THE UV RADIATION EFFECT ON APHIDS' MOBILITY

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Abstract. There is an increasing interest in understanding crop pest insects' dynamics. The main objectives of pest control management are reducing pest pressure in crops and pesticide utilization. Increasing ultraviolet radiation that reaches the Earth's surface has led to greater interest in its potential effects on herbivorous insects and its use in pest control. Researchers and farmers pay special attention to aphids due to their significant impact on crops. The aphids' first response to increased UV radiation influences their dynamics, and this aspect has been poorly investigated so far. Our study used two complementary approaches: supplementary UV radiation and reduction of UV rays. Winged aphids respond quickly to UV radiation, leaving the exposed leaf surface. We noticed a pattern in insect behaviour when they left the leaves. Our results demonstrate the potential importance of UV radiation to insect herbivore mobility.

Keywords: UV, plants, aphids, mobility.

Rezumat. Efectul radiației UV asupra mobilității afidelor. Nevoia de înțelegere a dinamicii insectelor fitofage din culturi este din ce în ce mai mare. Două dintre obiectivele principale ale managementului controlului dăunătorilor sunt: diminuarea presiunii acestora și reducerea pesticidelor. Creșterea radiațiilor ultraviolete care ajung pe suprafața pământului a dus la creșterea interesului cercetătorilor față de efectele potențiale a radiațiilor ultraviolete asupra insectelor fitofage și a utilizării sale în combaterea insectelor. Cercetătorii și fermierii acordă o atenție deosebită afidelor determinată de impactului major pe care acestea îl au asupra culturilor. Răspunsul inițial al afidelor la creșterea radiației UV influențează dinamica lor, iar acest aspect a fost puțin investigat până în prezent. În studiul nostru, am folosit două abordări complementare: suplimentarea radiației UV și reducerea radiației UV. Afidele cu aripi răspund rapid la radiația UV părăsind suprafața expusă a frunzei. Am observat un model în comportamentul insectelor când acestea părăsesc frunzele expuse. Rezultatele noastre demonstrează importanța radiației UV asupra mobilității insectelor fitofage.

Cuvinte cheie: UV, plante, afide, mobilitate.

INTRODUCTION

During the last decades, insect pest control has become an essential research topic in agronomy and ecology. Diminishing harmful pesticides has several positive effects. It improves consumers' health and reduces the pressure on the environment and the cost associated with crop production. Several agricultural practices are applied to reduce susceptibility to pests and improve plant vigour. Such practices include companion planting of pest-repelling plant species (PARKER et al., 2013) or resistant cultivars to insect pests, microbial pesticides application (PATHAK et al., 2017), the utilization of blue or green fluorescent light traps and UV light manipulation (SHIMODA & HONDA 2013). Understanding insect pests' population dynamics under different UV light doses is essential for future pest management plans.

Insects can perceive the reflective UV radiation of plants (MAZZA et al., 2002). This capacity is vital for insect flight navigation and their ability to find host plants (CHYZIK et al. (2003). Aphids find a host plant using UV, blue, and green photoreceptors and a colour opponency mechanism in which green light is the positive input and blue and UV light is the negative input (DORING & CHITTKA, 2007).

There is a daily and even hourly variation in UV radiation reaching the plants. Because of the plants' architecture, some parts receive more or less solar radiation. The whole plant is a mosaic of patches with different degrees of exposure to solar radiation. Microhabitat conditions in these patches regulate the aphids' distribution on the plant. Wax, trichome and leaf itself reduce the UV radiation entering the leaf (KARABOURNIOTIS et al., 1995; LONG et al., 2003). Aphids prefer the abaxial side of the leaf because it receives less UV radiation (NOGUES et al., 1999) and has a reduced temperature. In laboratory conditions, aphids seem to spread on the entire plant and show no preference for the abaxial side of the leaf (BURDICK, 2013). Empirical studies using field or semi-field data are a powerful and more realistic approach to understanding insect population trends.

