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Highly Efficient Airblast Sprayer Design within the Project: *Healthy Crop, Healthy Environment, Healthy Finances – H_3O*

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Summary

Cropland covers almost 25% of the EU (4.4 million km^2) and most of that area is subject to phytosanitary treatments. With the EU Horizon 2020 project *Healthy crop, Healthy environment, Healthy finances through Optimization* **(**H_3O**)**, Pulverizadores Fede will bring a completely new generation of plant protection product application devices (sprayers) to market, with the aim of reducing the amount of product that is released into the environment by 50% and saving 38.5% of diesel. This will result in savings worth €462.5 per hectare annually. Moreover, the project is meeting key requirements of the EU Directive 2009/128/EC on sustainable use of pesticides and is in line with the food chain industry standard *GLOBALG.A.P*.

Key words: Drift, traceability, GLOBALG.A.P, farmers' profitability, human health, environment protection, ultrasound sensors, Cloud Services, Software-as-a-service.

Introduction

Cropland covers almost 25% of the EU (4.4 million km^2) (Eurostat, 2010) and most of that area is subject to phytosanitary treatments. The current spraying equipment used in fruit growing is hydraulic and assisted by air, known as airblast sprayers. During the treatments part of the amount of *plant protection product* (PPP) sprayed does not reach its target, and is lost in the atmosphere, in the ground and in surface water. Among these losses, *drift* is recognised as being the most important source of diffuse environmental contamination (Jong *et al.*, 2008; Maski & Durairaj, 2010) (Fig. 1). Drift is defined as the quantity of PPP that is carried out of the sprayed area by the action of air currents during the application process (ISO, 2005) and has potential effects on living organisms in areas adjacent to the treated ones, *e.g.* affecting nearby residents, bystanders, fauna and flora (Gil & Sinfort, 2005; de Schampheleire *et al.*, 2007; Cunha *et al.*, 2012).

The efficiency of pesticide treatments depends on the vegetation's dimensions, weather conditions, spray mix, sprayer design, and sprayer configuration. Pesticide losses have been quantified in several studies (Pergher *et al.*, 1997; Holownicki *et al.*, 2000; Richardson *et al.*, 2000; Salyani *et al.*, 2007; Chueca *et al.*, 2011) and it was found that losses can reach up to 50%. Loss reduction will improve environmental health as well as save money to producers.

Adjusting the plant protection product dose to structural and morphological characteristics of the vegetation is recognized at European level as an essential goal to improve the efficiency of the applications and to reduce the risks arising from the application of pesticides. Electronic systems based on ultrasound or infrared sensors to detect the vegetation have been developed. These technologies have a reasonable price and, hence, are currently deployed in commercial sprayers. Others sensors based on *laser imaging detection and ranging* (LIDAR) to characterize the vegetation's shape and estimate the vegetation's volume are also under study, but are still relatively expensive.

Fig. 1. Drift caused by conventional airblast sprayer in an orange orchard.

In general, the information form ultrasound, infrared or LIDAR sensors is used to control the water flow by solenoid valves or other systems. In this line, over the years different prototypes have been developed (Giles *et al*., 1998; Moltó *et al*., 2001; Walklate *et al*., 2002; Zaman *et al*., 2005; Solanelles *et al*., 2006; Rosell *et al*., 2009; Llorens *et al*., 2011). Further, within the EU Project ISAFRUIT (www.isafruit.org), an automatic crop adapted spray application prototype has been developed with a crop identification system as well as crop health sensors. Also an environmentally-dependent application system, identifying environmental circumstances during spray applications (Balsari *et al*., 2008) has been developed but is not yet commercially available.

To change this, Pulverizadores Fede has focused on designing a commercial highly efficient airblast sprayer, good for resource-efficient eco-innovative food production as well as for food producers' competitiveness. To finance developments, Pulverizadores Fede has successfully applied for a two year European project under the EU Horizon 2020 Framework Program entitled "*Healthy Crop, Healthy Environment, Healthy Finances through Optimization – H_3O*". Its main objective is the use of new information and telecommunications technologies in the application process to decrease the amount of product that reaches the ground, air or surface water, as well as to grant application traceability. The innovative development greatly simplifies the work for farmers/growers and technicians, while significantly reducing costs of agricultural production.

