WFL Publisher
Science and Technology

Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.7 (3&4) : 496-502. 2009 *www.world-food.net*

Response of alate aphid species to mulch colour in watermelon

Katja Žanić [1]*, Dean Ban [2], Smiljana Goreta Ban [1], Tanja Gotlin Čuljak [3] and Gvozden Dumičić [1]

*[1] Institute for Adriatic Crops and Karst Reclamation, Put Duilova 11, Split 21000, Croatia. [2] Institute of Agriculture and Tourism, Carla Huguesa 8, Poreč 52440, Croatia. [3] Faculty of Agriculture, University of Zagreb, Svetošimunska cesta 25, Zagreb 10000, Croatia. *e-mail: katja@krs.hr, Katja.Zanic@krs.hr*

Received 20 July 2009, accepted 7 October 2009.

Abstract

Mulching is common practice in the field production of vegetables. The aim of this study was to investigate the effect of polyethylene mulches (black, brown, clear, green, white) on single aphid species in a watermelon field. Aphids were sampled weekly using yellow water traps. During two spring seasons we detected a total of 70 species in 48 genera, of which 33 species which represented more than 5% of the total per catch were analysed for mulch colour attractiveness in each season. Among them 13 aphid species in 2004 and 16 in 2005 showed a response to the colour of the plastic mulch at least once in six samplings. Different response to mulch colour considering overall seasonal number was found for 15 species in both years. The four most economically important aphid species which transfer cucurbit viruses, *Acyrtosiphon pisum* (Harris), *Aphis craccivora* Koch, *Aphis gossypii* Glover and *Myzus persicae* (Sulzer), expressed different responses to mulch colour. Generally, *A. pisum* was of low abundance on brown mulch, *M. persicae* was less attracted to black, brown and clear mulches. The cowpea aphid *A. craccivora* was less attracted to black mulch. The abundance of *A. gossypii* was low in traps over clear mulch at two sampling dates and as overall seasonal number in 2004, the same was true on two of four samplings and as overall seasonal aphid number in 2005. Our results demonstrated that mulch colour not only affects the total number of aphids which populate crops, but also the presence of individual species may depend on mulch colour depending on sampling date and season. The presented species are mostly polyphagous and their preference for certain mulches can be used in crop protection management.

Key words: Aphididae, *Citrullus lanatus*, PE film, yellow trap.

Introduction

A number of aphid species have been recorded as Cucurbitaceae crop feeders [11, 17, 21, 22]. Alate aphids land on the crops soon after planting. In addition to feeding on plants, some aphids transmit one or more virus diseases. The natural spread of aphid transmitted cucurbit viruses is often accomplished by *Acyrthosiphon pisum* (Harris) [3, 7], *Aphis craccivora* Koch [14, 27], *Aphis gossypii* Glover [7, 10, 19, 27] and *Mysus persicae* (Sulzer) [3, 7, 10, 14, 19]. Aphid-transmitted viruses in cucurbits have been poorly investigated in Croatia, *Cucumber mosaic cucumovirus* (CMV) sporadically occurs on cucurbits but it has not been documented as yet (pers. observation).

The non-chemical control of aphids includes the use of coloured mulches because mulch colour may influence the type of aphid populations that land on the crop and thus the incidence of virus infection. The onset of symptoms of cucurbit viruses can be delayed by three to six weeks in plants grown on mulch, which is a critical period for the initiation of normal flowering and fruiting[21]. Coloured mulches create a specific microenvironment around the plants [8]. 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 back to the leaves [2, 16]. The reflected energy from the mulch affects not only plant growth and development, but also the behaviour of the insects visiting the plants [15].

Döring *et al.* [9] recorded that 15 different types of mulch attracted aphids less than unmulched soil. Clear, black, and white mulches reduce the aphid number compared to bare soil [11, 12]. In contrast, Walters [24] showed that white mulch treatment led to a higher population of aphids compared to unmulched treatment. Silver reflective mulch is superior to white, yellow or black with yellow edges in the reduction of the aphid population [6]. Kring and Schuster [15] recorded that the number of aphids was lower on plants grown on aluminium - painted mulch than on plants grown on white or black mulches. Csizinsky *et al.* [8] found that aluminium and yellow mulches were less attractive to aphids than blue.

Despite the ample evidence of the mulch effect on aphid density in crops, data documenting aphid species preferences for mulch colour are rather limited. Yellow and, to a lesser degree, orange mulches attract green peach aphid (*M. persicae*) [1, 26]. 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 [9]. The number of winged individuals of *A. gossypii* was higher on plants grown on bare soil than on those grown on reflective, metallized plastic or straw mulches [22]. Wallis *et al.* [25] recorded that yellow trap was more attractive to *M. persiace* and *A. gossypii* than green. However, *A. gossypii* showed an increased attraction to green compared to the other species captured in green traps.

