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Aphid populations (Hemiptera: Aphidoidea) depend of mulching in watermelon production in the Mediterranean region of Croatia

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Abstract

Winged morphs of aphids were investigated under field conditions during 2008, 2010 and 2011 in the Mediterranean region of Croatia. Field experiments were conducted to record aphid diversity and compare polyethylene black mulch to straw mulch and bare soil in terms of their attractiveness to aphid species in a watermelon crop. Aphids were collected weekly using yellow water metal traps from May to July. During the study, 44 species in 31 genera were detected; 36 species in 24 genera were identified in 2008, 18 species in 15 genera were identified in 2010, and 34 species in 25 genera were identified in 2011. The overall seasonal percentage composition showed that *Aphis fabae* Scopoli and *Myzus persicae* (Sulzer) were consistently eudominant species, whereas *Acyrtosiphon pisum* (Harris) was consistently dominant. Cabbage aphid *Brevicoryne brassicae* (L.) was determined as the dominant species in 2008 and as eudominant species in 2011. Additionally, *Macrosiphum rosae* (L.) was twice recorded as the dominant species, whereas *Aphis gossipii* Glover was dominant once, and *Phorodon humuli* (Schrank) was eudominant once. Our study also demonstrated that mulching sporadically affected the abundance of individual species. The attractiveness of mulching for aphid species differed between the treatments. It was found that bare soil was attractive to *A. pisum* and *M. rosae*, black mulch was attractive to *B. helichrysi* and *P. humuli*, and straw mulch was attractive to four aphid species, of which two were eudominant, *A. fabae* and *M. persicae*. The presented species are mostly polyphagous, and their preference for certain mulches can be used in crop protection management.

Additional key words: *Citrullus lanatus;* black polyethylene film; straw; yellow trap.

Introduction

Aphids are important pests of many crops. A number of aphid species have been recorded as Cucurbitaceae crop feeders (Farias-Larios & Orozco-Santos, 1997; Stapleton & Summers, 2002; Summers *et al.*, 2005; Kos *et al.*, 2012). Alate individuals land on crops soon after planting and damage plants directly by feeding on phloem sap.

The non-chemical control of aphids includes the use of coloured mulches because mulch colour may influence the abundance and composition of aphid populations. Coloured mulches create a specific microenvironment around plants (Csizinszky *et al.*, 1995). Compared to bare soil, changes in the microenvironment include alteration in root-zone temperature and in the quantity and quality of light reflected from the mulch surface towards the leaves (Ban *et al.*, 2009). The reflected energy from the mulch affects not only plant growth and development but also the behaviour of insects visiting the plants (Kring & Schuster, 1992). Mulching is a common practice in the field production of watermelons in Croatia, and the most frequently used mulch is black polyethylene film (Goreta *et al.*, 2005).

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Abbreviations used: DAP (days after planting); PE (polyethylene).

During an earlier study on watermelons (Ban *et al.*, 2009), we selected a clear film for an early spring planting because of its effect on the total number of aphids and yield components. Clear mulch could be a practical management tool for reducing aphid populations, increasing yield, and enhancing fruit quality in watermelons under tropical conditions (Farias-Larios & Orozco-Santos, 1997). Döring *et al*. (2004) reported that 15 types of mulch attracted fewer aphids than unmulched soil. Additionally, Walters (2003) showed that white mulch treatment led to higher populations of aphids than an unmulched treatment in summer squash. Kring & Schuster (1992) reported that fewer aphids were present on peppers grown on aluminium – painted mulch than on plants grown on white or black mulches.

