Fighting powdery mildew with a UV robot: from science fiction to reality

The autonomous application of UV-C light in strawberry cultivation offers a good alternative to the many sprays to control white disease. By applying a dose of 90 J/m2 three times a week, you can perfectly control powdery mildew. The robot is best to perform the treatment at night, from one hour before sunset and until three hours before sunrise. UV-C fits within the IPM strategy because the predatory mites for biological control are sufficiently spared.

The tests show that UVC is very effective in controlling powdery mildew on leaves, flower stems and fruits.

Powdery midlew is a year-round threat to strawberry cultivation. The repeated use of fungicides is necessary, but this promotes resistance and a large number of residues on the strawberries come from powdery mildew agents. In the Inter-reg project 'UV-ROBOT' we are investigating the possibilities of UV-C light as an alternative control method. The ultimate goal is a fully autonomous control of powdery mildew. In this article we discuss the most important results of four years of UV-C research in strawberries at Proefcentrum Hoogstraten (PCH).

UV-C as a sustainable physical alternative to fungicides

UV-C or ultraviolet-C includes the high energy wavelengths between 100 and 280 nm. Due to the high energy content, exposure to UV-C light leads to DNA damage in organisms. In the literature we find that UV-C applications have a clear suppressive effect on white disease. The dose applied is critical. Too high a dose will damage the plant, too low a dose does not sufficiently inhibit the powdery midlew fungus.

If we want to make the application of UV-C a sustainable and safe alternative to the labour-intensive spraying against whitewash, then it is necessary to automate the application. It is important to note that UVC is indeed harmful to humans. It is also in sunlight, but the ozone layer protects us from these harmful UV-C rays.

From lamps on harvest cart to autonomous robot

PCH already started UV-C tests in strawberries in 2010. Several UV-C lamps were mounted on a harvest cart. By pushing the cart faster or slower, we were able to vary the dose. The first results on powdery mildew control were promising, but the manual application was very labour-intensive. Automation was urgent. In 2018, we received the first UV robot prototype at PCH in use, which was developed by Octinion as one of the partners in the UV-ROBOT project. This device was semi-autonomous and controlled with a remote control. Two x four 160 W lamps (Cleanlight) provided the UV-C light. From 2019, the robot consisted of two times three 55 W lamps (Philips) and was controlled with an app via the smartphone. With this app we maneuvered the robot to the beginning of the row. Once here, the UVC application in this row happened automatically and the robot returned to the beginning of the row. Then we manually moved the robot again to the next row. A fully autonomous robot from Octinion was not tested for the first time until 2021. This robot switches completely autonomously between the rows and consists of one plane of lamps.

Applying UV-C at night is more effective than during the day

Fungi are able to repair DNA damage through specific enzymes. a

Overzicht van de evolutie van het uv-C-toestel van 2010 tot 2021: de oogstkar met lampen (A) werd een prototype aangestuurd met een afstandsbediening (B), dan een prototype aangestuurd met de smartphone (C) en uiteindelijk een volledig autonoom toestel (D).

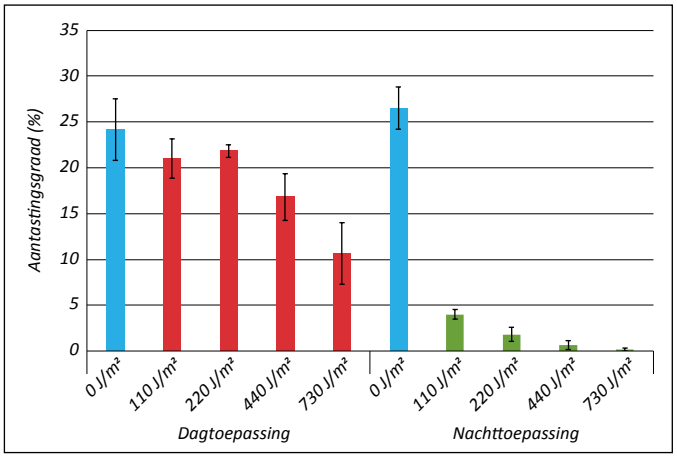

Figure 1. - Infestation rate of powdery mildew on September 18, 2018 in an autumn crop of Elsanta (glass) with day and night applications of UV-C. The plants were illuminated three times a week (Monday, Wednesday, Friday) with 110, 220, 440 or 730 J/m².