Materials & Methods

State of the art in sprayer technology is shown through the dark blue blocks in Fig. 2 (a). The crop type, its dimensions and spacing are taken into account manually to calibrate the sprayer and to adjust the dosage of the PPP. To assist agro-engineers and operators in this task, the software *G-Spraytech*® has been developed and is successfully used by operators. The software contains years of experience mathematically mapped into calibration and treatment parameters.

This way, operators are able to perform highly efficient treatments. However, sprayer adaptation is manual. No automatic adaptation to plant size, plant proximity and foliage density exists. Air-flow and product output are adjusted to the worst case and this is inefficient.

Moreover, there exists the risk of application mistakes (*e.g.* due to wrong tractor speed/wrong gear, wrong pressure settings), which have the potential to render treatments ineffective, but there is currently no automatic warning message that proactively informs operators about potential problems in the application process. Only after some days, is the lack of control efficacy observed, which means that a second treatment has to be applied. This second treatment, however, is not only very bad for the environment, but also costly, as twice the amount of PPP, fuel and working time is required. Further, a second treatment might render the crop un-sellable to certain supermarket chains that have a "residue free" policy, where "residue free" means that no pre-harvest treatment may be detected on the freshly picked crop, which requires a quarantine period between product application and harvest. Consequences are usually that the harvest can only be sold at a significantly lower prices. Although never sold with residual limits above those legally allowed, it still means that more traces of PPP might enter the food chain, which is certainly not in favour of consumers' health.

Further, on state of the art sprayers, the sprayer control interface is hardwired from the tractor to the sprayer, which is robust but has wiring inconveniences. Moreover, although Pulverizadores Fede's current products adhere to all compulsory standards and specifications, there is no remote link. The calibration software is available in the old fashioned way, but an online *software-as-a-service* (SAAS) solution is certainly desirable to continually update the calibration software to the latest standardization and regulatory developments.

