AUTOMATICALLY CONTROLLED SPRAYER TO IMPLEMENT SPRAY DRIFT REDUCING APPLICATION STRATEGIES IN ORCHARDS

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A B S T R A C T

Within the EU project ISAFRUIT (*www.isafruit.org*) a Crop Adapted Application System (CASA) was developed to ensure precise, efficient and safe spray application in orchards, according to actual needs of the crop and with respect to the environment. The CASA system consists of three sub-systems: (i) Crop Health Sensor (CHS) identifying heath status of fruit crops, (ii) Crop Identification System (CIS) identifying the tree canopy size and density, (iii) Environmentally Dependent Application System (EDAS) identifying environmental circumstances during spray applications. In order to protect sensitive areas within the orchards surroundings (e.g. surface water, melioration wells, public sites) the spray application parameters such as droplet size and air flow velocity need to be carefully adjusted taking into account wind direction and velocity as well as position of sprayer in relation to these areas. On EDAS sprayer wind velocity and direction is measured with an ultrasonic anemometer, and sprayer position is determined by GPS. Nozzles are altered automatically depending on wind situation to adjust droplet size according to drift risk level. A novel fan construction allows the supporting airflow to the left and right hand sections of the sprayer to be adjusted independently. This adjustment is done automatically depending on the wind situation and sprayer position.

Key words: precise spray application, fruit growing, GPS navigation, ultrasonic anemometer, airflow, spray quality

INTRODUCTION

In orchards, pesticides are usually applied regardless of the actual health status of protected crops, and with spray volume and airflow settings that ignore variable requirements of the target plants expressed in terms of their size and density. This is because conventional axial fan sprayers have no systems to identify plant health status and plant characteristics, and they are not equipped with devices to adjust critical spray application parameters such as spray volume, droplet size and airflow according to the actual need.

Plant protection, especially where pesticides are used very intensively as in fruit growing, should not have any negative impact on the environment. In the surroundings of orchards there may be sensitive areas such as surface water, melioration wells, sensitive crops or public sites. These areas must not be contaminated by a spray drift which is influenced not only by wind velocity but also by application parameters controlled by the operator, such as droplet size and airflow parameters. Conventional sprayers have no ability to alter the application parameters automatically according to the wind situation and proximity of sensitive areas.

The consumers' demand for healthy fruits, the growers' requirements for lower production costs and the environmental concerns of society stimulate research on low input plant protection techniques. Precision agricultural tools are needed to identify the problem and the target, as well as recognise the environmental circumstances in order to apply pesticides according to the actual requirements at a precise rate and with respect to the environment. This was one of the objectives of the EU project within the 6th Framework Programme: "Increasing fruit consumption through a trans disciplinary approach leading to high quality produce from environmentally safe, sustainable methods – ISAFRUIT" (ISAFRUIT, 2006). Within this 5-year project (2006-2010) a Crop Adapted Spray Application system (CASA) was developed according to the concept reported by Doruchowski et al. (2009). The objective of the CASA system is to adjust spray application parameters automatically according to the crop health status and crop characteristics, as well as the wind situation and sprayer position in the orchard. This is in order to reduce pesticide input and hence improve the quality and safety of fruit and environment.

The CASA system consists of three sub-systems developed independently by the project partners and ultimately integrated on a CASA sprayer model: (i) Crop Health Sensor (CHS) – determining crop health status to support decision making on spray application, as reported by Van de Zande et al. (2007); (ii) Crop Identification System (CIS) – identifying target characteristics for precision spray application, as reported by Balsari et al. (2007); (iii) Environmentally Dependent Application System (EDAS) – recognising the wind situation and position of the sprayer to protect sensitive areas in the orchard environment, as reported by Doruchowski et al. (2007). The concept and development of the EDAS sub-system are presented in this paper.

The aim of the work was to develop an automatic adjustment system for the fan of orchard sprayer that would allow to reduce the environmental impact of spray application in fruit growing. The objective of the measurements was to identify the best set-up of the system which may bring environmental benefit in different field situations by implementing drift reducing spray application strategies.