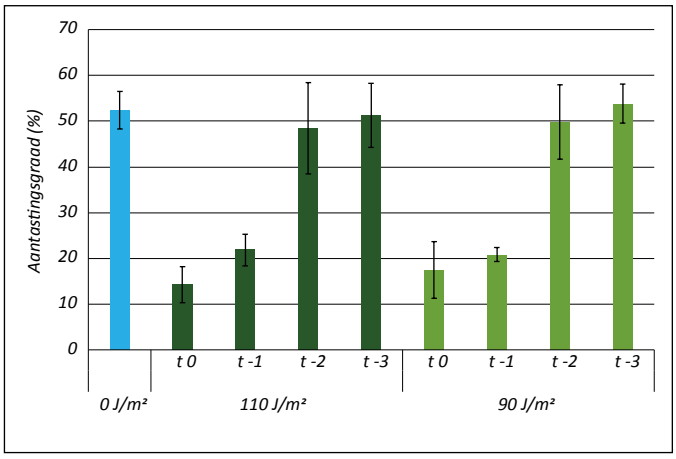

Figure 2. - Infestation rate of powdery mildew on September 23, 2020 in an autumn crop of Elsanta (hillside greenhouse). Plants were illuminated three times a week with 90 or 110 J/m2 (t 0 = at sunset; t-1, t-2 and t-3 = 1 hour, 2 hours and 3 hours before sunset).

An important aspect of this repair mechanism is that it is initiated in the presence of sunlight. We therefore see that the effect of UV-C is much more effective if we apply it after sunset. In the autumn crop (glass) of 2018, we saw that a daytime application (three times a week) of 730 J/m did not reduce the white disease infestation rate below 10% (Figure 1). In the applications (three times a week) after sunset, we already saw a sufficient effect at 110 J/m2 (less than 5% infestation rate).

From one hour before sunset to three hours before sunrise

In the literature, it is often assumed that a dark period of four hours after a UV-C treatment is necessary in order not to give the fungus's recovery mechanism a chance and therefore for good control of powdery mildew. In the summer (short nights) this considerably limits the time that the robot can drive around in the greenhouse. In full summer there are nights of only seven hours. a dark-A period of four hours after the treatment means that there is only three hours of treatment time per night.

In an autumn crop (Heuvelserre) from 2020, we saw that starting UV-C treatments one hour before sunset had no negative effects on white disease control (Figure 2). The difference in white disease infestation between starting at sunset (t0) and one hour before sunset (t-1) is negligibly small. This applies to both a dose of 110 J/m2 and 90 J/m2. We observed an infestation rate of 50% on the untreated plants. Starting treatment two or three hours (t-2 and t-3) before sunset does lead to excessive infestation. After the treatment, sunlight is still available for a long time to repair the damage to the DNA of the fungus.

From a small trial during the autumn of 2020 (covered racks) we concluded that a dark period of three hours after UV-C application instead of four hours does not cause an increased powdery mildew infestation. A dose of 110 J/m2 three times a week followed by a three hour dark period did not significantly increase infection compared to the same dose followed by the previously used four hour dark period.

A combination of these two trials gives us an additional two hours of treatment time. We can start treatment one hour before sunset and continue until three hours before sunrise. During short summer nights with only a seven-hour dark period, this corresponds to a 40% time gain. In spring and autumn, the treatment time is much less of a problem because the nights are longer.

Correct dosage leaves production untouched

Production was also recorded in the 2018 trial. This showed that production gradually decreased when UV-C doses were too high (Figure 3). From doses of 440 J/m2, production decreased significantly. The plants treated with these high UV doses were a bit more stocky and showed some leaf burn here and there. However, these high doses are not necessary, we showed that a dose of 110 J/m2 perfectly controls powdery mildew.