Mulching is a common practice in the field production of watermelons in Croatia and the most frequently used cover is

black polyethylene mulch [13]. The aim of this study was to determine the effect of commonly used coloured polyethylene mulches on individual aphid species in watermelon fields in the main area of watermelon production in Croatia.

Material and Methods

Experimental site: A field experiment with watermelon [*Citrullus lanatus* (Thunb.) Matsum & Nakai], cv. Fantasy (Known-You Seed Co., Ltd., Taiwan) was conducted during 2004 and 2005 at Opuzen (43°00′N, 17°34′E, 3 m elevation) located in the Mediterranean area of Croatia. Opuzen is situated in the delta of the river Neretva, which represents the most important watermelon-growing area in Croatia. The average annual rainfall in Opuzen is 1232 mm and the mean annual air temperature is 15.7°C.

***Experimental design and treatments*:** Treatments (five differently coloured PE mulches) were arranged in a randomized complete block design with three replications. The black, brown, and green PE films were 0.02 mm thick and 120 cm wide (Ginegar Plastics Products Ltd., Kibbutz Ginegar, Israel), the clear film was 0.04 mm thick and 120 cm in width (Brković d.o.o., Sveta Nedjelja, Croatia), and the white mulch (white/black with white side up) was 0.07 mm thick and 120 cm in width (Eiffel Plastics Industry - Bernardi Paride, Fontanellato-Parma, Italy). The white mulch was applied only in 2005. In the experiment conducted in 2004, each plot consisted of a single row (1.0 m wide x 100 m long). In the 2005 experiment each plot (4.5 m wide x 21 m long) comprised three rows (1.0 m wide x 21 m long).

***Cultivation practice*:** The field was ploughed to a depth of 25-30 cm a month before planting, and preplant fertilizer 7N-14P_2O_5-21K_2O at 1000 kg ha^{-1} was evenly applied and dug into a depth of 20 cm. The herbicide Devrinol 45 FL (napropamid, Pinus TKI d.d., Rače, Slovenia) at a concentration of 4 L ha^{-1}, was incorporated with fertilizer. Additionally water soluble fertilizer Kristalon™ (Hydro Agri Norge AS, Oslo, Norway), used at a concentration of 92 kg ha^{-1} per irrigation, was fertigated five times during the season. The transplants were sown in a heated greenhouse in the second half of February. The planting was carried out on 27 April 2004 and on 19 April 2005. Planting beds were 1.0 m wide and 0.1 m high and were covered with PE films. The rows were set 2.0 m apart and the in-row plant spacing was 1.5 m. A 3 kg ha^{-1} concentration of the soil insecticide Volaton G5 (foksim, Pinus TKI d.d., Rače, Slovenia) was incorporated into the holes during planting. Weeds growing between the rows were removed by hand if necessary, while diseases and pests were controlled according to common practices in commercial production.

Aphid sampling: Aphid sampling was carried out using Moericke yellow water pan traps which were placed in the middle of the single row in each plot in 2004 or in the middle of the centre row in each plot in 2005. Depending on the environmental conditions water was added to the pans during the week. A total of 12 traps were used in 2004 and 15 traps in 2005. Traps were installed at the date of transplanting and observed every day in order to determine initial aphid flight prior to the first sampling. Insect samples were collected once a week from the pans until the mulches became covered by the plant canopy. The material collected 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.

Species identification and their abundance: Winged adult aphids were identified and counted according to taxonomy keys [5, 6, 23]. The number of individual species per trap was recorded to determine the effect of coloured mulches on the number of different aphid species for each of the sampling dates and for overall season. Aphid species which made up more than 5.0% of the total population in the trap, even those recorded at only one sampling date, were considered dominant and subjected to statistical analysis.

Statistical analysis: A general linear model procedure [20] was used for statistical analyses. The mean number of winged aphids per trap was transformed if needed and data were analyzed by repeated-measures analysis of variance (ANOVA) with date of measurement as a repeated factor. Since a significant interaction was found between mulch colour and date of measurement, the data were analyzed separately for each date and the mean separation was done using an LSD test with significance set at $P \leq 0.05$.

Results

During the study of the aphid population, 70 species in 48 genera were detected, with 63 species in 42 genera being identified in 2004 and 44 species in 31 genera in 2005. All species belonged to the Aphididae. The overall seasonal percentage composition showed that *Toxoptera aurantii* (Boyer de Fonscolombe) (34% in 2004 and 23% in 2005) and *A. gossypii* (15% in 2004 and 24% in 2005) were consistently predominated in both years [2].