MATERIAL AND METHODS

EDAS is a spray application system for orchards which identifies environmental circumstances and adjusts application parameters accordingly, so that spray distribution is optimised and spray loss is minimised. This protects sensitive areas within the surroundings of orchards. The environmental circumstances to be identified are: wind velocity and direction, measured with an ultrasonic anemometer (Vaisala WINDCAP® Ultrasonic Wins Sensor WMT50), as well as orchard boundary and sensitive areas such as surface water, melioration wells, buildings, sensitive crops, public sites, etc. acquired from a digital orchard map (e.g. GIS data). According to the wind situation and sprayer position relative to the orchard boundary and sensitive areas (GIS/GPS), the spray quality is automatically adjusted by altering the nozzles (fine spray/coarse spray) in order to minimise the spray drift. In addition, appropriate nozzles are closed to respect the local standards for buffer zones. Furthermore, in order to minimise the emission of spray towards sensitive areas, and yet ensure the best possible spray distribution in the orchard, the supporting air jet is adjusted individually for left and right section of the sprayer by manipulation of airflow on the inlet and outlet of the fan. The scheme of EDAS concept is shown in Figure 1.

The EDAS sprayer was designed and a novel air jet adjustment system was constructed and assembled on a Hardi Arrow sprayer with a double rotor radial fan P540D (19 000 m^3 h^{-1}). An air collector was developed and fixed on the fan to distribute the airflow uniformly to 16 individual air spouts (8 for each section of sprayer). Then an adjustable air vane was assembled inside the air collector to adjust or close the airflow individually to the left and right sections of the sprayer (Fig. 2A). The simultaneous measurements of air velocity from the 8 air spouts were made with a set of hot film anemometers and an 8-channel data logger in stationary, dynamic and orchard situations. In each scenario, closing the airflow on one section resulted in an increase in air velocity on the other section by 30-40%. In order to avoid this, a diaphragm leaf shutter was designed and fixed on the fan inlet (Fig. 2B). Once the collector vane closes the airflow to one section, the leaf shutter may restrict the flow of air sucked in by the fan accordingly so that the air velocity remains constant when one section is

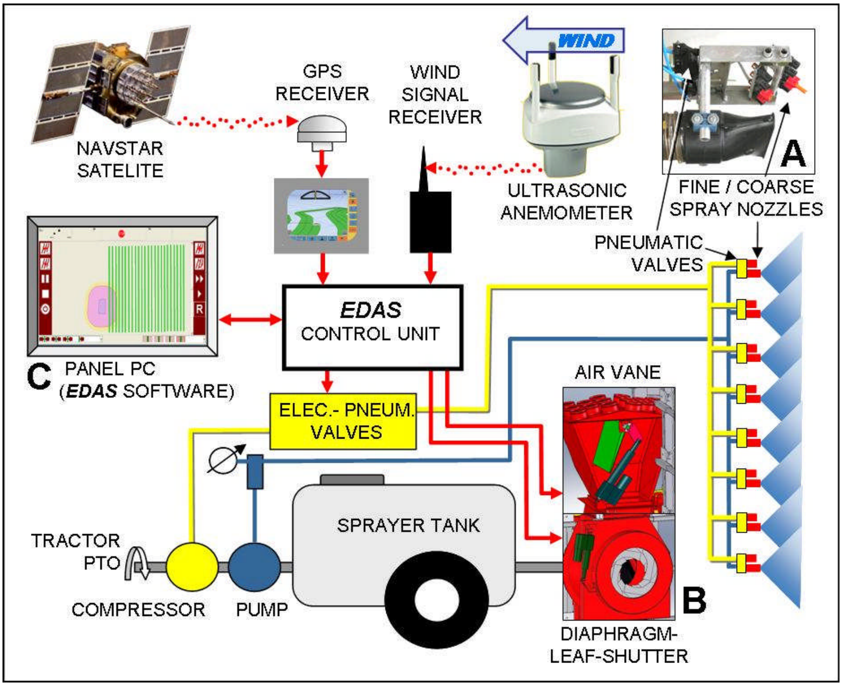

Figure 1. Orchard sprayer with an EDAS system: A – spray quality adjusted by the alteration of nozzles (fine spray / coarse spray); B – air velocity adjusted by manipulation of the diaphragm-leaf-shutter on the inlet and the air vane on the outlet of the radial fan; C – system controlled by the panel PC with the EDAS software