UV-C fits in IPM strategy with biological control agents

UV-C treatments must be compatible with the IPM strategy and therefore also with the release of beneficial insects. During a large-scale validation trial in the spring of 2020 (Heuvelserre), we applied a UV-C strategy (110 J/m2 three times a week).

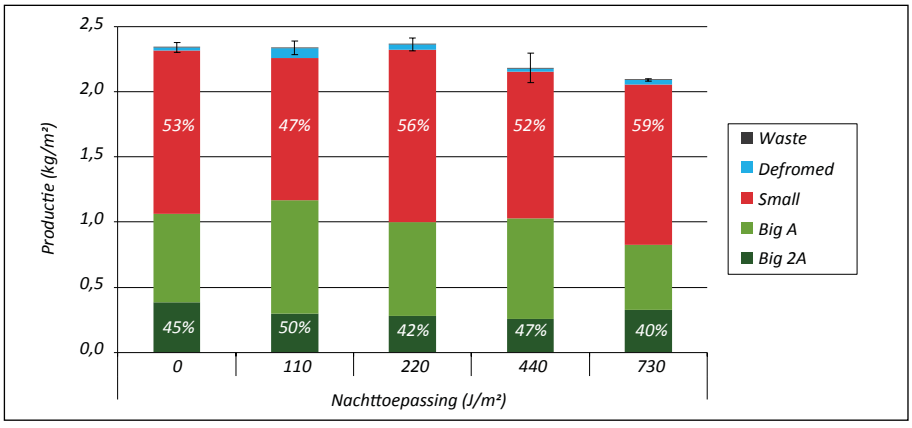

Figure 3 - Production and sorting in kg/m2 of an autumn crop of Elsanta (glass, 2018) with UV-C night applications.

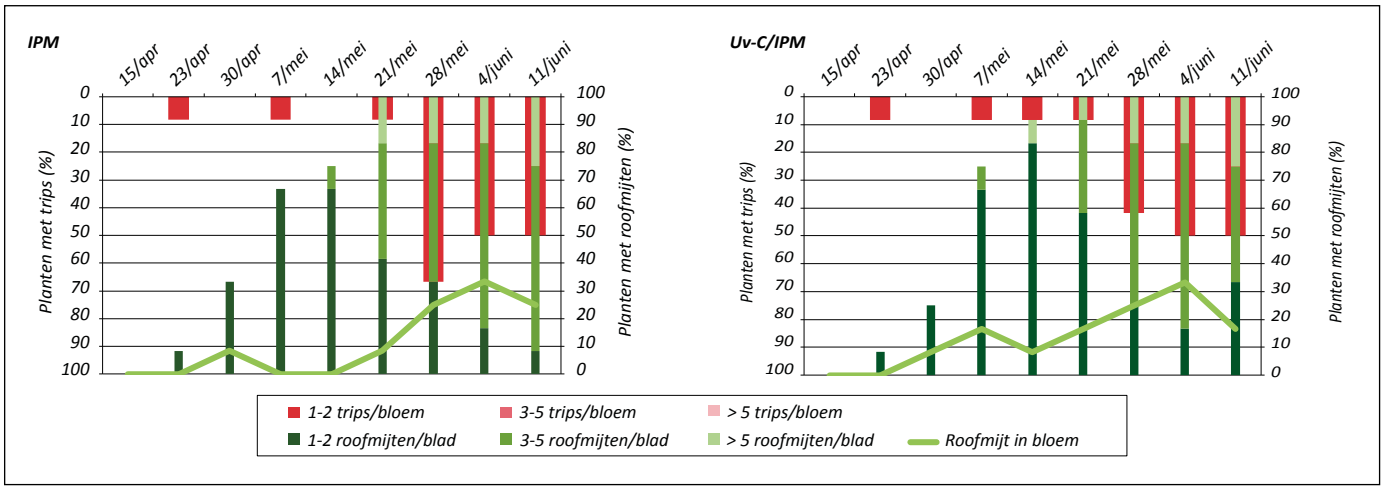

Figure 4. - Thrips control monitoring results are similar in IPM and UVC/IPM departments during spring 2020 crop (hillside greenhouse)

Table 1. - Overview of crop protection measures in the IPM and UVC/IPM department during a spring crop in 2020 (Heuvelserre).