Despite ample evidence for an effect of mulch on aphid density in crops, data documenting aphid species' preferences for mulch colour remain rather limited. Aphid fauna on watermelons have been partially investigated in Croatia (Zanic *et al.*, 2009). In the southern coastal region in Croatia, 70 species in 48 genera were detected; 63 species in 42 genera were identified in 2004 (Ban *et al.*, 2009), and 44 species in 31 genera were identified in 2005 (Zanic *et al.*, 2009; Gotlin-Culjak *et al.*, 2011). All species belonged to the Aphididae. The overall seasonal percentage composition showed that *Toxoptera aurantii* (Boyer de Fonscolombe) and *Aphis gossypii* Glover consistently predominated in both years. The four most economically important aphid species that transfer cucurbit viruses, *Acyrtosiphon pisum* (Harris), *Aphis craccivora* Koch, *A. gossypii* and *Myzus persicae* (Sulzer), express different responses to mulch colour (Zanic *et al.*, 2009). Thus, *A. pisum* was present in low abundance on brown mulch, whereas *M. persicae* was most numerous on green mulch and less attracted to black, brown and clear mulches. According to Adlerz & Everett (1968) and Wolfenbarger & Moore (1968), yellow and, to a lesser degree, orange mulches attracted *M. persicae*, whereas aluminium and silver mulches repelled this pest. Döring *et al.* (2004) noted that catches of *M. persicae* in green water traps were highest on bare soil, followed by dark green mulch, and lowest in traps on a white or silver background. The cowpea aphid *A. craccivora* was less attracted to black mulch, whereas the abundance of *A. gossipii* was low in traps over clear mulch (Zanic *et al.*, 2009).

Because the use of polymeric materials presents serious environmental pollution and requires increasing investments in production (due to the cost of materials, and installation and removal of the polyethylene film), alternatives have been examined (Summers *et al.*, 2005). One such alternative is the use of straw mulch as an environmentally friendly traditional material that is easily available, particularly in agricultural areas. The effect of straw mulch on aphid attractiveness is not well documented. Therefore, the aim of this study was to compare the effects of wheat straw mulch, black polyethylene (PE) mulch and bare soil regarding their attractiveness to aphid species.

Material and methods

Experimental site

Field experiments with watermelon [*Citrullus lanatus* (Thunb.) Matsum & Nakai], cv. Farao (S&G Syngenta Seeds-Vegetables, Nederlands/Belgium) were conducted at Valtura-Pula (44° 52' N, 13° 54' E, 10 m elevation) in the Mediterranean region of Croatia during 2008, 2010, and 2011. Pula is situated in Istria, one of the most important vegetable-growing areas in Croatia. The average annual rainfall is 783.8 mm, and the mean annual air temperature is 14.2°C. The experiments were carried on Terra rossa, a type of red clay soil produced by the weathering of limestone and dolomites.

Experimental design and treatments

The treatments (bare soil, black PE film and straw mulches) were arranged in a randomised complete block design with three replications. Seedlings were planted manually at 50 days old, with 2-3 leaves, on 9 May 2008, 17 May 2010, and 5 May 2011. To eliminate soil and foliar pests, the insecticide Actara 25 WG (thiametoksam, Syngenta Agro d.o.o., Croatia) was used to drench the seedlings before planting. The rows were spaced 1.5 m apart, and in-row plant spacing was 1.0 m. Each plot (4.5 m × 10 m) consisted of three rows (1.0 m × 10 m). At each of nine plots, plants in the central row were assessed; the two remaining rows were not assessed to reduce the border effect. However the actual distance between blocks was 1 m, and the plots under each of the three repetitions were spaced 0.5 m apart.

Black PE film, 0.02 mm thick and 120 cm wide (Ginegar Plastics Products Ltd., Kibbutz Ginegar, Israel) was used. The black mulch was applied using mulch-laying equipment, whereas the wheat straw was spread manually at 50 kg per plot in a 20-cm layer.

Cultivation practice

During the early spring of each season, the field was ploughed to a depth of 25-30 cm, and cow manure was added at 40 t ha^{-1}. During the additional plugging with a disc roller, preplant fertiliser 7N-14P_2O_5-21K_2O was applied at 600 kg ha^{-1} and dug into a depth of 20 cm. The herbicide Devrinol 45 FL (napropamid, Pinus TKI d.d., Rače, Slovenia) was incorporated with fertiliser at a concentration of 4 L ha^{-1}. Additionally, during the growth seasons, the watermelon was fertigated weekly with urea (46% N), from planting to the period before fruit harvesting. The plant phenological phase was used as the basis to estimate the rate of nitrogen application according to Hartz & Hochmuth (1996). The rate of N application during basic fertilisation and fertigations was 120 kg ha^{-1} yr^{-1}. Weeds growing between the rows were removed by hand if necessary. To prevent foliar diseases/pests, the fungicide Daconil 720 SC (chlorothalonil, Syngenta Agro d.o.o., Croatia) was sprayed 10 days after planting (DAP), and a combination of the fungicide Stroby (krezoxim-methyl, Chromos Agro d.d., Croatia) with insecticide Actara 25 WG was applied on 30 DAP.

