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Activity of alatae aphids landing on open-field pepper crops in Spain

Aktivität und Vorkommen geflügelter Blattläuse auf Freilandpaprika in Spanien

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Summary

Horizontal mosaic-green-tile traps were placed in various pepper-growing areas of Spain: Aranjuez and Arganda del Rey (Madrid), Balboa (Badajoz), Cadreita (Pamplona), Mendavia and Sartaguda (Logroño), Montañana (Zaragoza), Pueblo Nuevo (Valencia) and Torrepacheco (Murcia). These mosaic-green-traps resembled much better the pepper canopy than the commonly used yellow water traps, as indicated by absorbance spectrophotometry. Sampling was extended throughout the pepper crop cycle during 1990, 1991 and 1992. Over that time, 14,363 aphids, belonging to 99 species/taxa were captured. *Aphis* was the principal genus captured:

57.5 % of the total (17 % belonging to the species *Aphis fabae* (Scopoli)). Other abundant species were: *Myzus (Nectarosiphon) persicae* (Sulzer) (7.46 %), *Diuraphis noxia* (Mordvilko) (5.23 %), *Brachycaudus* spp. (3.73 %), *Sitobion avenae* (F.) (2.51 %), *Macrosiphum euphorbiae* (Thomas) (2.46 %), *Rhopalosiphum* spp. (2.20 %) and *Therioaphis* spp. (1.99 %). The species included in the genus *Aphis* were the most abundant in all the regions sampled, although *M. (N.) persicae* was also predominant in the Zaragoza and Pamplona region, and *D. noxia* was frequently found in the Madrid region. A first aphid peak was observed soon after transplanting (May–June) in most of the regions and years sampled.

Key words: Aphids; mosaic-green-tile traps; identification; pepper

Zusammenfassung

Horizontale mosaikgrüne Farbfallen wurden in verschiedenen Paprika-Anbaugebieten in Spanien aufgestellt: Aranjuez und Arganda del Rey (Madrid), Balbao (Badajoz), Cadreita (Pamplona), Mendavia und Sartaguda (Logroño), Montañana (Zaragoza), Pueblo Nuevo (Valencia) und Torrepacheco (Murcia). Diese mosaikgrünen Fallen ähnelten sehr viel besser den Farben des Paprikabestandes als die üblicherweise eingesetzten gelben Wasserfallen wie durch Absorptionsspektrometrie festgestellt wurde. Die Probennahmen erfolgten während der ganzen Wachstumsphasen des Paprikas in den Jahren 1990, 1991 und 1992. In diesen Zeiträumen konnten 14363 Blattläuse gefangen werden, die 99 Arten/Taxa angehörten. Die Gattung *Aphis* wurde mit 57,5 % am häufigsten gefangen, 17 % gehörten zur Art *Aphis fabae* (Scopoli). Andere häufig vorkommende Arten waren: *Myzus (Nectarosiphon) persicae* (Sulzer) (7,46 %), *Diuraphis noxia* (Mordvilko) (5,23 %), *Brachycaudus* spp. (3,73 %), *Sitobion avenae* (F.) (2,51 %), *Macrosiphum euphorbiae* (Thomas) (2,46 %), *Rhopalosiphum* spp. (2,20 %) und *Therioaphis* spp. (1,99 %). Die zur Gattung *Aphis* gehörenden Arten waren in allen beprobten Regionen am häufigsten, obgleich *M. (N.) persicae* in den Regionen Zaragoza und Pamplona auch sehr häufig vorkam. *D. noxia* trat häufig in der Madrider Region auf. Ein erster Höhepunkt des Blattlausaufretens wurde in den meisten Regionen und Jahren schon bald nach dem Auspflanzen (Mai–Juni) beobachtet.

Stichwörter: Blattläuse; mosaikgrüne Farbfallen; Identifizierung; Paprika

1 Introduction

Sweet pepper (*Capsicum annuum* L.) is one of the most important horticultural crops grown in Spain, yielding about 925,000 t per year in 23,000 ha (Anonymous 1999). Pepper exports, especially directed to the European Union have increased very much in the last years. Hence, pepper is one of the most profitable crops grown in Spain both under greenhouse and open-field conditions.