KUHLMANN & MULLER (2010) found that high UV radiation can negatively affect aphid reproduction. UV-exposed *Brevicoryne brassicae* had increased development time, higher adult weight and reduced fecundity (RECHNER & POEHLING 2014). According to CHYZIK et al. (2003), less UV radiation affects the aphid *Myzus persicae* population growth and propagation. Also, under UV filters, fewer *Aphis gossypii* aphids were recorded (KUMAR & POEHLING, 2006).

The plants' response to UV plays an important role in insect pest population dynamics. The UV-B radiation-induced plant defends against insect pests (ESCOBAR-BRAVO et al., 2019). Plant biochemical changes induced by UV, such as the accumulation of phenylpropanoid derivatives (IZAGUIRRE et al., 2007), might explain the observed anti-herbivore effect of the UV. DADER et al. (2014) point out that accumulating secondary metabolites, total protein content, carbohydrates, and free amino acids in pepper leaves exposed to UV might indirectly promote insect pest performance. The plants' morphological modifications, such as a thick wax layer or a high trichomes number, are induced by UV radiation (STEINMULLER & TEVINI, 1985; KARABOURNIOTIS et al., 1995). These modifications are also part of plant defence against insects (DALIN et al., 2008; BOHINC et al., 2014).

This work focused on cosmopolitan mealy aphids *Hyalopterus* cf. *pruni* Koch (Hemiptera: Aphididae), representing a significant pest crop. For mealy aphids, plants represent their only food and habitat; thus, host plants tremendously influence the aphids' evolution (PECCOUD et al., 2010). Aphids might cause direct injury to plants, retarding the development of shoots and premature leaves drop (VASILEV et al. 2020). Indirectly, aphids can affect plants by transmitting plant viruses (NG & PERRY, 2004) and favouring sooty mould (JOURAEVA et al., 2006). Due to the aphid's short generation time and high reproductive capacity (YAMAMURA & KIRITANI, 1998), the effects of aphids on the crop are amplified. In April, when temperatures exceed 14°C, the eggs hatch, and several apterous (wingless) aphids' generations succeed until alatae (winged) aphids emerge (LATHAM & MILLS 2011). Usually, apterous aphids colonize, in a large number, the abaxial side of leaves and disperse in the same host tree. Winged aphids are capable of dispersing to other neighbouring trees. In summer, the alate individuals spread to the reeds, and in late August, they return to the primary host and lay eggs. (LATHAM & MILLS, 2011). All *Hyalopterus* species inhabit reed plants (such as Phragmites) in summer (VASILEV et al., 2020). In winter, *H. amygdali* (Blanchard) inhabits almonds, *H. pruni* (Koch) plums and *H. persikonus* (Miller, Lozier & Footitt) peaches. All three species are associated with apricot (LOZIER et al., 2008; RAKAUSKAS et al., 2013; LIU et al., 2020). The rapid population growth and their ability to disperse over long distances (LOZIER et al., 2008) made mealy aphids a good candidate for pest studies.

Insect pests' population dynamics change in terms of ecological interactions. Climate change affects aphids in many complex ways. Global warming might increase the aphid populations, geographic distribution, number of generations and winter survival (SKENDZIC et al., 2021). Although several researchers pointed out the aphid sensitivity to increased temperature (LATHAM & MILLS, 2011; SUN et al., 2022), in the global warming context, our understanding of aphid dynamics in response to increased UV radiation is still limited. There is even less information on the primary aphid's response after sudden exposure to UV radiation, which is important in understanding aphids' dynamics. In our paper, we report the direct short-term effects of UV on plum mealy aphids' mobility.

MATERIAL AND METHODS

We conducted two experiments using two complementary methods. In one, we used a filter that blocked UV radiation; in the other, we had additional UV radiation. The experiments were carried out in an experimental field near Bucharest, in June 2021. The cloud free erythemal average UV dose during the experiment was 4.8 kJ/m^2 (data made available by ***TEMIS)

We randomly selected sixty-eight leaves from the same *Prunus domestica* L. tree colonized with mealy plum aphids. The petiole of plum leaves has been inserted into a flower sponge with a high-water retention capacity to avoid water stress. We turned upside down the leaves colonized with aphids with the abaxial side facing up. We exposed all the samples for 30 min. We placed the samples on ceramic containers 20 cm in diameter. The containers were placed in plastic trays (30 cm in width, 60 cm long) with 5 cm high edges to reduce the microclimate effect. We used white containers and filled the plastic trays with water at ambient temperature to lower the temperature during sample exposure. Treatments and control were relocated between repetitions to avoid location confounding.