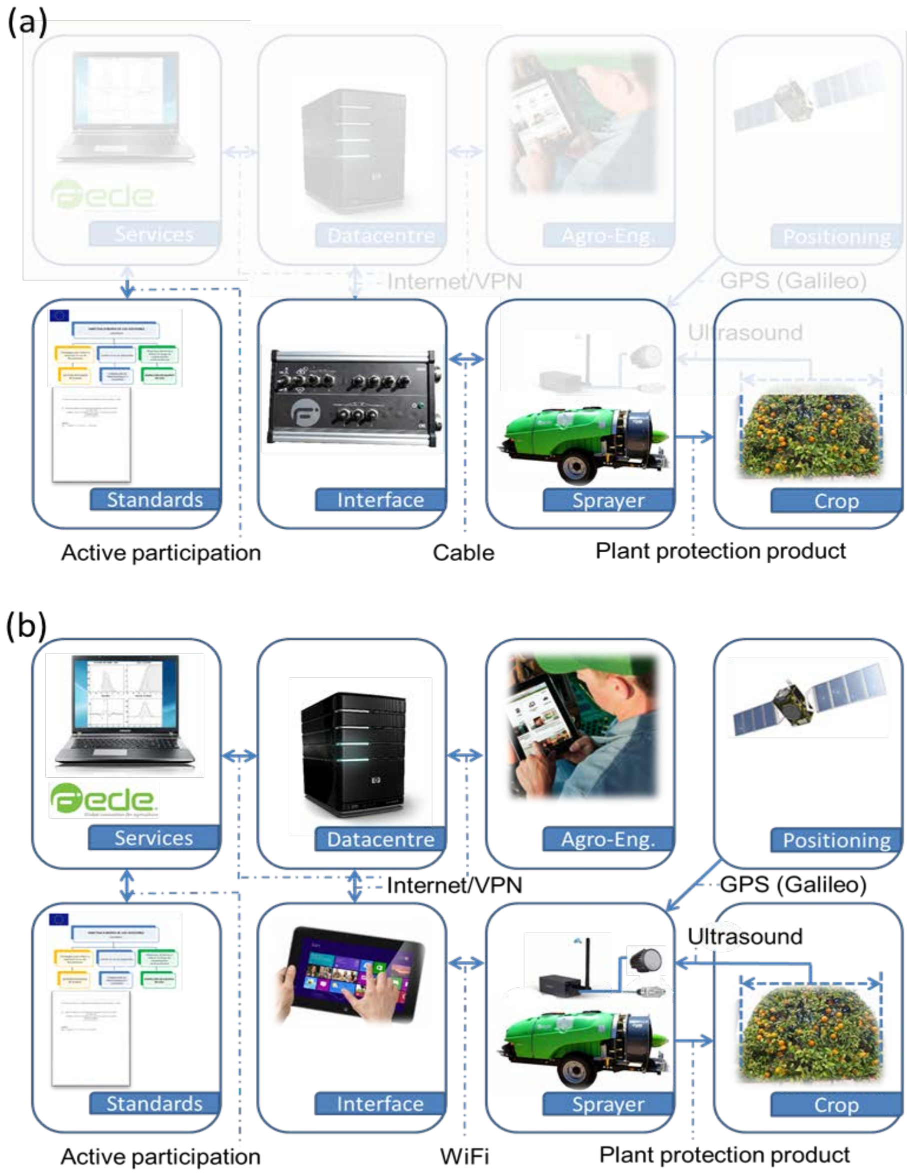

Fig. 2. (a) State of the art. (b) Beyond state of the art H_3O technology.

Having detected these deficiencies in the state of the art sprayer technology displayed in Fig. 2 (a), the first step to design the highly efficient airblast sprayer was to define its functionalities. The new sprayer had to be able to spray taking into account the characteristics of the vegetation, weather conditions, to acquire geo-location data and to deliver direct economic value for growers. Fig. 2 (b) shows our beyond state of the art H_3O architecture. An *ultrasound sensor*, a *GPS receiver* and *meteorological sensors* will be implemented in the sprayer. Therewith the air-flow, as well as the amount of released plant protection product could be adapted in real-time, based on the plants dimensions. For fine grain air-flow regulation a novel, patented air turbine with angle-adjustable blades is used, for which we received the 2014 *Innovation Award*, at the *International Agricultural Machinery Fair of Zaragoza*. Further, GPS and product output data logging (as well as time, temperature and meteorological conditions) will allow treatment traceability which is important to achieve *Healthy Crop*, *Healthy Environment* and *Healthy Finances* (H_3O). To assure traceability, treatment data between the sprayer and a tablet running a sprayer control app is wirelessly synchronised. As an option, this app could be additionally installed on the operator's smart phone to have a backup control interface. From the sprayer control app, the traceability data will be uploaded to a Cloud service. This is indicated through the box label "Datacentre" in Fig. 2 (b). Customers will be able to use a web interface to the datacentre to access detailed treatment control and treatment analysis tools, as well as tools that enable remote diagnostics and calibration.

Also, proactive warning messages will be displayed in real time, if the system detects application problems (*e.g.* a warning message will be issued if the tractor velocity exceed the recommended limits). Traceability and proactive warnings decrease the losses of pesticides in the environment because the sprayer is adapted to the climatic conditions. Furthermore, they reduce the risk that a second treatment becomes necessary and, hence, helps growers to meet industry standards as *GLOBALG.A.P.*.

Returning to Fig. 2 (b), the SAAS architecture will allow to incorporate the latest developments from regulations and standardization. Another side benefit is that the ultrasound scans of the plant dimensions and foliage conditions could be used to detect problems, *e.g.* with respect to the watering system or the soil quality, since very detailed crop maps could be obtained, on which problem areas of reduced crop growth can be easily identified. It is, hence, clear that apart from being able to offer a smart phone/tablet controlled, highly efficient, high-end sprayer, H_3O technology also will offer a long list of value added digital services. The advantages of H_3O are summarised in Table 1.