Aphid sampling

Aphids were sampled using Moericke yellow water pan traps, which were placed in the middle of the centre row in each plot. Water was added to the pans during the week depending on environmental conditions. Nine traps were used. The traps were installed at the date of planting and observed every day to determine initial aphid flight prior to the first sampling. Insect samples were collected from the pans once a week until the mulches were covered by the plant canopy. Sampling started during the second half of May. Six samplings were conducted in 2008, five in 2010 and five in 2011. The collected material was inspected, and aphids were separated out using a stereomicroscope (Zeiss, Stemi 2000). Aphid specimens were preserved in plastic vials containing 70% ethanol until identification.

Identification and abundance of species

To identify aphid species and their abundance on watermelon, winged adult aphids were identified and counted according to taxonomic keys (Taylor, 1980; Blackman & Eastop, 1994, 2000). The number of individuals of each species per trap was recorded to determine the effect of PE, organic mulch, or bare soil on the number of aphid species for each of the sampling dates and for the season as a whole.

The dominance rate (D_i) was calculated as a percentage of the individuals of a given species in the sample according to following formula: $D_i = n_i / N \cdot 100\%$; n_i is the number of individuals of species i, and N is the total number of individuals in the sample. The results are presented according to Tischler's scale (Tischler, 1949), as eudominant, dominant, subdominant, recedent and subrecedent.

Aphid species comprising more than 5.0% of the total population in the trap, even those recorded on only one sampling date, were considered dominant and subjected to statistical analysis.

Statistical analyses

The data were analysed by analysis of variance (ANOVA) using StatView statistical software (StatView for Windows; SAS Inst. Inc. Vers. 5.0). Following a significant F-test, the means were compared using the LSD-test at $p \leq 0.05$.

Results

Aphid species composition

During the aphid population study, 44 species in 31 genera were detected; 36 species in 30 genera were identified in 2008 (Table 1), 18 species in 15 genera were identified in 2010 (Table 2), and 34 species in 25 genera were identified in 2011 (Table 3). All of the identified species belonged to the Aphididae.

The overall seasonal percentage composition showed that *Aphis fabae* Scopoli (30.54% in 2008, 46.25% in 2010 and 30.75% in 2011) and *M. persicae* (11.16% in 2008, 28.35% in 2010 and 10.42% in 2011) were consistently eudominant species, whereas *A. pisum* (6.13% in 2008, 6.43% in 2010, and 7.69% in 2011) was consistently dominant. The cabbage aphid *Brevicoryne brassicae* (L.) was determined as the dominant species (7.29%) in 2008 and as a eudominant species (18.65%) in 2011. Additionally, *Macrosiphum rosae* (L.) was twice recorded as the dominant species (6.13% in 2008 and 5.95% in 2011), whereas

Table 1. Dominance of aphids in 2008 (%)