The filter we used to block UV radiation was a 6mm glass. We placed the filter 1 m high above the samples to reduce the greenhouse effect. We exposed the control directly to sun radiation.

We obtained UV-B supplementation using fluorescent tubes Philips TL 40 W/12 RS UV-B (Philips, Holland). We positioned the UV tubes 15 cm directly overhead the sample in a shady area. The tubes were turn-on for 30 min. We exposed the control samples in a similar area but under a turned-off fluorescent tube.

We recorded the environmental conditions during the experiment at the same high as the samples. We used a regular thermometer for temperature, while for the radiation spectra, we used a Spectrometer Ocean Optics USB 2000+. For the spectrum display, recognition and analysis, we used Spectrum Analyzer 1.7 (NAVRATIL et al., 2006).

We used the ImageJ (RASBAND, 1997-2018) software for image analysis and calculating each leaf's area and the density of the aphids for each sample. For data analysis, we counted the aphids for each sample before and after exposure. Aphids count and x, y coordinates were obtained using Cell Counter plugins, developed in 2001 by Kurt De VOS (O'BRIEN et al., 2016).

For statistical data analysis and point pattern analysis, we used the statistical software PAST 4.03 (HAMMER et al., 2001). To assess whether the density of the aphids that left the UV-exposed samples differed significantly from the density of the control samples, we performed a Shapiro-Wilk W normality test. For the supplementation experiment data, we performed a student t-test ($P \leq 0.05$); for the UV exclusion experiment, we performed a Mann-Whitney test.

RESULTS AND DISCUSSIONS

In our experiments, we tried to manipulate UV radiation and keep other abiotic factors as similar as possible. In the UV exclusion experiment, the temperature was on average 40 ± 2.4°C under direct sun and 38.6 ± 2.7 °C under the filter. In the UV supplementation experiment, the temperature was on average 25.5 ± 2°C. Figures 1 and 2 show the electromagnetic spectrum beneath the filter and UV lamp (intensity – count x75).

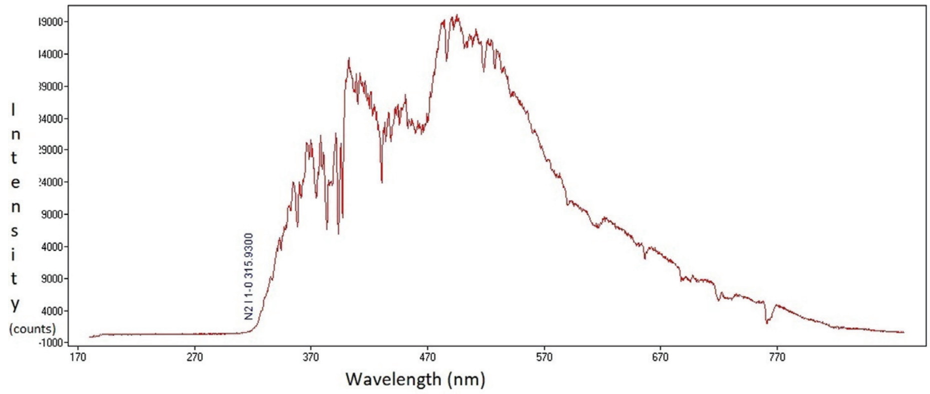

Figure 1. The electromagnetic spectrum beneath the filter.