Table 1. *Main customer problem, state of the art, and our beyond state of the art H_3O solution*

Farmers' Problems	Today's Solutions	H3O
Losses=> high plant protection product consumption. Around 50% of plant protection product does not reach the target plant, as air-flow and product usage are not adapted in real time to every plant.	So called "*over spraying* " is used, *i.e.* the equipment is adjusted for the worst case, to avoide that a plague ruins the crop. Crop type, its dimensions/spacing, as well as field specific aspects are taken into account manually to calibrate the sprayer and adjust its plant protection product dosification. "O*ver spraying* " is kept as small as possible, while still obtaining treatment efectiveness.	Ultrasound sensors scanning the plant dimensions and **adapting** the **air-flow** and **plant protection product output in real-time**. The result is a **drift reduction by 50%** and a **fuel saving** of around **38.5%**, *i.e.* 3.85 l/h.
High fuel consumption, around 10l/h, due to constant van and pump usage at full output.	The spraying equipment is calibrated to the overall field and plant dimensions, but cannot be adjusted in real time to every plant. Fuel consumption remains relatively high.	
Time consuming, inaccurate, paper based treatment documentation. **Stringent food supply chain requirements.** Big supermarket chains often impose a *zero-residuo* requirement, meaning that no plant protection products may be detected on the crop at the time of harvest. Further, there are already chains that push for full treatment traceability.	Treatment reports are mandatory in many countries, but are often only filled out manually hours after the treatment was applied based on errorprone guess work. An experienced agro-engineeer determines the dose and timing of treatment to meet the *zero-residuo* requirement. Alternatively, the harvest may have to be sold into less stringent food supply chains at a much lower price.	Precise **data logging** of time, air-flow, product output, geo-location, temperature and wind speed. Data is **safely stored** in a Cloud based datacentre and is retrived for **automatic generation of mandatory traceability reports**.

Results

Specifically, for the H_3O technology, the customer focussed design objective is to reduce pesticide losses by 50%, and fuel consumption by 38.5%, while at the same time keeping H_3O costs below €6500. This will be achieved thanks the sprayer adaptation to the vegetation characteristics and climatic conditions during applications, as well as through a proactive warning system that will diminish the need to carry out second PPP treatments. This will result in savings of €462.5 per hectare per year, using Spanish prices for plant protection products and diesel fuel. H_3O technology will, hence, yield for an average grower with 10 hectares of vertical crop yearly savings of €4625, which in turn results in a payback period of less than 1.4 years.

Industrial size farms are able to manage up 35 hectares with a single sprayer, which results in an even shorter payback period of less than five months. Assuming a 10 year sprayer life time, the average 10 hectares grower's *return on investment* (ROI) turns out to be (€46250-€6500)/€6500=612%.

Further, GPS geo-location data, stored together with plant dimensions and PPP output will allow for treatment analysis together with a long list of value-added Cloud based services. These developments also will have a significant positive impact on food safety due to introducing traceability through the entire food chain, and on farmers' competitiveness.

Moreover, all H_3O developments go well in line with the European Union Directive 2009/128/EC "establishing a framework for Community action to achieve the sustainable use of pesticides", as well as Directive 2009/127/EC, "amending Directive 2006/42/EC with regard to machinery for pesticide application", which requires that "machinery must be designed and constructed to ensure that pesticide is deposited on target areas, to minimise losses to other areas and to prevent drift of pesticide to the environment".

Putting H_3O phytosanitary product savings into the bigger picture, if Europe's entire vertical crop surface would be treated with H_3O technology, farmers would bring 18 930 000 litres less PPP out into the fields each year, which makes it clear that H_3O not only produces *Healthy crop, Healthy environment, Healthy finances*, but potentially much improved living conditions for all of us.

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