Aphid species	YWT[a] 1	YWT 2	YWT 3	YWT 4	YWT 5	YWT 6	YWT 7	YWT 8	YWT 9	Dominance	Results[b]
Acyrtosiphum pisum	7.6	6.9	5.1	3.6	8.5	7.8	4.8	4.6	6.4	6.13	Dominant
Anoecia corni	1.5	0.0	2.6	0.3	0.8	0.1	1.3	2.1	0.5	1.04	Recedent
Aphis fabae	27.4	26.7	23.7	33.4	22.1	33.2	33.7	38.8	35.9	30.54	Eudominant
Aulacorthum solani	3.7	0.0	4.5	2.5	1.7	1.4	2.3	1.0	1.0	2.02	Subdominant
Brachycaudus cardui	1.4	0.0	3.6	1.7	2.0	1.6	2.0	1.4	0.4	1.55	Recedent
Brachycaudus helichrysi	2.8	3.9	2.7	2.9	2.0	4.2	2.7	2.7	3.0	3.00	Subdominant
Brevicoryne brassicae	6.3	12.8	7.3	5.2	6.7	7.8	5.8	9.3	4.4	7.29	Dominant
Capitophorus horni	0.5	0.0	0.1	0.7	0.7	0.0	1.0	0.3	0.5	0.42	Subrecedent
Cavariella aegopodii	0.6	3.9	2.4	1.8	2.5	3.3	3.1	3.3	7.2	3.12	Subdominant
Cavariella theobaldi	0.8	0.3	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.13	Subrecedent
Chaitophorus leucomelas	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.10	Subrecedent
Chaitophorus populeti	0.3	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.08	Subrecedent
Cryptomyzus ribis	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.05	Subrecedent
Drepanosiphum dixoni	0.0	0.0	0.0	0.0	0.0	0.7	1.6	0.0	0.0	0.25	Subrecedent
Dysaphis plantaginea	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.05	Subrecedent
Elatobium abietinum	1.5	0.0	0.7	0.6	1.2	0.0	0.0	0.2	1.4	0.63	Subrecedent
Eriosoma ulmi	0.2	0.0	0.0	1.3	0.0	0.0	0.8	0.0	0.5	0.31	Subrecedent
Eucalipterus tiliae	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.04	Subrecedent
Hyalopterus pruni	2.2	1.5	1.4	2.0	1.2	1.6	1.1	1.0	2.2	1.59	Recedent
Hyperomysus lactucae	2.9	4.4	3.0	1.3	1.3	0.8	5.0	1.7	2.9	2.60	Subdominant
Macrosiphum euphorbiae	3.1	0.8	1.5	3.6	2.4	2.0	1.3	2.0	1.7	2.07	Subdominant
Macrosiphum rosae	4.3	5.6	5.2	6.6	11.4	6.2	6.3	4.7	4.9	6.13	Dominant
Metopolophium dirhodum	0.7	1.4	0.7	1.7	2.2	3.1	1.1	0.4	1.2	1.39	Recedent
Myzus ascalonicus	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.02	Subrecedent
Myzus persicae	8.1	11.3	10.1	12.2	11.7	11.2	10.4	12.9	12.5	11.16	Eudominant
Pemphygus sp.	0.0	0.0	0.0	0.2	0.0	0.0	1.3	0.0	0.0	0.17	Subrecedent
Periphyllus californiensis	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.5	0.21	Subrecedent
Phorodon humuli	18.3	15.9	16.1	11.1	10.3	4.5	7.4	9.7	7.1	11.21	Eudominant
Phyllaphis fagi	0.7	1.0	3.6	0.5	3.9	2.3	0.7	0.0	0.0	1.40	Recedent
Pterocalis alni	0.0	1.4	0.5	1.4	0.7	0.0	0.0	0.0	0.0	0.43	Subrecedent
Rophalosyphum padi	0.0	0.2	0.2	0.6	0.7	0.0	1.2	0.0	0.0	0.33	Subrecedent
Sitobion avenae	3.5	1.7	3.1	3.2	3.5	3.8	3.1	2.5	4.0	3.16	Subdominant
Sitobion fragariae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.04	Subrecedent
Tetraneura sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.02	Subrecedent
Therioaphis trifolli	1.3	0.0	1.2	0.8	2.0	2.4	0.8	1.4	1.9	1.30	Recedent
Tinocallis sp.	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	Subrecedent

[a] YWT: yellow water trap. [b] Eudominant species > 10%; dominant species 5-10%; subdominant species 2-5%; recedent species 1-2%; subrecedent species < 1%.

A. gossipii was dominant once (5.41% in 2011) and *Phorodon humuli* (Schrank) was eudominant once (11.21% in 2008).

Mulch comparison according to aphid numbers

The differences in the numbers of all winged aphids between bare soil, black PE mulch and straw mulch were not significant in 2008 and 2010 with respect to each individual sampling date and the season taken as a whole.

During the season of 2011, black PE mulch was the most attractive to all aphid populations at two assessment periods, 23 May and 6 June, whereas straw mulch was more attractive than bare soil on 23 May (Table 4).

Mulch comparisons according to aphid species response

The aphid species identified during the three seasons are shown in Tables 1, 2, and 3. Species represented by more than 5% of the total weekly or overall

Table 2. Dominance of aphids in 2010 (%)