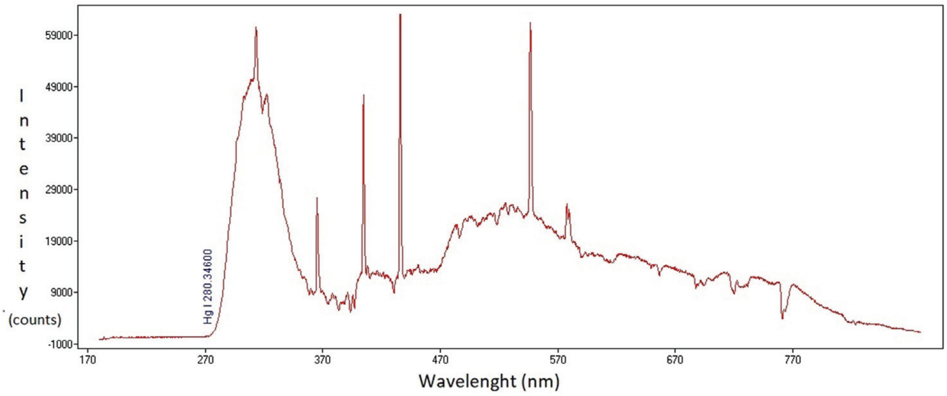

Figure 2. The electromagnetic spectrum beneath UV lamp.

The mealy plum aphids on the plum leaf (Fig. 3) were early-stage nymphs, late-stage nymphs, apterae and alate (Fig. 4). After exposure to the abaxial leaf surface, the mealy aphids migrate to the adaxial surface or down on the petiole. The same effect was recorded by SAKAI & OSAKABE (2010) for spider mites *Tetranychus urticae* Koch. We noticed a pattern of aphid movement when they leave the exposed leaf surface. They move to the leaf's edge or to the main rib towards the petiole. The movement of aphids to the main rib might have several causes. Aphids can perceive the rib as a landmark towards the stem and for the colonization of another leaf, or the hairs in this area can protect the aphids from the stress factor. We noticed that after the exposure time, the nymphs' individuals predominate over adult individuals and that winged adults were seldom present on the exposed surface of the leaf.

Figure 3. Plum leaf colonized by mealy aphid (original).

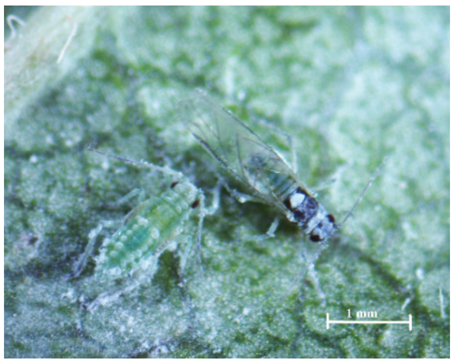

Figure 4. Apterae and alate individuals on plum leaf (original).

In the UV exclusion experiment, the mean of aphids leaving the leaves when exposed to the direct sun was 88.8 ± 2.2, while it was 82.4 ± 3.2 under the filter (Fig. 5). The statistical analysis reveals no significant differences between them ($P<0.05$). This might be due to higher temperature and its effect on aphids' mobility. Our results sustain NGUYEN et al.'s (2009) findings that high temperature had a more significant impact on aphids than UV-B radiation. BURDICK (2013) found minimal effect on soybean aphid densities under UV filters. Moreover, LEGARREA et al. (2012) found that *Macrosiphum euphorbiae* density was lower under a UV absorbing filter and CHYZIK et al. (2003) observed a low flight activity, propagation rate and a reduced density of green peach aphid.

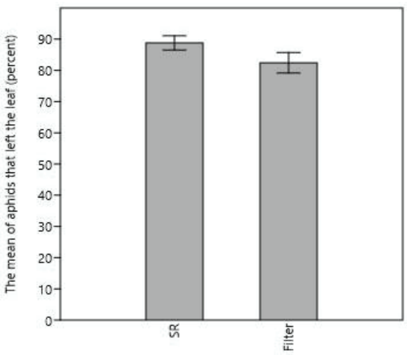

Figure 5. The mean of the aphids that left the leaf (per cent) in the UV exclusion experiment.