Mulch comparisons: During two seasons we identified 63 species in 2004 and 44 in 2005 (Table 1). Aphid species, represented by more than 5% of the total weekly catch per trap, were analyzed for mulch colours comparison. The number of aphid species analyzed per single sampling ranged from four to 23 species in 2004 and from seven to 20 species in 2005 (Table 1). Regardless of different number of identified species in two years (63 in 2004 vs. 43 in 2005), the 33 species were represented by more than 5% and

Table 1. The number of identified aphid species, analyzed species (with dominance > 5%) and species responded to mulch colour per date and overall season in watermelons during 2004 and 2005.

Date	No. of identified species	No. of analyzed species	No. of species affected by mulch colour
		2004	
5 May	21	13	4
12 May	27	23	5
19 May	40	18	4
26 May	38	11	2
2 June	37	7	4
9 June	28	4	1
Season	63	33	15
		2005	
12 May	23	19	6
19 May	22	20	6
26 May	30	19	6
2 June	28	12	3
9 June	23	8	6
16 June	23	7	4
Season	44	33	15

analyzed in both years. Similarly, different response to mulch colour as overall seasonal number was found for 15 species in both years (Table 1).

Aphid species for which significant differences between mulches per sampling date and as overall seasonal number were detected are shown in Tables 2 to 5. Species that transmit cucurbit viruses, most abundant species and important vegetable pests are included in the results. *Aphis* sp. was not commented or included in the results.

The difference in number of the pea aphid, *A. pisum*, between the mulches was found at only one assessment per year. The number of aphids was lower on brown than on clear mulch on 2 June 2004 (Table 2). At the beginning of flight season 2005 (12 May), no *A. pisum* specimens were found on black, brown and green mulches while it occurred on clear and white mulches(Table4).

The differences between the mulches in abundance of the cowpea aphid *A. craccivora* in 2004, are shown in Table 2. On 12 May, the number of *A. craccivora* was lower on brown, clear and green mulches than on black. One week later, on 19 May, the

Table 2. Number of aphid species per yellow water pan trap per sampling date in watermelons grown on differently coloured mulches during 2004.

	Mulch colour			
	Black	Brown	Clear	Green
Aphid species	(No. aphids per trap)			
5 May				
*Aphis gossypii**	2.5 a	0.3 ab	0.0 b	1.0 ab
Aulacorthum solani	4.5 ab	5.0 a	1.0 b	2.7 ab
Macrosiphum euphorbiae	0.5 ab	0.0 b	0.3 ab	1.7 a
Macrosiphum rosae	2.0 a	0.0 b	0.0 b	0.0 b
12 May				
Aphis craccivora	2.5 a	0.0 b	0.3 b	0.3 b
Aphis fabae	3.0 ab	4.0 a	1.3 b	1.1 b
Aphis gossypii	5.5 a	3.3 b	0.0 c	0.3 c
Dysaphis plantaginea	1.0 a	0.3 ab	0.0 b	0.3 ab
Macrosiphum rosae	1.0 a	0.0 b	0.0 b	0.3 ab
19 May				
Aphis craccivora	2.3 ab	8.0 a	1.3 b	1.3 b
Hyperomyzus lampsanae	0.7 ab	2.0 a	0.3 ab	0.0 b
Mysus persicae	2.0 ab	0.0 b	2.3 a	0.7 ab
Toxoptera aurantii	4.7 a	4.3 ab	1.3 ab	0.3 b
26 May				
Brachycaudus helichrysi	0.7 b	1.0 b	5.0 a	1.7 ab
Macrosiphum euphorbiae	1.3 ab	2.0 ab	4.3 a	0.0 b
2 June				
Aphis gossypii	33.5 b	65.0 a	40.5 ab	52.5 a
Acyrtosiphon pisum	27.0 ab	14.5 b	36.5 a	27.0 ab
Aphis sp.	37.5 a	23.0 b	2.0 c	16.0 bc
Hyalopterus pruni	10.0 b	16.5 b	13.5 b	29.5 a
Toxoptera aurantii	91.0 ab	79.5 b	87.5 ab	118.0 a
9 June				
Toxoptera aurantii	673.5 ab	1615.5 a	620.0 b	889.0 ab

*Means within rows followed with different letters are significantly different at P≤ 0.05 by LSD test.

Table 3. Overall season number of aphid species per yellow water pan trap in watermelons grown on differently coloured mulches during 2004.