Previous studies show that aphid-borne virus diseases are one of the most threatening factors for pepper production in Spain. The most prevalent aphid-borne viruses found in open-field pepper are *Cucumber mosaic* virus (CMV) and *Potato virus Y* (PVY) (Garcia-Arenal 1992; Soto et al. 1994; Romero et al. 2001). Both viruses are present in all major pepper-growing areas of Spain, such as Badajoz, Logroño, Murcia, Valencia and Zaragoza (Luis 1989). These two viruses are transmitted in a non-persistent manner by several aphid species landing in the crop and making brief superficial probes. Therefore, the progress of the disease in the field depends on the number of vectors alighting and probing in the plants (vector activity) as well as on the natural probability of each aphid vector species to inoculate the virus (vector propensity) (Irwin and Ruesink 1986). The propensity of aphid vectors transmitting CMV and PVY to open-field peppers grown in Israel and Spain has been investigated in the past (Raccah et al. 1985; Perez et al. 1995). However, information on the population dynamics of aphid vectors landing on the major pepper-growing areas of Spain is lacking. Both vector activity and propensity need to be known to predict virus disease outbreaks by means of simulation models, such as the one describing the *Soybean mosaic virus* (SMV) pathosystem (Ruesink and Irwin 1986).

The goal of the current work was to study the activity of the aphid species landing on the major open-field pepper growing areas of Spain during a 3-year consecutive sampling period. The information provided should be useful for construction of simulation models of aphid-borne viruses infecting pepper crops.

2 Material and methods

Horizontal mosaic-green-tile traps similar to the ones described by Irwin (1980) were used at each sampling location. Mosaic-green-tile traps have been used in the past to monitor flying aphids landing in crops such as soybean or melon (Webb and Kok-Yokomi 1993). We examined the suitability of our mosaic-green-tile traps to monitor aphids landing on the pepper canopy. The following solid materials were analyzed by absorbance spectrophotometry (Varian spectrophotometer, Model 2300): a sample of the mosaic-green tile used for aphid trapping, a sample of a yellow water pan trap (Moericke 1951), a CMV-infected pepper leaf, and a non-infected pepper leaf (control). A PVY-infected leaf was not included in the analysis because changes in color with respect to a healthy plant were almost unnoticed to the naked eye. The mosaic-green tiles appeared to have a similar reflectance spectrograph to the one obtained for pepper leaves, as described below. Therefore, the mosaic-green tiles were selected as the most suitable for sampling aphids landing at the level of the pepper canopy.

The mosaic-green-tile traps were filled with a 50 % solution of ethylene glycol and water to preserve specimens and avoid evaporation. The traps were maintained always at a height equal to the top of the pepper canopy in the middle of the field plot. The traps were located during 1990, 1991 and 1992 in pepper fields at the following sites: Balboa (Badajoz), Aranjuez (Madrid), Arganda del Rey (Madrid), Torrepacheco (Murcia), Pueblo Nuevo (Valencia), Montañana (Zaragoza), Cadreita (Pamplona), Mendavia (Logroño) and Sartaguda (Logroño). The sampling period lasted from the establishment of the crop (transplanting) until harvest.

Insect samples were collected weekly from the traps and aphids were separated in the laboratory using a binocular scope (Nikon, SMZ 2T, Nikon Corp. Tokyo, Japan). All aphid specimens were preserved in a 70 % ethanol solution until clarification and identification of the samples. All aphids were prepared and identified using the same methodology as previously described (Perez et al. 1995). A permanent collection of voucher specimens (property of J. M. Nieto, Universidad de León, Spain) was used for verification of certain individuals. Occasionally, when identification of certain aphid specimens was difficult, more than one genus option was proposed.