Aphid species	YWT[a] 1	YWT 2	YWT 3	YWT 4	YWT 5	YWT 6	YWT 7	YWT 8	YWT 9	Dominance	Results[b]
Acyrtosiphum pisum	2.5	6.2	8.5	5.4	10.3	13.1	2.6	4.8	4.5	6.43	Dominant
Anoecia corni	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.15	Subrecedent
Aphis fabae	57.2	36.2	59.3	50.3	44.9	26.2	38.5	56.5	47.2	46.25	Eudominant
Aphis gossypii	5.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.73	Subrecedent
Aulacorthum solani	0.0	0.0	0.0	0.0	3.7	0.0	6.8	0.0	0.0	1.18	Recedent
Brachycaudus helichrysi	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.08	Subrecedent
Brevicoryne brassicae	0.6	1.5	0.0	0.7	2.8	0.0	8.5	0.0	1.1	1.70	Recedent
Capitophorus horni	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.15	Subrecedent
Hyperomysus lactucae	1.9	3.8	3.4	2.0	1.9	0.0	2.6	0.0	0.0	1.73	Recedent
Macrosiphum rosae	4.4	4.6	0.0	5.4	3.7	3.3	0.0	0.0	9.0	3.39	Subdominant
Myzus cerasi	0.0	0.0	0.0	0.0	1.9	3.3	0.0	0.0	0.0	0.57	Subrecedent
Myzus persicae	17.0	43.8	28.8	22.4	20.6	16.4	35.9	38.7	31.5	28.35	Eudominant
Periphyllus californiensis	0.0	0.0	0.0	1.4	5.6	11.5	0.0	0.0	0.0	2.05	Subdominant
Pterocalis alni	1.3	0.0	0.0	2.7	0.0	0.0	2.6	0.0	2.2	0.98	Subrecedent
Rophalosyphum insertun	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.18	Subrecedent
Rophalosyphum padi	6.3	0.0	0.0	0.7	0.9	3.3	0.0	0.0	0.0	1.24	Recedent
Sitobion avenae	3.1	2.3	0.0	4.8	2.8	19.7	0.0	0.0	3.4	4.01	Subdominant
Therioaphis rhiemi	0.6	0.0	0.0	0.7	0.9	1.6	2.6	0.0	1.1	0.84	Subrecedent

[a] YWT: yellow water trap. [b] Eudominant species > 10%; dominant species 5-10%; subdominant species 2-5%; recedent species 1-2%; subrecedent species < 1%

seasonal catch per trap were analysed to compare their response to bare soil, black PE or straw mulch.

Aphid species for which significant differences were detected between the treatments per sampling date and regarding the overall seasonal number are shown in Table 5.

A difference in the number of pea aphids, *A. pisum,* captured in the pans between the treatments was found in 2010. Traps on soil captured more pea aphids than traps on black mulch on 25 May and on straw mulch on 21 June; this finding was confirmed during analysis of the overall season data.

Differences in the abundances of the black bean aphid *A. fabae* between treatments were recorded in all three years. On 2 June 2008, straw and soil attracted more individuals of *A. fabae* than black mulch. The same effect of straw mulch was confirmed on 23 June. Analysis of the overall season data also showed that straw mulch is an attractive mulch for *A. fabae*. The attractiveness of both mulches, plastic and organic, to *A. fabae* was recorded once in 2010 (14 June). A similar trend was revealed on 23 May in 2011, as confirmed by the data for the entire season. Black mulch, in particular, caught the highest number of *A. fabae* on 6 June.

The number of *Brachycaudus helichrysi* (Kaltenbach) was higher on mulches than on bare soil once in 2008, on 19 May. The mulches were attractive to sowthistle aphid, *Hyperomyzus lactucae* (L.), once, on 19 May 2008. Traps on mulches captured fewer *Macrosiphum rosae* than traps on uncovered soil, as noted on 16 June 2008. Furthermore, straw mulch attracted the greatest number of peach aphids *M. persicae* on 2 June 2008. Based on the last assessment of the year (23 June), during the period when the aphids' population density was low, bare soil attracted more *M. persicae* individuals than straw or black mulch. The attractiveness of straw mulch to *M. persicae,* which was recorded at the beginning of June during the period of high aphid population density, was not statistically confirmed by the seasonal data, although the greatest total number of individuals was collected in the traps on straw mulch. Additionally, the damson hop aphid, *Phorodon humuli,* exhibited an affinity for black mulch at the beginning of June 2008.

Discussion

In total, 44 aphid species were identified from the traps in the watermelon field at Pula. Compared to aphid fauna (70 species) recorded on watermelons at Opuzen (Ban *et al.*, 2009; Zanic *et al.*, 2009; Gotlin-Culjak *et al.*, 2011), the species composition at Pula was different, and fewer species were identified.