	Mulch colour			
	Black	Brown	Clear	Green
Aphid species	(No. aphids per trap)			
Overall season				
*Aphis craccivora**	35.7 b	116.7 a	85.0 ab	83.0 ab
Aphis fabae	129.0 a	81.0 bc	122.3 ab	88.7 b
Aphis gossypii	208.7 b	498.3 a	244.7 b	182.3 b
Brachycaudus sp.	5.0 b	4.0 b	4.0 b	14.0 a
Capitophorus similis	0.0 b	0.0 b	0.3 b	1.7 a
Cavariella aegopodii	0.3 c	1.3 bc	2.0 ab	3.0 a
Hyadaphis phoeniculi	0.7 b	7.0 b	16.0 a	16.7 a
Hyalopterus pruni	25.3 c	74.7 a	60.0 ab	42.7 bc
Hyperomyzus lampsanae	0.7 b	4.7 a	0.3 b	0.0 b
Macrosiphum rosae	3.7 a	2.7 ab	1.0 b	1.3 b
Metopolophium dirhodum	1.7 b	18.7 a	4.0 b	2.0 b
Myzus persicae	16.0 c	23.0 b	24.3 b	34.7 a
Rhopalosiphum padi	9.0 a	2.7 b	2.7 b	8.3 a
Tetraneura sp.	1.7 b	0.7 ab	3.3 a	2.3 ab
Toxoptera aurantii	795.3 b	1700.3 a	730.0 b	1030.7 b

*Means within rows followed with different letters are significantly different at P≤0.05 by LSD test.

Table 4. Number of aphid species per yellow water pan trap per sampling date in watermelons grown on differently coloured mulches during 2005.

	Mulch colour				
	Black	Brown	Clear	Green	White
Aphid species	(No. of aphids per trap)				
12 May					
*Acyrtosiphon pisum**	0.0 b	0.0 b	0.3 ab	0.0 b	1.0 a
Hyadaphis phoeniculi	0.0 b	1.0 ab	2.7 a	0.7 ab	2.7 a
Hyperomyzus lactucae	0.7 b	1.0 b	2.0 b	3.3 b	8.0 a
Hyperomyzus pieridis	0.7 ab	3.3 a	0.0 b	2.7 ab	2.3 ab
Macrosiphum euphorbiae	0.0 b	1.0 ab	2.3 a	0.3 ab	0.0 b
Toxoptera aurantii	0.0 b	1.3 a	0.0 b	0.0 b	0.0 b
19 May					
Aphis craccivora	0.7 b	0.3 b	0.7 b	0.3 b	2.7 a
Aulacorthum solani	1.7 a	0.0 b	0.7 ab	0.0 b	0.7 ab
Hyperomysus lampsane	0.3 b	0.7 b	0.3 b	6.0 a	6.3 a
Hyperomyzus pieridis	0.0 b	0.3 ab	1.3 ab	0.3 ab	2.7 a
Myzus persicae	0.7 a	0.0 b	0.0 b	0.3 ab	0.3 ab
Macrosiphum rosae	0.0 b	0.0 b	0.0 b	0.7 a	0.0 b
26 May					
Aphis fabae	1.0 ab	0.0 b	0.7 ab	0.3 ab	1.7 a
Hyalopterus pruni	0.7 b	0.3 b	0.7 b	2.0 a	0.3 b
Hyperomyzus lactucae	1.7 b	3.3 ab	3.3 ab	6.7 a	4.0 ab
Hyperomyzus pieridis	0.0 b	0.7 ab	0.3 ab	1.0 ab	1.3 a
Toxoptera aurantii	0.3 b	0.3 b	0.3 b	0.7 b	2.0 a
2 June					
Aphis sp.	3.7 b	9.7 ab	13.7 a	10.3 ab	3.3 b
Dactynotus sp.	3.3 a	0.7 b	0.0 b	0.0 b	1.7 ab
Hyperomysus lampsane	0.3 b	1.7 ab	3.0 a	1.1 ab	2.3 ab
Myzus persicae	4.5 b	7.9 ab	10.7 a	7.3 ab	9.8 ab
9 June					
Aphis fabae	28.0 ab	6.7 b	44.0 a	21.3 ab	51.7 a
Aphis gossypii	152.7 a	132.7 a	48.7 b	44.3 b	131.3 a
Brevicoryne brassicae	42.0 a	25.0 ab	3.0 c	16.0 bc	29.0 ab
Hyperomyzus lampsane	13.0 ab	0.0 b	5.3 b	30.3 a	36.0 a
Myzus persicae	38.7 a	21.7 ab	12.7 b	29.0 ab	16.7 ab
Toxoptera aurantii	118.3 ab	114.7 ab	41.7 b	235.0 a	80.3 b
16 June					
Aphis craccivora	12.7 b	20.7 ab	14.0 ab	17.0 ab	31.7 a
Aphis gossypii	23.0 c	35.3 bc	31.7 c	62.7 ab	74.7 a
Aphis sp.	17.7 a	16.0 a	0.0 b	10.3 a	12.3 a
Hyperomyzus lactucae	11.7 b	17.3 b	16.7 b	53.3 a	19.3 b
Hyperomyzus lampsane	10.0 b	9.7 b	12.3 b	17.7 ab	31.0 a