Week	Gewasbeschermingsstrategie	
	uv-C/IPM	witziektebehandeling in IPM-afdeling
14	Paraat + gele vangplaten	
15		Vacciplant
16	Pirimor + N. cucumeris	Takumi + Vacciplant
17	Serenade + A. limonicus	Vacciplant
18	Teldor + A. limonicus	Flint
19	Serenade + P. persimilis	Vacciplant
20	P. persimilis	Vacciplant
21		Takumi + Frupica
22		Vacciplant
23		Vacciplant
24		Luna Sensation

The same actions were performed in both departments (deploying biological control agents, general disease and pest control). The only difference was the powdery mildew treatments, in the object UV-C/IPM were performed exclusively via UV-C, in the object IPM powdery mildew was controlled chemically.

sunset) combined with IPM (UV-C/IPM) and compared to a conventional IPM strategy. Table 1 shows the crop protection measures in the two sections. The conventional IPM strategy includes twelve treatments to control whiteness. These chemical and biological sprays were divided over ten time points. The combined UVC/IPM strategy does not include any anti-powdery mildew sprays. There were no problems with powdery mildew in either ward.

In both departments the predatory mites N. cucumeris and A. limonicus were also released to control thrips and P. persimilis to control spider mites. The predatory mite A. limonicus also eats whitefly eggs. The predatory mites managed to establish themselves well in both departments. In both objects we observed A. limonicus predatory mites in all spots from 20 May onwards. As a result, we had no significant problems with thrips. The population structure of predatory mites was excellent in this crop and was thus unaffected by the UV-C radiation applied three times a week (Figure 4).

Validation through field trials at growers

This new UV-C/IPM strategy is currently being validated at some growers. A fully autonomous application was not without a struggle for these growers. For example, the structure of each conservatory is different, which makes autonomous navigation even more challenging. Both a robot on pipe rails and a robot on pneumatic tires were validated. This year PCH monitored three crops at two growers. In both a Sonsation spring crop, an Elsanta summer crop and a Sonsation summer crop (all under glass), we did not observe an infestation rate above ten percent at any time during the cultivation process. In any case, there is great interest among strawberry growers. UV-C is therefore expected to be included in the IPM strategy in the coming years.

Proeven leiden tot concreet advies voor uv-C-toepassingen binnen IPM-strategie

Op basis van de resultaten van de proeven uitgevoerd op PCH tijdens de afgelopen vier jaar kunnen we dit advies formuleren.
Witziekte kan je op deze manier volledig bestrijden met uv-C:

- drie keer per week, startend vanaf de eerste hergroei van de planten;
- nachtbehandeling: start één uur vóór zonsondergang en stop drie uur vóór zonsopkomst;
- dosis: 90 J/m² (2x 45 J/m²).

Ook de neveneffecten naar plagen en biologische bestrijders werden in kaart gebracht en hieruit blijkt dat uv-C kan worden gecombineerd met IPM:

- uv-C heeft een werking tegen spint maar tegelijkertijd blijven de roofmijten *N. californicus* en *P. persimilis* voldoende gespaard;
- *N. cucumeris* en *A. limonicus* blijven voldoende gespaard voor tripscontrole;
- *A. limonicus* blijft voldoende gespaard voor wittevliegcontrole.

S. Laurijssen, P. Melis,
M. Hofkens & D. Baets
Proefcentrum Hoogstraten, Hoogstraten

Dit onderzoek werd uitgevoerd in het kader van het Interreg NWE project 'UV-ROBOT' met steun van het Europees Fonds voor Regionale Ontwikkeling. De toepassing van uv-C wordt in Vlaanderen ook onderzocht op tomaat (PCH), sla en komkommer (PSKW).