3 Results

3.1 Reflectance spectrograph of mosaic-green-tile, yellow pan trap and pepper leaves

Figure 1 shows the spectrograph of the mosaic-green-tile, yellow Moericke trap, and pepper leaves (healthy and CMV-infected). This Figure represents the absorbance in arbitrary units as a function of the light wavelength (nm). The spectrograph of pepper leaves resembles well the one obtained for the mosaic-green-tile, except for a slight difference in the peak of maximum absorbance at the 600–700 nm range, that differs in 30 nm to one another (Fig. 1). Conversely, the yellow Moericke trap spectrograph is very different to the one obtained for pepper leaves. Very slight changes were detected between the spectrographs obtained for the CMV-infected and non-infected pepper leaves. Therefore, the reflectance spectrograph of the mosaic-green tiles seem to match much better the pepper canopy than the one of the commonly used yellow water traps.

3.2 Aphid activity

3.2.1 Montañana (Zaragoza)

Most of the aphids (72.9 % of the total) captured in 1990 (Table 1), belong to the *Aphis* genus, being *Aphis gossypii* Govierand *Aphis craccivora* Koch the most abundant. These aphid species are major virus vectors with high propensity for PVY transmission, as indicated in a 3-year study conducted in the Madrid region (Perez et al. 1995). Other predominant genus trapped in Zaragoza were: *Therioaphis* spp., *Brachycaudus* spp., *Myzus (Nectarosiphon) persicae* (Sulzer) and *Diuraphis noxia* (Mordvilko). In 1991, *Aphis* spp. (39.9 %) was also predominant, being *Aphis fabae* Scopoli the most abundant species (Table 1). Other abundant species were *M. (N.) persicae, Rhopalosiphum insertum* (Walker)/*R. padi* (L.), *Brevicoryne brassicae* (L.), *D. noxia, Hyperomyzus lactucae* (L.) and *Acyrthosiphon pisum* (Harris). In 1992, the *Aphis* genus (49.0 %) was by large the most numerous. The most abundant species were *M. (N.) persicae, A. fabae, Sitobion avenae* (F.), *A. craccivora, H. lactucae* and *D. noxia.*

In 1990, one major aphid population peak was observed at the beginning and end of June (35 days after pepper transplant), most of them identified as *Aphis* spp. In 1991 and 1992, a similar peak was obtained at the beginning and at the middle of June, respectively. These last 2 years, *M. (N.) persicae* was also very abundant as well as *Aphis* spp. in the month of June.

3.2.2 Aranjuez and Arganda del Rey (Madrid)

Aphid traps were located in two different locations in the Madrid region: Aranjuez during 1990 and 1991 and Arganda del Rey in 1992. The most abundant genus in 1990 was *Aphis* spp. (57.0 %), being *A. gossypii* the most abundant species. Other species captured were: *D. noxia, Therioaphis* spp., *Brachycaudus* spp., *Hyalopterus pruni* (Geoffroy) and *A. pisum.* The most abundant genus in 1991 was also *Aphis* (46.2 %). Other predominat aphid species were: *Brachycaudus* spp., *Macrosiphum euphorbiae* (Thomas), *Therioaphis* spp., and *M. (N.) persicae.* A larger number of aphids were collected in 1992 (1564 individuals). The most abundant genus was *Aphis* spp. (36 %). The main species identified were: *D. noxia, A. fabae, Hyadaphis foeniculi* (Passerini), *S. avenae, Brachycaudus (Thuleaphis) amygdalinus* (Schouteden), and *M. (N.) persicae.*

In 1990, the first aphid peak was observed soon after transplant (end of May). In 1991, the highest aphid peak was delayed until 30 days after transplant (middle of June). In 1992, an aphid peak was detected at the end of June (45 days after transplant). Most of the aphids collected during the month of June were identified as *Aphis* spp.