*Means within rows followed with different letters are significantly different at P≤ 0.05 by LSD test.

cowpea aphid was less numerous on clear and green than on brown mulch. Overall seasonal number of *A. craccivora* was lower on black than on brown mulch (Table 3). In 2005, the mulch effect on *A. craccivora* was recorded at two assessments (Table 4). The number of *A. craccivora* was the highest on white mulch on 19 May, while on 16 June it was lower on black than on white mulch.

Mulch colour affected the abundance of the black been aphid *Aphis fabae* Scopoli in both years. On 12 May 2004, a lower number of aphids was recorded on clear and green than on brown mulch (Table 2). The overall seasonal number of *A. fabae*, calculated during entire 2004, was lower on brown and green than on black mulch (Table 3). On 26 May 2005, *A. fabae* was less numerous on brown than on white mulch (Table 4). Brown mulch was again less attractive for *A. fabae* compared to clear and white mulches on 9 June. In 2005, the overall seasonal number of *A. fabae* was lower on brown than on clear and white mulches (Table 5).

The cotton aphid, *A. gossypii*, was one of the two most abundant species caught in watermelon field in both years. The differences between the mulches in *A. gossypii* trapping were observed on three dates in 2004 (Table 2), and on two dates in 2005 (Table 4). The number of aphids was lower on clear than on black mulch on 5 May 2004, whereas on 12 May 2004, the greatest number of aphids was recorded on black mulch compared to other colours. At the beginning of June 2004 (2 June), *A. gossypii* was less numerous on black than on brown and green mulches. The overall seasonal number of aphids was the greatest on brown mulch in 2004 (Table 3). On 9 June 2005, the number of aphids was lower on clear and green than on other three mulch colours. One week later, the cotton aphid was less numerous on black, brown and clear than on white mulch. The overall seasonal number of *A. gossypii* was less numerous on clear than on black and white mulches in 2005 (Table 5).

Hyadaphis phoeniculi Passerini was less manifested on black and brown than on clear and green mulches in the season 2004 (Table 3). Black mulch again attracted fewer *H. phoeniculi* adults than clear and white at first assessment in 2005 (Table 4), and the almost same trend was observed in entire season (Table 5).

On 2 June 2004, the plum aphid, *Hyalopterus pruni* (Geoffroy), was the most numerous on green mulch (Table 2) while the overall seasonal number of aphids was lower on black than on brown and clear mulches (Table 3). On 26 May 2005, *H. pruni* was once again the most numerous on green mulch (Table 4) while the overall

Table 5. Overall season number of aphid species per yellow water pan trap in watermelons grown on differently coloured mulches during 2005.

	Mulch colour				
	Black	Brown	Clear	Green	White
Aphid species	(No. of aphids per trap)				
Overall season					
*Aphis fabae**	35.3 bc	14.0 c	52.0 ab	29.3 bc	80.3 a
Aphis gossypii	231.0 a	210.3 ab	114.7 b	164.0 ab	250.3 a
Brachycaudus helichrysi	8.7 a	4.3 ab	4.0 ab	4.0 ab	1.3 b
Brevicoryne brassicae	65.7 a	46.0 b	7.3 c	33.3 b	45.7 b
Cavariella sp.	0.0 b	0.3 ab	0.0 b	0.3 ab	2.0 b
Dysaphis plantaginea	0.3 ab	2.0 a	0.3 ab	1.3 ab	0.0 b
Hyadaphis phoeniculi	0.3 b	3.3 a	5.0 a	2.7 ab	4.3 a
Hyalopterus pruni	5.0 ab	6.0 ab	5.3 ab	9.3 a	1.7 b
Hyperomyzus lampsane	26.3 bc	15.0 c	27.0 bc	59.3 ab	81.7 a
Hyperomyzus pieridis	3.3 b	6.3 ab	4.3 ab	8.0 ab	9.3 a
Macrosiphum rosae	0.0 b	0.0 b	0.0 b	1.0 a	0.3 b
Myzus persicae	93.0 b	117.3 b	103.3 b	270.7 a	261.3 a
Phyllaphis fagi	1.7 ab	3.7 ab	3.0 ab	5.0 a	1.3 b
Tetraneura sp.	3.0 ab	6.3 a	2.0 ab	2.7 ab	1.3 b
Therioaphis trifolii	0.0 ab	0.0 ab	1.7 a	0.0 ab	0.0 ab

*Means within rows followed with different letters are significantly different at P≤ 0.05 by LSD test.

seasonal number of aphids was lower on white than on green mulch (Table 5).