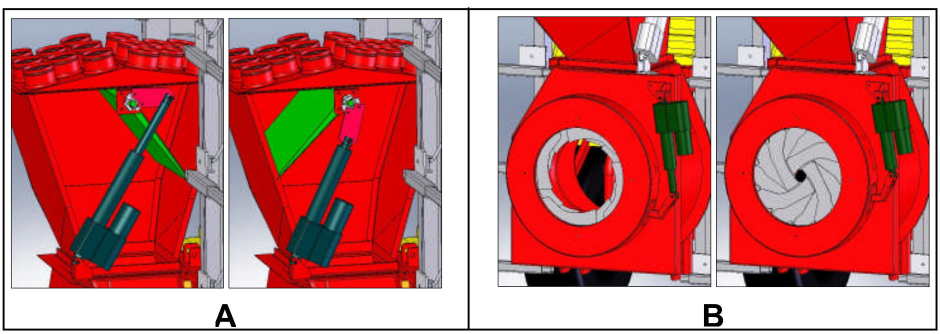

Figure 2. Airflow adjustment system on EDAS sprayer: A – air vane in the air collector (position V1 and V11); B – diaphragm leaf shutter on the inlet of radial fan (position S5 – fully open and S0 – closed)

closed. The measurements of air velocity were repeated for all possible combinations of:

11 positions of air vane in the air collector (from V1 to V11), where:
- V1 = airflow closed to the right section and fully open to the left section.
- V6 = central position – equal distribution of airflow to both sections.
- V11 = airflow closed to the left section and fully open to the right section.

6 positions of the leaf shutter (from S0 to S5), where:
- S0 = leaf shutter closed.
- S5 = leaf shutter fully open.

The measurements were made 30 cm from the outlet of the air spouts, in 5 replications for each combination, simultaneously for 8 spouts, separately for left and right section (in total: 5 280 measurements).

Double nozzle holders with fine spray and coarse spray nozzles controlled individually by on/off pneumatic valves, were assembled at the air spouts. The valves alter the nozzles (fine spray/coarse spray) depending on the wind situation and position of the sprayer in relation to the orchard boundary and the sensitive areas. The EDAS control unit and EDAS software were developed to control both air and spray emission systems in various situations and to integrate them with GPS.

RESULTS AND DISCUSSION

The results of air velocity measurements showed that by the manipulation of the diaphragm leaf shutter on the fan inlet and air vane in the air collector of EDAS sprayer, it was possible to adjust air velocity individually for each section (Tab. 1). With the shutter/vane setting being S2/V6 as a reference (average airflow velocity LEFT/RIGHT section = 14.0/15.4 ms^{-1}) the com-binations of shutter and vane positions were identified to obtain air velocities on LEFT/RIGHT air spout section fairly corresponding with the required ones in various typical situations (expressed in percentage deviation from reference air velocity values) (Tab. 1), e.g.:
- S0/V1 (+29%/-100%) or S0/V11 (-100%/+12%) – when spraying the boundary row, to protect sensitive areas in orchard surrounding from contamination by spray blown through the last outer row;
- S0/V2 (+13%/-68%) or S0/V10 (-64%/+2%) – when spraying the last but one row, to protect sensitive areas in orchard surrounding from contamination by spray blown through the two outer rows;
- S1/V4 (-4%/-25%) or S1/V9 (-36%/+1%) – when spraying the last but two rows, to protect sensitive areas in orchard surrounding from contamination by spray blown through the three outer rows;
- S3/V3 (+32%/-23%) or S3/V9 (-16%/+20%) – at cross wind $\geq 2\ ms^{-1}$, to ensure satisfactory spray penetration into crop canopy on both sides of the sprayer by compensating for a cross wind resistance.

Table 1. Average airflow velocities (m/s) measured for left (L) and right (R) air spout sections for different positions of diaphragm leaf shutter on the fan inlet (from S0 to S5) and air vane in the air collector (from V1 to V11) of EDAS sprayer model (average of 8 air spouts in 5 replications). The reference (standard) setting of the fan is S2/V6 (marked with black cells)

Air vane position	Leaf shutter position (S0 – closed; S5 – fully open)											
	S0		S1		S2		S3		S4		S5	
	L	R	L	R	L	R	L	R	L	R	L	R
V1	18.1	0.0	18.5	0.0	19.4	0.0	21.0	0.0	22.1	0.0	21.7	0.0
V2	15.8	5.0	16.9	5.2	18.5	5.4	20.2	6.0	21.2	6.1	20.7	6.0
V3	14.4	8.9	15.3	9.3	16.4	10.4	18.5	12.0	19.6	11.8	19.3	11.9
V4	12.5	11.4	13.4	11.7	15.0	13.6	17.4	15.4	18.5	15.4	18.3	15.4
V5	11.8	12.3	12.7	13.1	14.2	14.5	17.0	16.4	18.3	16.8	18.1	16.3
V6	11.6	13.1	12.5	13.9	**14.0**	**15.4**	16.8	17.2	18.2	17.5	17.9	17.2
V7	11.5	13.1	11.9	14.0	13.5	15.6	16.1	17.2	17.9	17.6	17.8	17.5
V8	10.5	13.3	11.2	14.0	12.4	15.8	14.8	17.7	16.8	18.0	16.6	18.0
V9	8.4	15.0	9.0	15.7	10.2	17.1	11.7	18.7	12.7	18.1	12.2	18.2
V10	5.1	15.9	5.4	16.7	5.8	18.1	6.3	19.7	6.5	20.5	6.4	20.3
V11	0.0	17.5	0.0	18.2	0.0	19.1	0.0	20.2	0.0	21.0	0.0	20.9