Table 1. Aphid species caught using mosaic-green-tile traps placed in pepper fields at different locations in Spain during 1990-1992

	Zaragoza			Madrid			Murcia			Pamplona			Logroño			Valencia		Badajoz				
Species	90	91	92	90	91	92	90	91	92	90	91	92	90	91	92	91	92	90	91	92	Total	%
Acyrthosiphon pisum	8	30	2	31	18	35	2	0	5	12	21	6	5	10	3	11	1	23	5	4	241	1,68
Aphis craccivora	79	31	29	105	56	32	4	1	9	20	13	21	6	14	72	24	3	16	17	23	627	4,37
A. gossypii	81	0	0	282	71	0	25	0	0	20	0	0	13	0	0	0	0	62	0	0	571	3,98
A. fabae	30	174	149	47	52	223	19	62	43	14	49	28	18	63	272	73	2	877	154	30	2451	17,06
A. nasturtii	33	0	0	28	0	0	81	0	0	7	0	0	0	0	0	0	0	29	0	0	208	1,45
A. (Protaphis) spp.	0	12	27	0	25	9	0	5	3	0	8	0	0	4	7	1	2	0	5	4	130	0,91
Aphis spp.	82	174	185	67	234	299	44	136	250	8	146	45	8	92	152	1541	62	20	216	275	4267	29,71
Brachycaudus spp.[1]	0	3	3	0	25	8	0	2	16	0	2	0	0	0	0	7	0	0	0	0	74	0,52
B. helichrysi[2]	0	7	4	0	0	11	0	3	5	0	2	1	0	18	0	6	1	1	1	3	112	0,78
B. amygdalinus	0	10	14	0	0	68	0	16	3	0	4	1	0	3	3	4	0	0	7	4	158	1,10
Brachycaudus spp.	24	1	2	52	63	2	1	1	2	3	0	0	5	4	1	0	0	19	4	2	193	1,34
Brevicoryne brassicae	0	44	2	0	1	12	0	12	25	0	21	1	3	5	1	3	0	1	0	12	145	1,01
Capitophorus elaeagni	2	2	3	6	0	23	1	4	0	8	0	6	0	4	3	3	0	9	0	0	79	0,55
C. hippophaes	0	2	2	0	3	15	0	0	0	0	0	0	0	1	0	3	0	0	6	15	57	0,40
Capitophorus spp.	0	20	9	0	0	3	0	15	43	0	8	0	0	5	0	4	3	0	0	6	116	0,81
Diuraphis noxia	11	43	28	75	4	259	0	8	33	41	22	28	44	19	4	1	0	0	0	1	751	5,23
Hayhurstia atriplicis	0	3	8	23	2	36	2	5	33	2	7	1	0	3	0	0	0	1	6	35	179	1,25
Hyadaphis foeniculi	0	0	0	3	2	137	0	1	9	0	1	1	1	3	0	0	0	1	3	2	165	1,15
Hyalopterus pruni	3	6	0	44	5	25	13	6	7	1	4	1	0	2	0	3	0	6	1	2	178	1,24
Hyperomyzus lactucae	3	39	29	11	15	9	0	10	36	1	25	4	0	14	1	11	0	6	6	6	237	1,65
Macrosiphum euphorbiae	1	31	11	3	40	52	1	0	17	0	20	7	2	28	16	35	0	3	16	56	353	2,46
Metopolophium dirhodum	1	9	1	0	2	8	0	5	1	1	3	3	3	5	31	1	0	2	0	1	77	0,54
Myzus (Nectarosipho) persicae	20	173	162	30	24	66	6	23	40	2	124	17	5	38	53	29	1	6	4	16	1072	7,46
Rhopalosiphum padi[3]	0	48	9	1	5	53	10	5	15	0	14	6	0	3	2	11	0	0	2	1	207	1,44
Rhopalosiphum spp.	2	7	13	3	5	8	6	2	6	8	8	2	2	6	6	8	5	2	5	5	110	0,77
Schizaphis graminum	0	2	7	0	1	30	0	8	22	0	0	0	0	1	1	0	0	0	0	0	72	0,50
Sitobion avenae	5	19	31	3	2	77	0	4	12	1	5	37	6	8	118	5	8	6	3	11	361	2,51
Therioaphis spp.	32	10	3	72	28	15	15	7	10	8	6	1	4	9	1	1	1	8	8	5	286	1,99
Others	1	64	54	33	46	38	3	11	19	3	21	12	4	15	20	27	7	9	31	22	479	3,33
Unidentified	0	14	8	7	211	11	15	13	8	0	8	3	12	6	8	18	0	24	23	11	407	2,83
Total	418	978	795	926	940	1564	241	365	672	160	542	232	141	383	775	1830	96	1131	523	552	14363	100