The list of Croatian aphidofauna, which was completed in 2002, includes 199 aphid species, which are

Table 3. Dominance of aphids in 2011 (%)

Aphid species	YWT[a] 1	YWT 2	YWT 3	YWT 4	YWT 5	YWT 6	YWT 7	YWT 8	YWT 9	Dominance	Results[b]
Acyrtosiphum pisum	4.6	5.8	7.9	15.0	13.1	1.5	9.1	5.6	6.6	7.69	Dominant
Anoecia corni	2.7	0.0	1.3	1.4	2.8	0.0	0.0	0.0	0.9	1.01	Recedent
Anuraphis sp.	0.2	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.40	Subrecedent
Aphis fabae	29.3	38.9	43.7	25.9	25.4	0.0	34.4	40.5	38.5	30.75	Eudominant
Aphis gossipii	1.1	3.2	0.3	0.0	6.4	28.4	4.3	0.3	2.3	5.41	Dominant
Aulacorthum solani	0.0	0.0	0.0	0.0	1.8	33.7	0.0	0.0	0.3	3.97	Subdominant
Brachycaudus helichrysi	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.6	0.0	0.21	Subrecedent
Brachycaudus schwarzi	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	1.1	0.13	Subrecedent
Brevicoryne brassicae	19.5	23.8	13.6	26.7	21.6	0.0	16.3	18.4	27.9	18.65	Eudominant
Callipterinella minutissima	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	Subrecedent
Cavariella aegopodii	0.0	0.5	0.0	1.1	1.4	0.0	0.0	0.3	1.4	0.53	Subrecedent
Chaitophorus leucomelas	0.2	0.0	0.3	0.0	0.0	0.0	1.0	0.0	0.3	0.19	Subrecedent
Cinara sp.	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.15	Subrecedent
Drepanosiphum dixoni	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.12	Subrecedent
Forda formicaria	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.15	Subrecedent
Hyalopterus pruni	0.0	0.0	3.7	0.0	0.7	1.1	1.0	0.0	0.0	0.72	Subrecedent
Hyperomysus lactucae	1.9	1.1	0.3	0.0	0.0	7.6	1.9	0.0	0.3	1.45	Recedent
Macrosiphum euphorbiae	0.8	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.3	0.30	Subrecedent
Macrosiphum rosae	8.6	9.8	4.2	2.2	7.1	0.0	5.3	9.2	7.2	5.95	Dominant
Myzus ascalonicus	0.6	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.32	Subrecedent
Myzus cerasi	0.4	0.0	0.0	0.0	1.4	9.8	1.0	0.0	0.0	1.40	Recedent
Myzus certus	0.0	0.5	0.0	0.0	0.7	1.1	0.0	0.0	0.0	0.26	Subrecedent
Myzus persicae	14.8	7.7	14.9	13.4	8.1	0.0	12.9	14.2	7.8	10.42	Eudominant
Pemphigus sp.	2.1	0.0	0.0	2.2	0.7	0.0	0.0	0.6	0.6	0.69	Subrecedent
Periphyllus californiensis	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.14	Subrecedent
Phorodon humuli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.1	0.22	Subreceden
Phyllaphis fagi	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.6	0.15	Subrecedent
Rhopalosiphum insertum	0.4	1.3	0.0	0.6	1.1	2.3	3.3	0.6	0.0	1.06	Recedent
Rophalosyphum padi	2.7	1.6	2.9	3.1	1.1	1.9	1.9	4.2	0.3	2.17	Subdominant
Sitobion avenae	6.5	2.1	2.4	3.3	4.6	0.0	7.7	2.2	2.9	3.52	Subdominant
Sitobion fragariae	0.6	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.23	Subrecedent
Therioaphis rhiemi	1.0	1.9	0.8	2.2	1.4	0.0	0.0	1.4	0.0	0.96	Subrecedent
Therioaphis trifolli	0.0	1.9	0.0	0.0	0.7	0.0	0.0	0.6	0.0	0.35	Subrecedent
Toxoptera aurantii	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	Subrecedent

[a] YWT: yellow water trap. [b] Eudominant species > 10%; dominant species 5-10%; subdominant species 2-5%; recedent species 1-2%; subrecedent species < 1%.

categorised into 3 families, 10 subfamilies, 16 tribes and 84 genera (Gotlin-Culjak & Barcic, 2002). According to Tsitsipis *et al*. (2007), the Greek aphidofauna comprised 301 species in 2007. Wallis *et al.* (2005) identified 42 aphid species on peaches, also a monoculture crop, in orchards in Pennsylvania (USA) over two years.