During three assessments in 2005 it was noted that the number of sowthistle aphid, *Hyperomyzus lactucae* (L.), was related to mulch colour (Table 4). On 12 May, *H. lactucae* was the most abundant on white mulch. On 26 May, the number of aphids was lower on black than on green mulch. The last assessment on 16 June indicated that the sowthistle aphid was most attracted to green mulch.

The difference between the mulch colours in catching of the peach aphid *M. persicae* was noted at one of six assessments in 2004 (Table 2). On 19 May, a significant difference in number of *M. persicae* was recorded between brown and clear mulches while it was not represented on brown mulch. Overall seasonal number of aphids was the highest on green and lowest on black mulch (Table 3). The effect of black and clear mulches on *M. persicae* number alternated during three assessments in 2005 (Table 4). On 19 May, black mulch was more attractive to *M. persicae* than brown and clear which caught no aphid individuals, while on 2 June clear mulch was more attractive to *M. persicae* than black. One week later, the peach aphid was more abundant on black than on clear mulch. Related to the overall seasonal number *M. persicae* was less numerous on black, brown and clear mulches than on green and white (Table 5).

The black citrus aphid *T. aurantii*, together with *A. gossypii*, was predominant during the experimental period. The differences between the mulches in effect on *T. aurantii* during 2004 are showed in Table 2. On 19 May 2004, *T. aurantii* was less abundant on green than on black mulch. On 2 June, the black citrus aphid was less numerous on brown than on green mulch. One week later, the number of *T. aurantii* was lower on clear than on brown mulch. As shown in Table 3, the overall seasonal number of aphids was the highest on brown mulch. The differences between the mulches in catching of *T. aurantii* during season 2005 were recorded on three dates (Table 4). On 12 May, the presence of *T. aurantii* was recorded only on brown mulch, while on 26 May this aphid was most abundant on white mulch. On, 9 June, *T. aurantii* was less numerous on clear and white than on green mulch.

Discussion

In total, 70 aphid species were identified from the traps in watermelon field at Opuzen, situated in the delta of river Neretva. The delta is a meliorated marshy valley, characterized by a high level of biodiversity. Consequently, the composition of aphid species recorded on watermelon plants, reflected the adjacent landscape which has a rich variety of cultivated and wild plant species.

In this study, the abundance of 33 species, represented by more than 5% of total aphid population per trap, was compared in 2004. Among them 13 aphid species showed a response to the colour of the plastic mulch at least once during experiment which is included in Table 3. The overall seasonal number of aphids per trap per mulch colour was differently affected by mulch colour in 15 species, including *Capitophorus similis* van der Goot, *Cavariella aegopodii* (Scopoli), *H. phoeniculi, Metopolophium dirhodum* (Walker), *Rhopalosiphum padi* (L.) and *Tetraneura* sp. whose response to mulch colour was not detected during six successive assessments. Similarly, 33 aphid species were compared in 2005. The differences in distribution among various coloured PE mulches were found for 16 species at one or more assessments which is included in Table 4. The difference in overall seasonal number of aphids per treatment was noted for 15 species in 2005. Within the group of 15 species, 6 species, *Brachycaudus helichrysi* (Kaltenbach), *Cavariella* sp., *Dysaphis plantaginea* (Passerini), *Phyllaphis fagi* (L.), *Tetraneura* sp. and *Therioaphis trifolii* (Monell), showed no response to mulch colour on specific sampling dates during the experiment; however, their overall seasonal number was affected by mulch colour.

Although, aphid-borne viruses of cucurbits, primarily CMV, *Zucchini Yellow Mosaic Potyvirus* (ZYMV) and *Watermelon mosaic virus 2* (WMV2), were not the subject of the study, the

presence of their vectors in the area, with the predominance of *A. gossypii*, could be an important factor in the spread of cucurbits viruses.

The pea aphid *A. pisum*, has been reported to be a vector for ZYMV [3, 7, 14] and WMV2 [7]. Based on our results, get from two assessments, clear and white plastic mulches appear to be attractive to *A. pisum* while brown mulch attracted less aphids in both years, and to the best of our knowledge these are the first data to describe any preferences for mulch colour in this species.