[1] or *B. (Acaudus) cardui.* [2] or *Brachycaudus* spp., or *Roepkea phlomicola marchali* or *Appelia* spp. [3] or *R. insertum*

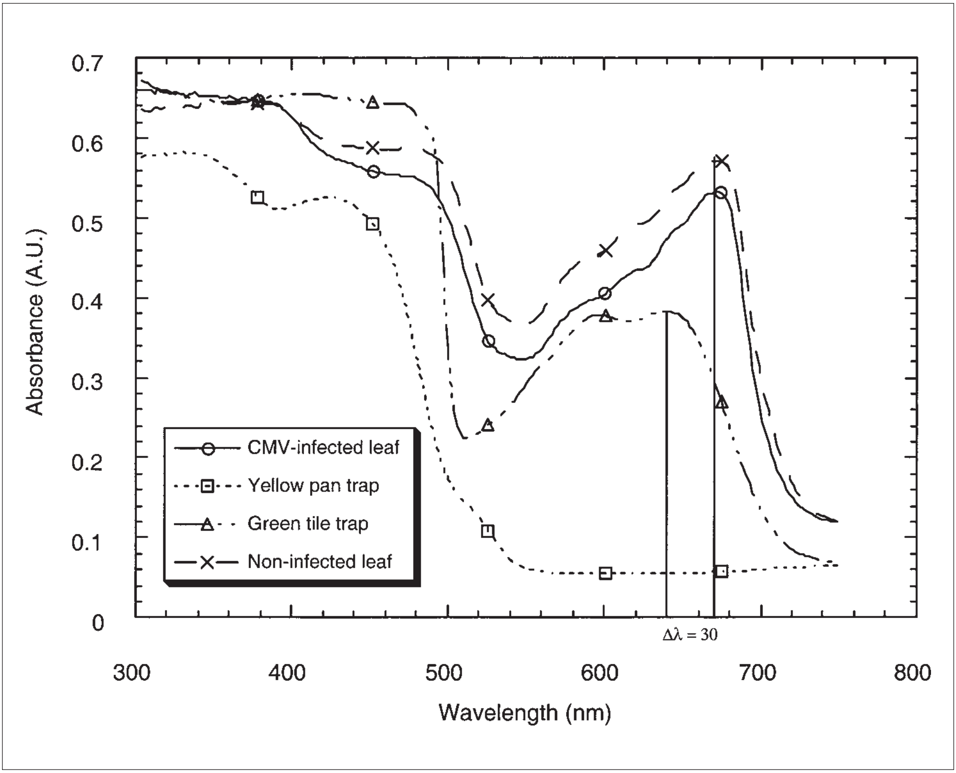

Fig. 1. Absorbance spectrograph of solid samples of the upper-surface of a mosaic-green-tile, a yellow Moericke pan trap, a CMV-infected pepper leaf and a non-infected pepper leaf.

3.2.3 Torrepacheco (Murcia)

Various *Aphis* spp. species were also the most abundant in this area during 1990 (Table 1). The rest of the most abundant species were *Therioaphis* spp., *H. pruni, R. padi* and *M. (N.) persicae.* Most of the aphid species captured in 1991 were identified as *Aphis, M. (N.) persicae, B. (T.) amygdalinus, Capitophorus* spp. and *Brevicoryne brassicae* (L.). In 1992, a similar proportion of each species was captured. In the 3 years, two major peaks were detected, the first one just after transplant (middle of May) and a second one 95 days after transplant (middle of August). The most abundant aphid species during these peaks were classified as *Aphis* spp.

