2
***Melanthrips* sp.**	2	0	1	4	1	3
***Neohydatothrips* sp.**	0	5	1	2	0	5
***Odontothrips* sp.**	0	0	0	0	0	1
***Tenothrips* sp.**	1	169	0	122	0	278
***Thrips* sp.**	0	544	3	587	61	736
***Aeolothrips* sp.**	80	1	56	2	117	3
Tubulifera	0	0	0	5	0	1
Larvae	0	9	0	52	1	24

Table 4. Total number of thrips identified per weed species in different crop boundaries.

Species	B1	Species	B2	Species	B3
Andryala integrifolia L	8	*Anacyclus radiatus* Loisel	10	*A. integrifolia*	89
Avena barbata Brot.	29	*Anagallis arvensis* L	3	*Avena sativa* L	4
Bromus catharticus Vahl.	1	*Bromus hordeaceus* L	10	*Briza maxima* L	1
Bromus tectorum L	1	*Chamaemelum mixtum* (L.) All.	11	*B. hordeaceus*	1
Coleostephus myconis (L.) Reichenb. fil	5	*C. myconis*	51	*Capsella rubella* Reuter	18
Fragaria x ananassa Duchesne	87	*Crepis capillaris* (L.) Wallr	12	*C.mixtum*	4
Holcus mollis L	9	*Crepis vesicaria* L.	2	*Cistus monspeliensis* L	1
Hordeum murinum L	2	*Dactylis glomerata* L	5	*C. myconis*	21
Hippochoeris radicata L	1	*Erodium cicutarium* (L.) L´Hér	1	*Cyperus eragrostis* Lam.	1
Lolium multiflorum Lam.	1	*Fragaria x ananassa*	66	*Echium plantagineum* L	3
Lolium rigidum Gaudin	4	*Galactites tomentosa* Moench	1	*Erica ciliaris* L	2
Lythrum hyssopifolia L.	1	*Geranium dissectum* L.	1	*F. x ananassa*	190
Mentha suaveolens Ehrh.	1	*Holcus lanatus* L	2	*H. lanatus*	3
Picris echoides L	6	*H.mollis*	16	*H. mollis*	5
Poa annua L	2	*H. murinum*	27	*Holcus setiglumis* Boiss & Reuter	2
Polypogon monspeliensis (L.) Desf.	13	*H. radicata*	2	*H.murinum*	8
Ranunculus trilobus Desf.	2	*L. rigidum*	18	*L.multiflorum*	8
Rubus ulmifolius Schott.	1	*Lythrum junceum* Banks & Solander	1	*L.rigidum*	1
Rumex conglomeratus Murray	2	*Medicago polymorpha* L.	2	*Lupinus luteus* L	33
Scirpoides holoschoenus (L.) Sojak	1	*Plantago lagopus* L.	1	*L. junceum*	6
Sisymbrium officinale (L.) Scop.	12	*Plantago major* L.	4	*Malva parviflora* L	5
Sonchus oleraceus L.	4	*P. monspeliensis*	16	*M. polymorpha*	3
Torilis arvensis (Hudson) Link	3	*R. trilobus*	39	*Misopates orontium* (L.) Rafin	1
Trifolium pratense L.	3	*Rumex crispus* L.	6	*Phalaris minor* Retz	15
Vicia angustifolia L.	3	*Silene gallica* L.	1	*Poa annua*	1
		S.officinale	8	*Poa trivialis* L	1
		S. oleraceus	1	*P-monspeliensis*	7
		Spergularia purpurea (Presl) G. Don. fil	1	*R.trilobus*	15
		T. arvensis	3	*R. raphanistrum*	5
		Trifolium campestre Schreber	1	*R.conglomeratus*	4
		T. pratense	16	*R. crispus*	2
		Trifolium repens L	4	*S. holoschoenus*	1
		Trifolium resupinatum L	1	*Senecio vulgaris* L	6
		V. angustifolia	5	*S. gallica*	2
				S. oleraceus	2
				S. purpurea	2
				T. arvenses	6
				Trifolium.alexandrinum L	1
				T.campestre	2
				T repens	7
				T.resupinatum	4
				Urtiga urens L	1
				V. angustifolia	13
				Vicia villosa Roth.	9

The most abundant thrips species collected within strawberry crop were: *Aeolothrips* spp. (72.1%) and *Thrips* spp. (20.0%), mainly *T. angusticeps* (78.8%), followed by *T. tabaci* Lindeman (15.0%). *Frankliniella* spp. was 3.0% of all thrips detected, mostly *F. occidentalis* (91.7%). In comparison, the following thrips species were most abundant on boundary plants: *Thrips* spp. (41.9 %), mainly *T. angusticeps* (73.7 %), followed by *T. tabaci* (18.8 %); *Limothrips* spp. (23.7 %) specially *L. cerealium* (94.4 %); Tubulifera (11.3 %); *Aeolothrips* spp. (9.7 %); *Frankliniella* spp. was 3.3% of all thrips detected, mostly *F. occidentalis* (88 %).