Pula is situated in the westernmost county of Croatia, which is characterised by a slightly colder climate than in Opuzen, which is situated in the delta of

Table 4. Number of winged aphids per trap in watermelon grown on bare or mulched soil during spring and overall season in 2011

Treatment	16 May	23 May	30 May	6 June	13 June	Season
Bare soil	38.3[a]	2.0[a]	101.0[a]	65.7[a]	76.3[a]	302.0[a]
Black PE mulch	44.0[a]	97.7[c]	84.3[a]	105.3[b]	97.3[a]	427.3[a]
Straw mulch	61.3[a]	60.7[b]	92.7[a]	47.3[a]	43.0[a]	305.0[a]

Means within a column followed with different letters are significantly different at $p \leq 0.05$ by LSD test.

Table 5. Number of aphid individuals per yellow water trap in watermelon grown on bare or mulched soil during 2008, 2010 and 2011

Aphid species	Treatment		
	Bare soil	Black PE mulch	Straw mulch
2008			
19 May			
Brachycaudus helichrysi	6.3[a]*	19.3[b]	17.7[b]
Hyperomysus lactucae	9.0[a]	1.0[ab]	26.3[b]
2 June			
Aphis fabae	81.0[b]	53.3[a]	73.3[b]
Myzus persicae	10.3[a]	8.3[a]	28.0[b]
Phorodon humuli	18.3[a]	40.3[b]	18.7[a]
16 June			
Macrosiphum rosae	13.3[b]	3.3[a]	1.7[a]
23 June			
Aphis fabae	1.0[a]	4.3[a]	5.0[b]
Myzus persicae	2.3[b]	0.0[a]	1.0[a]
Overall season			
Aphis fabae	250.6[ab]	197.3[a]	329.6[b]
2010			
24 May			
Acyrtosiphum pisum	3.7[b]	0.7[a]	1.7[ab]
14 June			
Aphis fabae	1.3[a]	3.7[b]	2.3[ab]
21 June			
Acyrtosiphum pisum	5.3[b]	2.3[ab]	0.0[a]
Overall season			
Acyrtosiphum pisum	9.0[b]	5.6[a]	3.3[a]
2011			
23 May			
Aphis fabae	9.0[a]	59.0[b]	38.0[ab]
6 June			
Aphis fabae	7.3[a]	31.3[b]	7.0[a]
Overall season			
Aphis fabae	80.0[a]	155.7[b]	117.0[ab]

Means within rows followed with different letters are significantly different at $p \leq 0.05$ by LSD test.

the river Neretva, in the southern coastal region. In addition to climatic conditions, the composition of aphid species recorded on watermelons in this area might be influenced by the adjacent landscape, which contains a different variety of cultivated and wild host plant species. Some main differences in species composition exist between the two Croatian locations, *e.g.,* cotton aphid *A. gossypii* is one of two predominant species in Neretva valley and has been classified as a eudominant species (Ban *et al.,* 2009; Zanic *et al.,* 2009), whereas its presence at Pula in 2010 and 2011 was of minor importance and determined it as a subrecedent species. Similarly, the black bean aphid, *A. fabae,* was consistently predominant at Pula (dominance > 30%) during three years, whereas its dominance in Neretva valley was approximately 5%. The green peach aphid, *M. persicae,* was more dominant at Pula than at Opuzen. Additionally, the ratio of genera *Macrosiphum*, in particular the species *M. rosae*, was higher in the aphid fauna at Pula.

A comparison of the number of all aphids in yellow water traps on bare soil, black PE film, and straw revealed no differences in 2008 and 2010 at Pula. Ban *et al*. (2009) recorded a similar trend while comparing coloured mulches in watermelon plots at Opuzen during the spring season of 2004. At both locations, the numbers of aphids captured during the sampling period were too variable to detect any differences between the mulches. The results were obtained under field conditions and are most likely linked to aphid biology and ecology, sampling date and season, and the influence of environmental factors, which are particularly characterised by the temporal wind pressure. During the season of 2011, two assessments at Pula demonstrated the attractiveness of black PE mulch to aphid populations. According to Döring *et al*. (2004), high numbers of winged aphids were captured in traps on dark backgrounds (black and dark green). While studying the effect of coloured mulches on pest populations, Farias-Larios & Orozco-Santos (1997) found that aphids were most numerous on bare soil and black mulch. Kring & Schuster (1992) found that traps on black mulch collected more aphids than traps on aluminium plastic film or aluminium-painted film in bell pepper crops.