3.2.4 Cadreita (Pamplona)

At this area, the most abundant aphid species landing on the mosaic-green-tile traps in 1990 was *D. noxia* (25.6 %). The rest of the aphids captured were predominantly identified as: *A. gossypii* and *Therioaphis* spp. (Table 1). In 1991, the most abundant genus was *Aphis* followed by *M. (N.) persicae, H. lactucae, D. noxia, A. pisum, B. brassicae* and *M. euphorbiae.* Again, the most abundant aphid species captured in 1992 were *Aphis* spp., *S. avenae, D. noxia, M. (N.) persicae* and *M. euphorbiae.*

In 1990, the most abundant aphid peak occurred at the end of June (22 days after transplant), being *D. noxia* the most numerous species. In 1991, the most abundant species was *M. (N.) persicae* flying soon after transplant (middle of June). In 1992, the peak occurred 42 days after transplant (beginning of July), and the most frequent species was *S. avenae.*

3.2.5 Mendavia and Sartaguda (Logroño)

The trap was located at Mendavia (Logroño) during 1990 and 1991. In 1992, the trap was changed to Sartaguda (Navarra), another locality at the border of the Logroño region. The total number of aphids captured the first year were 141, being *Aphis* (almost 32 %) the most abundant followed by *D. noxia* and *S. avenae* (Table 1). The most frequently aphid species captured in 1991 were *A. fabae, M. (N.) persicae, M. euphorbiae* and *D. noxia.* A larger number of aphids was captured in 1992 (Table 1). Most of them were *Aphis* (64.9 %), being *A. fabae* the most predominant. Others were: *S. avenae, M. (N.) persicae, Metopolophium dirhodum* (Walker) and *M. euphorbiae.*

The highest peak occurred at the end of June (20 days after transplant), both in 1990 and 1992. In 1991, the maximum aphid density was observed immediately after transplant (beginning of June). The most abundant aphid species captured during the periods of highest density were *D. noxia* in 1990, and *A. fabae* in 1991 and 1992.

3.2.6 Pueblo Nuevo (Valencia)

The trap was placed at this location only during 1991 and 1992. Therefore, information on aphid activity during 1990 is lacking at this location. In 1991, a very large number of aphids was captured (Table 1). Almost 90 % of the captures were identified as members of the *Aphis* genus. The rest of the major species present were *M. euphorbiae* and *M. (N.) persicae.* In 1992, very few aphids were captured due to a delay in the date of the establishment of the trap. Many farmers at the Valencia region were unable to grow peppers in 1992 due to an enormous outbreak of *Tomato spotted wilt virus* (TSWV) disease. Therefore, the aphid trap had to be established very late (June 30) because the first seedlings had to be replaced with new plants due to severe virus epidemics. Nevertheless, *Aphis* spp. was the most abundant in 1992, followed by *S. avenae.*

The highest population density was observed immediately after transplanting (beginning of June of 1991). The peak observed in 1992 was obtained at the end of August because the aphid trap was established after the typical aphid peak season in that region. *Aphis* spp. was the most prevalent during both peaks.

3.2.7 Balboa (Badajoz)

Most of the aphids identified in 1990 belonged to the species *A. fabae* (77.5 %) (Table 1). The rest abundant species were other *Aphis* species. In 1991, 75 % of the aphids captured were also identified as *Aphis* spp. Others were *Aploneura lentisci* (Passerini), and *M. euphorbiae.* In 1992, the following species were captured: *Aphis* spp., *M. euphorbiae, H. atriplicis, M. (N.) persicae, Capitophorus hippophaes* (Walker) and *B. brassicae.*

In 1990, the maximum aphid density was observed soon after transplant (end of May), while in 1991 and 1992 the highest peak appeared later (June–July). In all cases, *Aphis* spp. was the most abundant.