The reference setting S2/V6 with a symmetrical airflow distribution is to be used inside the orchard (e.g. from the third row on), during longitudinal winds and cross winds lower than e.g. 2 m s^{-1}. The wind threshold value may be set at operator's discretion in EDAS software (Fig. 1).

During spray application, the shutter/vane settings is adjusted automatically according to the position of the sprayer in orchard (GIS/GPS) and wind velocity/direction measured with the ultrasonic anemometer mounted on the mast, located in the orchard. The wind measurement data are sent to the EDAS control unit wireless (Fig. 1). The airflow might also be adjusted based on the canopy width and foliage density measured by the ultrasonic sensors of CIS system to support the spray application concept proposed by Salyani (2007).

CONCLUSIONS

The EDAS sprayer model equipped with wind sensor and GPS navigation system enables real time adjustment of application parameters such as airflow and spray quality to reduce the negative environmental impact of spray applications in orchards. It may be integrated with the CHS and CIS sub-systems to meet the objectives of the Crop Adapted Spray Application system to the full extent.

The in-field drift measurements with EDAS system need to be made in various climatic and growth stage situations in order to approve the system as a Spray Drift Reducing Technology (SDRT) and classify its drift reduction potential. With this SDRT classification the system may be included in the buffer zone schemes existing, or being developed, in EU Member States to implement the EU Directive 2009/128/EC on sustainable use of pesticides.

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AUTOMATYCZNIE STEROWANY OPRYSKIWACZ DO REALIZACJI NISKOZNOSZENIOWYCH ZABIEGÓW OCHRONY SADÓW

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STRESZCZENIE

W ramach projektu UE, ISAFRUIT (*www.isafruit.org*) opracowano inteligentny opryskiwacz, adaptowany do charakterystyki upraw (CASA – Crop Adapted Application System), w celu realizacji precyzyjnych, skutecznych i bezpiecznych zabiegów ochrony sadów, zgodnie z rzeczywistymi wymaganiami roślin oraz z poszanowaniem środowiska. W skład systemu CASA wchodzą trzy podsystemy: (i) CHS – Crop Helth Sensor – czujnik zdrowotności roślin; (ii) CIS – Crop Identification System – system identyfikacji charakterystyki upraw; (iii) EDAS – Environmentally Dependent Application System – środowiskowo regulowana technika opryskiwania – będąca przedmiotem publikacji. W celu ochrony obszarów wrażliwych w sąsiedztwie sadu (np. wody powierzchniowe, kanały melioracyjne, studnie, tereny publiczne) przed skażeniem środkami ochrony roślin należy ograniczać znoszenie cieczy użytkowej przez odpowiedni dobór parametrów zabiegu, takich jak wielkość kropel i prędkość strumienia powietrza, biorąc pod uwagę prędkość i kierunek wiatru oraz położenie opryskiwacza względem obszarów wrażliwych. Z użyciem systemu EDAS prędkość i kierunek wiatru pozyskiwane są bezprzewodowo z anemometru ultradźwiękowego, a położenie opryskiwacza wyznaczane jest za pomocą różnicowego systemu pozycjonowania satelitarnego (DGPS). Rozpylacze zmieniane są automatycznie w zależności od prędkości i kierunku wiatru, aby dostosować wielkość kropel do poziomu ryzyka znoszenia cieczy. Innowacyjna koncepcja regulacji strumienia powietrza pozwala na niezależne ustalanie prędkości powietrza po lewej i prawej stronie opryskiwacza. Regulacja ta wykonywana jest automatycznie w zależności od wiatru i położenia opryskiwacza.

Słowa kluczowe: precyzyjna ochrona roślin, sadownictwo, nawigacja GPS, anemometr ultradźwiękowy, strumień powietrza, jakość rozpylania