In this study, the abundance of 13 species, represented by more than 5% of the total aphid population per trap, were compared during the spring over three years. Among these species, seven exhibited differential responses to background colour at least once during the experiment or within the overall season catch. For the comparison, 13 species that were dominant in 2004 and 16 species that were dominant in 2005 exhibited differences in distribution among various coloured PE mulches at one or more assessments at Opuzen (Zanic *et al.,* 2009). In watermelons at Pula, the number of *A. pisum* was greatest on bare soil in 2010. A comparison of coloured mulches within the study conducted at Opuzen (Zanic *et al*., 2009) showed that clear and white plastic mulches were attractive to *A. pisum*. In this study, mulches were also not attractive to *M. rosae*. Furthermore, a black mulch was found attractive for *B. helichrysi* and for *P. humuli* at Pula. The response of *B. helichrysi* to black mulch is consistent with data obtained in 2005 by Zanic *et al*. (2009).

Within this study, the most abundant species was the black bean aphid. Straw was determined as the most attractive mulch to *A. fabae* in 2008. During two other seasons, both mulches caught more aphids than bare soil. In our previous study (Zanic *et al*., 2009), the overall seasonal number for *A. fabae*, calculated for the entire year of 2004, was highest on black mulch. The attractiveness of black and straw mulches for *Aphis* spp. was also reported by Döring *et al*. (2004). Furthermore, the attractiveness of straw mulch for *M. persicae* was observed at Pula in 2008 at a time close to the aphid population maximum, whereas the attractiveness of bare soil was noted during the period of aphid population decrease. According to Döring *et al*. (2004), who compared 15 coloured backgrounds with bare soil, *M. persicae* was most numerous on bare soil, followed by dark green mulch, whereas straw mulch collected more aphids than black mulch. Our previous results (Zanic *et al*., 2009) also found that green mulch was the most attractive for *M. persicae*. According to Adlerz & Everett (1968) and Wolfenbarger & Moore (1968), yellow and, to a lesser degree, orange mulches attracted *M. persicae*. Straw mulch was also attractive to the sowthistle aphid *H. lactucae* in this study, whereas white and green mulches were selected as attractive to this species in Zanic *et al*. (2009).

In addition to its attractiveness for predominant aphid species, straw mulch affects watermelon vegetative growth and yield (Ban *et al*., 2010). Thus, watermelon grown on straw mulch achieved the lowest yield, fruit mass and fruit number because it slowed vegetative growth.

In addition to feeding on plants, some aphids transmit one or more virus diseases. Although aphid-borne viruses of cucurbits were not the subject of the present study, the presence of *A. pisum*, *A. craccivora*, *A. gossypii* and *M. persicae* in the Istrian area during the experimental periods could be important factor in the spread of cucurbit viruses (Castle *et al.*, 1992; Basky *et al.*, 2001; Katis *et al.*, 2006). Aphid-transmitted viruses in cucurbits have been poorly investigated in Croatia; *Cucumber mosaic cucumovirus* (CMV) occurs sporadically on cucurbits although it has not been yet documented.

In summary, this work contributes to the knowledge of entomofauna in Mediterranean Croatia. The composition of aphidofauna on watermelons was recorded at Pula. In total, 44 aphid species were identified from the yellow water traps during 2008, 2010 and 2011. The study also demonstrated that mulching affects the abundance of individual species sporadically. Bare soil was obviously attractive to *A. pisum* and *M. rosae*, black mulch was attractive to *B. helichrysi* and *P. humuli*, and straw mulch was attractive

to four aphid species, of which two, *A. fabae* and *M. persicae,* were eudominant. The presented species are mostly polyphagous, and their preference for certain mulches can be used in crop protection management. Considering the results obtained during this study, in the Mediterranean part of Croatia (Pula), the use of black PE mulch is more effective than organic straw mulch for watermelon protection and production.

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