4 Discussion

Epidemiological understanding of aphid-transmitted virus diseases in row crops such as pepper requires an appropriate method to monitor vector activity (landing rates). The present work (Figure 1) shows that the spectral characteristics of the mosaic-green-tile traps were very similar to those of pepper leaves and can be used to sample aphids alighting in many crops including pepper, as suggested by Irwin and Ruesink (1986). Furthermore, Boiteau (1990) found out that the rate of capture of aphids by the mosaic-green-tile trap was independent of trap size and gave a good profile of the species landing when sampling in a potato field. The present study also shows that the yellow Moericke trap spectrograph is very different to the one obtained for pepper leaves, suggesting that aphids attracted to these traps may not be the same to those landing on pepper.

It is well known that some aphid species are attracted as much as thirty times as strongly as others are by yellow water traps than by suction traps (Eastop 1955). Suction traps (Johnson and Taylor 1955) as well may not be very effective to determine landing rates on row crops because aphids flying over the crop may not descend and land on the plant canopy. This was the case of a study conducted in potato fields which proved that only 50 % of the species caught in suction traps actually land on the crop (Boiteau 1990). Therefore, mosaic-green-tile traps seem to be more appropriate than yellow water traps or suction traps to determine aphid-landing rates on row crops.

Most of the specimens collected in our mosaic-green-tile traps were alatae virginiparous aphids, although a few apterae were also found. One *M. (N.) persicae* male was found at the trap located at Logroño in 1992. It is known that this species may have holocyclic, androcyclic or anholocyclic populations (Blackman 1974). The presence of *M. (N.) persicae* males in the Logroño region indicates a holocyclic or androcyclic behaviour of this species. Our 3-year study also indicated that the most abundant aphid species landing on open-field pepper crops in Spain were *Aphis* spp. (highest vector activity). The predominant *Aphis* species were *A. fabae, A. craccivora* and *A. gossypii*. In certain locations (Pamplona, Logroño and Madrid), many cereal aphids were captured. The major species were *D. noxia, M. dirhodum, R. padi* and *S. avenae*, probably flying from senescent cereals that are widely grown in the regions mentioned above. Other aphid species *(H. lactucae, M. euphorbiae* and *M. (N.) persicae)* were predominant in regions where horticultural crops are widely grown (Valencia, Murcia, Zaragoza and Badajoz). Certain species collected in our traps were also found in weeds close to the sampled areas (i.e., *H. pruni* was found on *Phragmites* spp. or *H. atriplicis* was found feeding on *Chenopodium album* L. in the Madrid region). Therefore, aphid species alighting in the mosaic-green-tile traps located at different sites may vary depending on the major crops and weeds growing around the sampled areas.

Our results also indicate that many non-colonizer aphid species are able to alight on pepper fields. Several of these species such as *A. fabae, A. gossypii* or *M. euphorbiae* are well-known vectors of CMV (Fritzsche et al. 1972) and PVY (Kennedy et al. 1962). In Spain, disease outbreaks due to CMV or PVY are responsible for heavy losses in certain years (Luis 1989; Soto and Ponz 1991). In 1990, PVY was widely spread in the Badajoz region causing severe losses (this same year we collected up to 877 *A. fabae* specimens in the mosaic-green-tile trap). Therefore, it seems very likely that *A. fabae* (highest vector activity) was the major vector of the virus. In other regions such as Zaragoza or Pamplona, *M. (N.) persicae* seems to play a more important role as virus vector in pepper fields because a large number of individuals was captured. Furthermore, *M. (N.) persicae* is the most efficient vector of PVY in peppers under controlled conditions (Fereres et al. 1993).

Our data indicates that aphid peaks occurred at different times of the year depending on the sampled location. Usually, a first peak was observed soon after transplanting (May–June), although sometimes it was delayed until July in colder regions such as Pamplona or Logroño. Therefore, careful monitoring of aphid flights should be initiated just after transplanting and preventive control actions should be applied before a large number of virus vectors are detected.

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