Cotton aphid is a vector for CMV [10, 19], WMV2 [7] and ZYMV [7, 27]. In contrast to *A. pisum*, it seems that in our study *A. gossypii* was less attracted to clear and more attracted to darker mulch colours (black and brown). Summers *et al*. [22] found that the number of winged *A. gossypii* individuals was higher on plants grown over bare soil than on those grown over reflective, metallic plastic or straw mulches.

ZYMV is efficiently transmitted by *A. craccivora* [14, 27]. According to our results, recorded on the dates when *A. craccivora* was more abundant or as overall seasonal number, the aphid was less attracted to black and more attracted to brown and white mulches.

The green peach aphid *M. persicae* is efficient in transmitting cucurbit diseases: CMV [10, 19], WMV2 [7] and ZYMV [3, 7, 14]. Our results, based on the seasonal catches in yellow traps 2004, selected green mulch as the most attractive to *M. persicae*. Black and clear mulches alternated in attractiveness for *M. persicae* during three assessments in 2005, while the overall seasonal number of *M. persicae* was lower on black, brown and clear mulches than on green and white. According to Adlerz and Everett [1] and Wolfenbarger and Moore [26], yellow and, to a lesser degree, orange mulch attracted *M. persicae*, while aluminium and silver mulches repelled green peach aphids.

According to Katis *et al.* [14], *A. spiraecola* and *Rhopalosiphum padi* are also amongst six of the most important aphid species in ZYMV epidemiology. *A. spiraecola* was present in low abundance in watermelons during the experimental period. The overall season percentage of *A. spiraecola* was less than 0.1% in both years and did not appear to display any preferences with regard to mulch colour. The proportion of *R. padi* was 0.3% in 2004 and 0.9% in 2005. The overall season number of *R. padi* in 2004 indicates the aphid's low preference to brown and clear mulches.

Although this article is more focused on cucurbit aphids, it is interesting to emphasise that white and green mulches attracted *H. lactucae* which can damage lettuce crops while black mulch was not attractive to this species. According to Nebrada *et al.* [18], *H. lactucae* is the main aphid species landing on lettuce in spring period.

Conclusions

The four most economically important aphid species which transfer cucurbit viruses (*A. pisum*, *A. craccivora*, *A. gossypii* and *M. persicae*) expressed different responses to mulch colour. Generally, *A. pisum* was of low abundance on brown mulch, *M. persicae* was less attracted to black, brown and clear mulches. The cowpea aphid *A. craccivora* was less attracted to black mulch. The abundance of *A. gossypii* was low in traps over clear mulch at two sampling dates and as overall seasonal number in 2004. The same was true on two of four samplings and as overall seasonal number of aphids in 2005.

Our results demonstrated that mulch colour affects not only the total aphid population that lands on crops, but also the abundance of individual species. The results were obtained under field conditions for the cultivation of watermelon crops, and probably are linked to aphid biology and ecology, sampling date and season, and the influence of environmental factors, which are particularly characterised by the NW wind pressure during the afternoon hours. The aphid species described here are mostly polyphagous and their preferences for certain mulch colour can be widely applied to crop protection management.

Acknowledgments

The authors thank Mario Odak who gave up part of his property for carrying out these experiments and was of valuable assistance during aphid sampling.

References

[1]Adlerz, W.C. and Everett, P.H. 1968. Aluminium foil and white polyethylene mulches to repel aphids and control watermelon mosaic. J. Econ. Entomol. **61**:1276-1279.

[2]Ban, D., Žanić, K., Dumičić, G., Gotlin Čuljak, T. and Goreta Ban, S. 2009. The type of polyethylene mulch impacts vegetative growth, yield, and aphid populations in watermelon production. J.Food. Agric.Environ. **7**(3&4):543-550.

[3]Basky, Z., Perring, T.M. and Tobias, I. 2001. Spread of zucchini yellow mosaic potyvirus in squash in Hungary. J. Appl. Ent. **125**:271-275.

[4]Blackman, R.L. and Eastop, V.F. 1994. Aphids on the World's Trees: An Identification and Information Guide. CAB International, Wallingford, 987 p.

[5]Blackman, R.L. and Eastop, V.F. 2000. Aphids on the World's Crops: An Identification and Information Guide. 2nd edn. Wiley, London, 466 p.

[6]Brown, J.E., Dangler, J.M., Woods, F.M., Tilt, K.M., Henshaw, M.D., Griffey, W.A. and West, M.S. 1993. Delay in mosaic virus onset and aphid vector reduction in summer squash grown on reflective mulches. HortScience **28**:895-896.