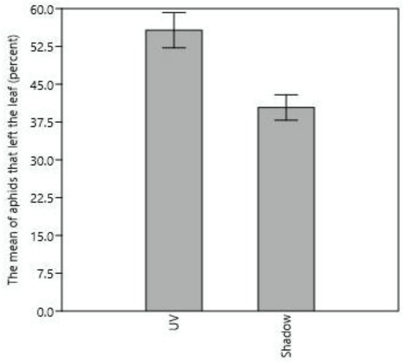

Figure 6. Percent of the aphids that left the leaf (per cent) in the supplementation experiment.

In the supplementation experiment, the data analysis reveals a statistically significant difference between the UV exposed versus control samples. The percent of aphids that left the leaves under the UV lamp was 55.7± 3.4. The percent of aphids that left the leaves kept in shadow was 40.3 ± 2.5 and might be related to the local microclimate or the leaves' upside-down position (Fig. 6).

After the exposure time, we noticed a clustering distribution of aphids (Fig. 7) in the supplemental experiment. Aphid crowding is usually due to the high reproduction rate and has implications on the production of winged aphids (SUTHERLAND, 1969); therefore, it has an indirect effect on aphids' long-distance distribution.

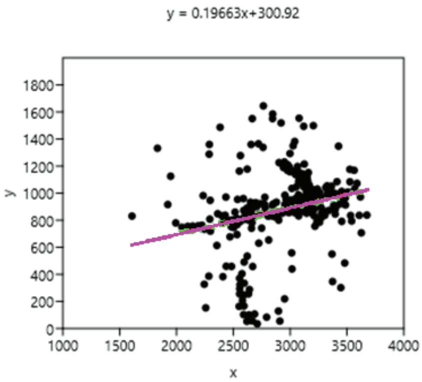

Figure 7. Aphid cluster distribution.

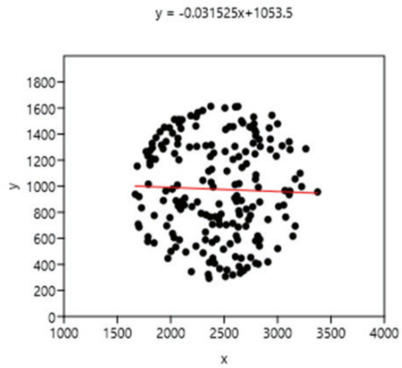

Figure 8. Aphid overdispersion distribution.

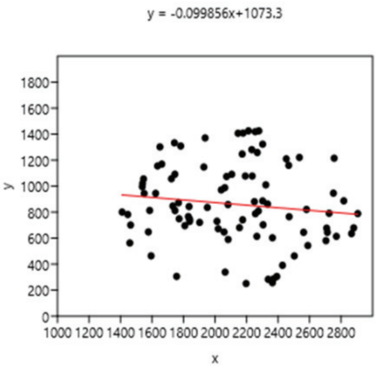

Figure 9. Aphid random distribution.

We perform the nearest neighbour point pattern analysis to assess whether the UV radiation influences the aphids' distribution on leaves. Mostly, the aphid distribution at the beginning of the experiment was overdispersion (Fig. 8). In fewer samples, the aphid distribution at the beginning of the experiment was random ($p<0.05$) (Fig. 9). At the end of the exposure time, the analysis revealed that the distribution was random ($p<0.05$) or significant clustering ($p<0.05$). The cluster distribution seldom appears in the shadow exposed samples. This change in aphid distribution on leaves might be more related to the patterns of aphids' movement when they leave the exposed leaf surface than to UV radiation.

CONCLUSIONS

Our supplementation experiment results demonstrate the UV radiation's potential impact on aphid behaviour.

We noticed a pattern of aphid movement when they leave the exposed leaf surface. Aphids move to the edge of the leaf, trying to reach the other side, or they move to the main rib towards the petiole. The change in aphid distribution on leaves might be more related to the patterns of aphid movement when they leave the exposed leaf surface than to UV radiation.

Following our results, other questions arise. What is the minimum dose of UV-B radiation that causes aphids to migrate? Does the dose of UV-B radiation influence the speed with which aphids move? These questions show that this subject field deserves further exploration.

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