Only *Frankliniella occidentalis* has been considered an economic pest on strawberry, in Portugal. In spite of the number of weed species identified in each crop boundary, thrips were always present in 50 % of the species: 62 plant species (20 families) were infested with one or more of the 27 species of thrips. *L. luteus*, just found in the border of plot 3, in the first three sampling dates, before soil incorporation, was the weed species with more abundance of *Aeolothrips* spp. specimens, a mean of one specimen per plant analyzed. These thrips began to be detected in strawberry crop at the fourth sampling date, immediately after *L. luteus* was incorporated in the soil. In relation to *T. angusticeps*, it was more abundant in *Andryala integrifolia* (1.5 specimens per plant), *Crepis capillaris*, and *Ranunculus trilobus* (both with one specimen per plant). No weed species revealed to be a special host of *T. tabaci* or *F. occidentalis*. *Limothrips* spp., with low abundance in the crop, were mainly present in Poaceae (74.9%); most *L. cerealium* was detected in *Polypogon monspeliensis*, followed by *Lolium rigidum*, in eight and four sampling dates, respectively. Tubulifera, not detected in the crop, were mainly identified in three Asteraceae (83.7%): *Andryala integrifolia*, *Chamaemelum mixtum* and *Coleostephus myconis,* which were present in almost the entire sampling period. Plant preference for the most important phytophagous thrips (*Frankliniella occidentalis*, *Thrips angusticeps* and *T. tabaci*) and predator thrips (*Aeolothrips* spp.) was published elsewhere (Mateus et al., 2015).

Boundary 1 (*ruderal vegetation*) proved to have the lowest diversity in plant species (S=55). Fifty percent of the species present were thrips hosts, similar to the other boundaries. Three weeds were most visited by thrips during the crop cycle: *Poaceae: Avena barbata; Polypogon monspelliensis* and *Brassicaceae: Sisymbrium officinale*. However, 43 % of total thrips were most abundant in strawberry crop. In boundary 2 (*natural vegetation with grazing)* the greater number of thrips was associated with *Asteraceae: Anacyclus radiatus* and *Ranunculaceae: Ranunculus trilobus.* Boundary 3 (*cover crop*) was the most diverse in plant species (S=66) most abounding in thrips; a total of 516 thrips visited the weed plants during the crop cycle, 36.8 % of which were also present in the crop. A greater number of thrips were associated with *Andryala integrifolia*; *Capsella rubella; Lupinus luteus* and *Vicia angustifolia*.

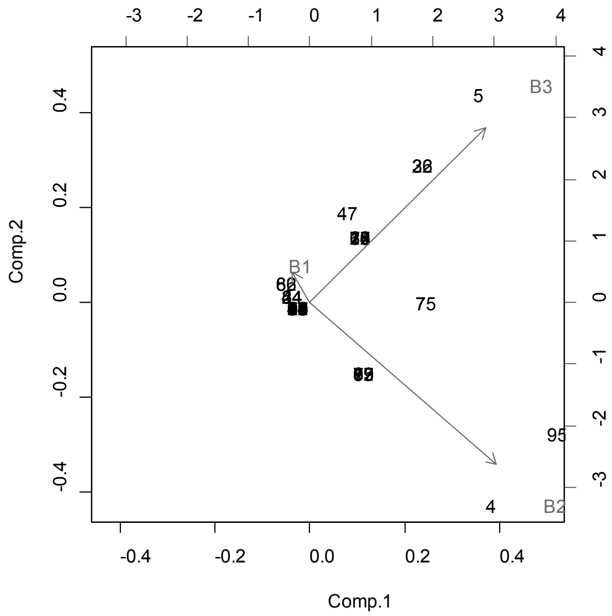

Figure 1. Principal component analysis (PCA) for the relation between the total number of thrips distributed among the 98 plant species within the three crop boundaries: B1) ruderal vegetation; B2) natural vegetation with grazing and B3) cover crop. Species were identified with numbers, for example, *Anacyclus radiatus* (4); *Andryala integrifolia* (5); *Capsella rubella* (20); *Lupinus luteus* (36); *Vicia angustifolia* (47) and *Ranunculus trilobus* (95).

First and second principal components explain 78 % of total variability. The multivariate analysis (Figure 1) showed that the distribution of the number of thrips on the crop boundary was different in the two types B2 and B3. In the boundary B2, the greater the number of thrips were associated with *Anacyclus radiatus* species and *Ranunculus trilobus*. In boundary B3, a greater number of thrips were associated with species *Andryala integrifolia*; *Capsella rubella*; *Lupinus luteus* and *Vicia angustifolia*. Two of this plant species were only present in boundary 3 and the other two species albeit being present in all type of boundaries were more visited by thrips in the boundary 3 (Table 4).

CONCLUSION

These preliminary results (one year experiment) indicate that crop borders enriched with Poaceae and Fabaceae species (B2 and B3) have the highest floristic diversity associated with greater diversity of thrips. In those borders, strawberry crop as lower pressure of these insects, compared to border 1 (ruderal vegetation): the percentage of thrips on strawberry crop was 43%, 18.97% and 36.8% respectively in borders B1, B2 and

B3. Management of enriched borders either by grazing (B2) or mowing of cover crop (B3) also contributes to such reduction. It seems that grazing could be preferable to mowing, as the former allows for a more regular renewing of the flora diversity instead of total removal of flowers of the dominant species (*Lupinus luteus*) in the latter. We conclude that border management (seeding enrichment or cover crop and type and time of mowing) is a major factor in reducing thrips number in strawberry crop.

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