[7]Castle, S.J., Perring, T.M., Farrar, C.A. and Kishaba, A.N. 1992. Field and laboratory transmission of watermelon mosaic virus 2 and zucchini yellow mosaic virus by various aphid species. Phytopathology **82**:235-240.

[8]Csizinszky, A.A., Schuster, D.J. and Kring, J.B. 1995. Color mulches influence yield and insect pest populations in tomatoes. J. Amer. Soc. Hort. Sci. **120**:778-784.

[9]Döring, T.F., Kirchner, S.M., Kühne, S. and Saucke, H. 2004. Response of alate aphids to green targets on coloured backgrounds. Entomol. Exp. Appl. **113**:53-61.

[10]Eastop, V.Y. 1977. Worldwide importance of aphids as virus vectors. In Harris, K.F. and Maramorosch, K. (eds). Aphids as Virus Vectors. Academic Press, New York, pp. 3-61.

[11]Farias-Larios, J. and Orozco-Santos, M. 1997a. Color polyethylene mulches increase fruit quality and yield in watermelon and reduce insect pest populations in dry tropics. Gartenbauwissenschaft **62**:255-260.

[12]Farias-Larios, J. and Orozco-Santos, M. 1997b. Effect of polyethylene mulch colour on aphid populations, soil temperature, fruit quality, and yield of watermelon under tropical conditions. New Zeal. J. Crop Hort. **25**:369-374.

[13]Goreta, S., Perica, S., Dumičić, G., Bućan, L. and Žanić, K. 2005. Growth and yield of watermelon on polyethylene mulch with different spacings and nitrogen rates. HortScience **40**:366-369.

[14]Katis, N.I., Tsitsipis, J.A., Lykouressis, D.P., Papapanayotou, A., Margaritopoulos, J.T., Kokinis, G.M., Perdikis, D.Ch. and Manoussopoulos, I.N. 2006. Transmission of Zucchini yellow mosaic virus by colonizing and non-colonizing aphids in Greece and new aphid species vectors of the virus. J. Phytopathol. **154**:293-302.

[15]Kring, J.B. and Schuster, D.J. 1992. Management of insects on pepper and tomato with UV-reflective mulches. Fla. Entomol. **75**:119-129.
[16]Lamont, Jr.W.J. 1993. Plastic mulches for the production of vegetable crops. HortTehnology **3**:35-39.
[17]Millar, I.M. 1994. A Catalogue of the Aphids (Homoptera: Aphidoidea) of Sub-Saharan Africa. Agricultural Research Council, Pretoria, 130 pp.
[18]Nebreda, M., Moreno, A., Pérez, N., Palacios, I., Seco-Fernández, V. and Fereres, A. 2004. Activity of aphids associated with lettuce and broccoli in Spain and their efficiency as vectors of lettuce mosaic virus. Virus Res. **100**:83-88.
[19]Ng, J. and Perry, K.L. 1999. Stability of the aphid transmission phenotype in cucumber mosaic virus. Plant. Pathol. **48**:388-394.
[20]SAS Institute 2000. SAS/STAT User's Guide. Version 8. SAS Institute Inc., Cary, NC.
[21]Stapleton, J.J. and Summers, C.G. 2002. Reflective mulches for management of aphids and aphid-borne virus diseases in late-season cantaloupe (*Cucumis melo* L. var. *cantalupensis*). Crop. Prot. **21**:891-898.
[22]Summers, C.G., Mitchell, J.P. and Stapleton, J.J. 2005. Mulches reduce aphid-borne viruses and whiteflies in cantaloupe. Calif. Agr. **59**:90-94.
[23]Taylor, L.R. 1980. A Handbook for Aphids Identification. Euraphid, Rothamsted, 171 p.
[24]Walters, S.A. 2003. Suppression of watermelon mosaic virus in summer squash with plastic mulches and rowcovers. HortTechnology **13**:352-357.
[25]Wallis, C.M., Fleischer, S.J., Luster, D. and Gildow, F.E. 2005. Aphid (Hemiptera: Aphididae) species composition and potential aphid vectors of plum pox virus in Pennsylvania peach orchards. J. Econ. Entomol. **98**:1441-1450.
[26]Wolfenbarger, D.O. and Moore, W.D. 1968. Insect abundance on tomatoes and squash mulched with aluminium and plastic sheeting. J. Econ. Entomol. **61**:34-36.
[27]Yuan, C. and Ullman, D.E. 1996. Comparison of efficiency and propensity as measures of vector importance in zucchini yellow mosaic potyvirus transmission by *Aphis gossypii* and *A. craccivora*. Phytopathology **86**:698-703.