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# Laser Applications in Agriculture : Leaf Wetness Sensing and Pest Control

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**Abstract:** Agriculture needs new sustainable solutions to reduce pesticide use. To this end, lasers could be used either for monitoring, such as for remote leaf wetness sensing, or for destruction, such as for pest control. © 2023 The Author(s)

## 1. Summary

The proliferation of agricultural pests is the main reason for the use of phytosanitary products. A growing number of studies have shown their negative impact on the environment and health. The transition to a sustainable agriculture is therefore taking place. Fungicides are applied against fungal diseases and represent 17.5% of global pesticide use [1]. Early detection of plant diseases is promising for reducing their use. Going further, early detection of the conditions necessary for disease emergence is even better. Fungal diseases typically require water to proliferate, such as mildew in vineyards. Thus, a wetness monitoring tool can help farmers stay ahead of diseases and prevent their spread. Unlike existing wetness sensors on the market today that are based on changes in resistivity or relative permittivity [2], a laser-based tool could allow fast and low-cost measurements in a compact form factor. In addition, insecticides account for 29.5% of pesticide use [1]. Alternatives have already been developed, but their efficiency is limited [3]. Some pioneering studies have already proven the effectiveness of lasers in eliminating mosquitoes or drosophila [4, 5]. However, laser irradiation has never been applied to agricultural pests. In our previous article [6] we present an application where aphids were chosen as the target pest.

### 1.1. Leaf Wetness sensing

In this context, such prototypes were developed and tested in controlled conditions. The first one, for the leaf wetness sensing, used the Heiligenschein phenomenon, which consists in bright light seen when looking at illuminated drop-covered surfaces. A large amount of light returns in direction of its source thanks to droplet sphericity in Heiligenschein phenomenon conditions. Hence, to exploit this phenomenon, a laser source and a camera were installed close together. Of prime importance in our protocol was the ability to generate dew on the leaf. For that purpose, a leaf was cooled down to the temperature required for water vapour condensation, depending on the ambient hygrometry, using a cooling/heating Peltier module. Hydrophobic and hydrophilic leaf surfaces used during experiment were respectively grapevine (*Vitis vinifera*) and rapeseed (*Brassica napus*) leaves. Besides, a commercial wetness sensor was fixed to the cooling plate in order to have a reference with measurements made with our method. In order to be closer to in-field conditions, an experiment on the influence of leaf orientation has also been conducted. Moreover, one advantage compared to commercialised wetness sensors would be the ability to measure remotely several areas across the field for a better monitoring. To that end, an experiment with an orientable mirror has also been conducted.

Results show that this method is very sensitive on both types of leaves. Indeed, water detection is possible from a low surface coverage with a high temporal precision at 1 m. In the hydrophobic case, water on leaf surface leads to an increase of the detected signal up to three times compared to a dry leaf. The corresponding minimum surface coverage detectable at 1 m is evaluated at 1.6% using 2D ray-tracing numerical simulations. In the hydrophilic case, on the contrary, water on leaf surface leads to a decrease of the detected signal by almost half. For both types, the dew detection delay is contained under five minutes and can be improved. The presented results pave the way to a field application.

### 1.2. Pest Control

To fully explore the applicability of this method, we must both choose a representative pest species and investigate the optimization of the method to be energy efficient and innocuous for the plant environment. Based on three aphid lines (*Acyrtosiphon pisum* LL01, YR2 and *Rhopalosiphum padi*) and wavelengths (532, 1070 and

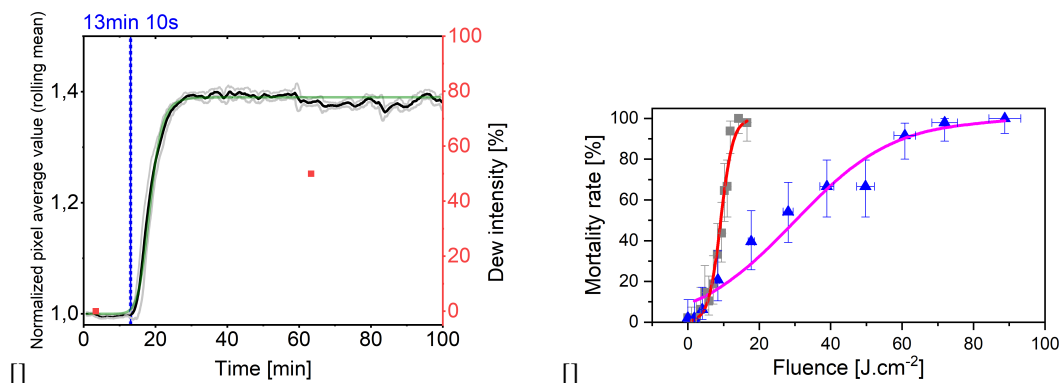


Fig. 1. **a)** Evolution of the pixel average value (moving average) with the cooling of a hydrophobic rapeseed leaf (*Brassica napus*) and a static measurement area (black). The moving standard deviation at  $\pm 2\sigma$  of the measurements is represented by the gray curves. The signal obtained by numerical simulation is represented in green. The vertical blue line and text represent the moment when the leaf temperature drops below the theoretically calculated dew point. The value of an average pixel is normalized by the first value of the measurement series for analysis and clarity purposes. The measurement points of the leaf wetness sensor are represented by red squares. **b)** Mortality rates as a function of the fluence for 532nm and 10.6 $\mu$ m lasers at Day + 1 on green aphids. Error bars are plus and minus exact binomial 95% confidence intervals. Control samples showed that 96% or more aphids survived. Blue dots and Gray squares refer to experiments done using the 532nm and 10.6 $\mu$ m lasers respectively. The purple and red solid lines are logistic regressions to the data obtained with the 532nm and 10.6 $\mu$ m lasers respectively. Extracted from [6].

10600nm), we first determined the lethal doses capable of causing 90% of death rate (LD90) at Day+1 and Day+7. By using synchronized 1st instar (N1) of the *A. pisum* LL01 line, we also assessed the influence of laser irradiation on the insect body in order to make the solution to be as less energy consuming as possible. Finally, a study was performed to ensure that fluences used to cause aphids death are innocuous for the host plants. Results show that both visible and far infrared wavelengths are effective in aphid elimination whereas the near infrared wavelength is ineffective. LD90 values at Day+7 applied on N1 *A. pisum* LL01 populations are ten times smaller than LD90 values for adults at Day+1 (1.15 J.cm<sup>-2</sup> and 12.91 J.cm<sup>-2</sup> respectively) with the far infrared wavelength. Laser impacts substantially irradiated populations affecting their mass, fecundity, development and mortality. Our results also suggest that irradiating at early stage is crucial to be effective. As a global strategy, we show that the energy cost will mostly depend on the chosen mobility vector and not on the electrical supply of the laser. LD90 irradiation conditions are harmless for host plants growth. This work suggests that a laser-based strategy is feasible and in-depth studies remain to be done in order to bring this solution to the market.

Therefore, if this method is applicable on aphids, it is also applicable on weeds, and it is easier because these targets are static. The use of this method on weeds is consistent with our previous motivations because herbicides represent almost half of the pesticides used [1]. This principle has been patented by Greenshield which is currently developing its dedicated weed control module.

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