GPS Navigated and Automatically Controlled Orchard Sprayer with Environmentally Dependent Application System (EDAS) to Implement Drift Reducing Application Strategies

Grzegorz Doruchowski, Waldemar Swiechowski, Artur Godyn and Ryszard Holownicki
Research Institute of Pomology and Floriculture, Department of Agro-Engineering,
Pomologiczna 18, 96-100 Skierniewice, Poland, Tel. +48 46 8345247, E-mail: gdoru@insad.pl

ABSTRACT

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.

Keywords: Precise spray application, fruit growing, GPS navigation, ultrasonic anemometer, airflow, spray quality, Poland

1. 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.

G. Doruchowski, W. Swiechowski, A. Godyn and R. Holownicki “GPS Navigated and Automatically Controlled Orchard Sprayer with Environmentally Dependent Application System (EDAS) to Implement Drift Feducing Application Strategies”. International Commission of Agricultural and Biological Engineers, Section V. Conference “Technology and Management to Increase the Efficiency in Sustainable Agricultural Systems”, Rosario, Argentina, 1-4 September 2009.

Plant protection, especially where pesticides are used very intensively as in fruit growing, should not have any negative impact on the environment; there may be sensitive areas neighbouring the orchards such as surface water, melioration wells, sensitive crops or public sites. These areas must not be contaminated by a spray drift (which is influenced by wind velocity, 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 is 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 launched in 2006, 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 works was to develop an 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.

2. MATERIALS 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 a ultrasonic anemometer (Vaisala WINDCAP® Ultrasonic Wins Sensor WMT50), and orchard boundary and sensitive areas such as surface water, melioration wells, buildings, sensitive crops, public sites, etc. from GIS. According to the wind situation and sprayer position relative to the orchard boundary/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.

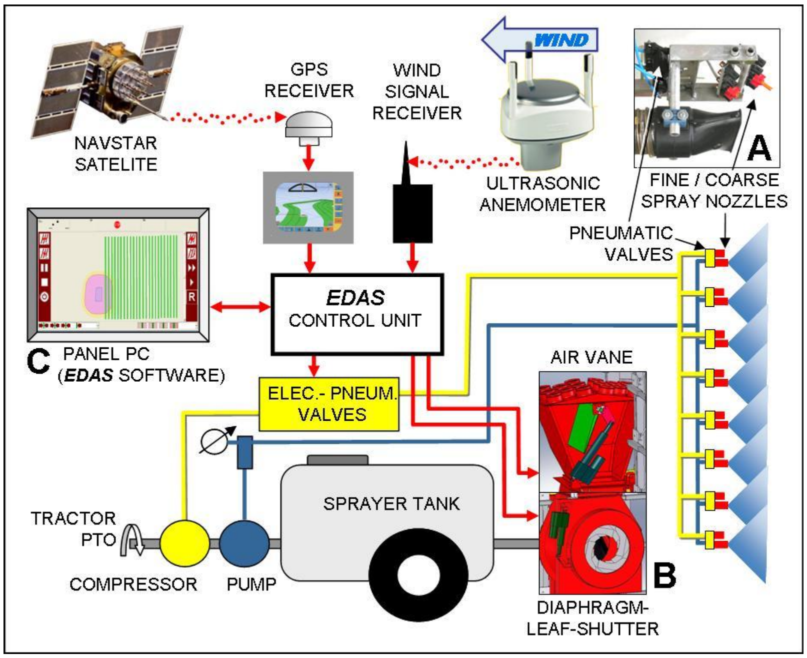

Figure 1. Orchard sprayer with an EDAS system: A - spray quality adjusted by the alteration of nozzles (fine spray / coarse spray); B - air velocity adjusted by manipulation of the diaphragm-leaf-shutter on the inlet and the air vane on the outlet of the radial fan; C - system controlled by the panel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

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^3h^{-1}). Initially, an air collector for distribution of airflow to 16 individual air spouts (8 for each section of sprayer) was elaborated and fixed to the fan. Having obtained the uniform air distribution from the collector, an adjustable air vane was assembled inside it to adjust or close the airflow individually to the left and right sections of the sprayer (figure 2 A). 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 (figure 2 B). Once the collector vane closes the airflow to one section, the leaf shutter restricts the flow of air sucked in by the fan accordingly. Thus, the air velocity remains constant when one section is closed. The measurements of air velocity, as described above, were repeated for all possible combinations of:

- 11 positions of air vane in the air collector (V1 ... 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 (S0 ... S5), where:
  - S0 = leaf shutter closed
  - S5 = leaf shutter fully open

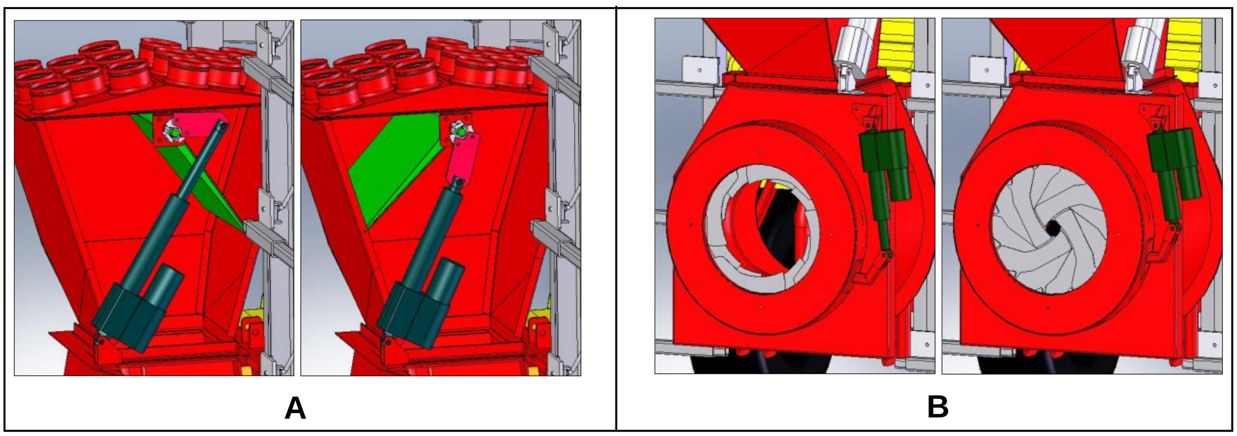

Figure 2. Airflow adjustment system on EDAS sprayer: A - air vane in the air collector (position V1 and V11); B - diaphragm leaf shutter on the inlet of radial fan (position S4 and S0).

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.

3. 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. With the shutter/vane setting being S2/V6 as a reference (average airflow velocity LEFT/RIGHT section = 14,0/15,6 ms^{-1}) the combinations 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) (figure 3), e.g.:

- S0/V1 (+29%/-100%) or S0/V11 (-100%/+12%) – when spraying the boundary row,
- S0/V2 (+13%/-68%) or S0/V10 (-64%/+2%) – when spraying the last but one row,
- S1/V4 (-4%/-25%) or S1/V9 (-36%/+1%) – when spraying the last but two row,
- S3/V3 (+32%/-23%) or S3/V9 (-16%/+20%) – to counteract a cross wind ≥ 2 ms^{-1}.

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

During spray application, the shutter/vane settings is adjusted automatically according to the position of the sprayer in the 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 (figure 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).

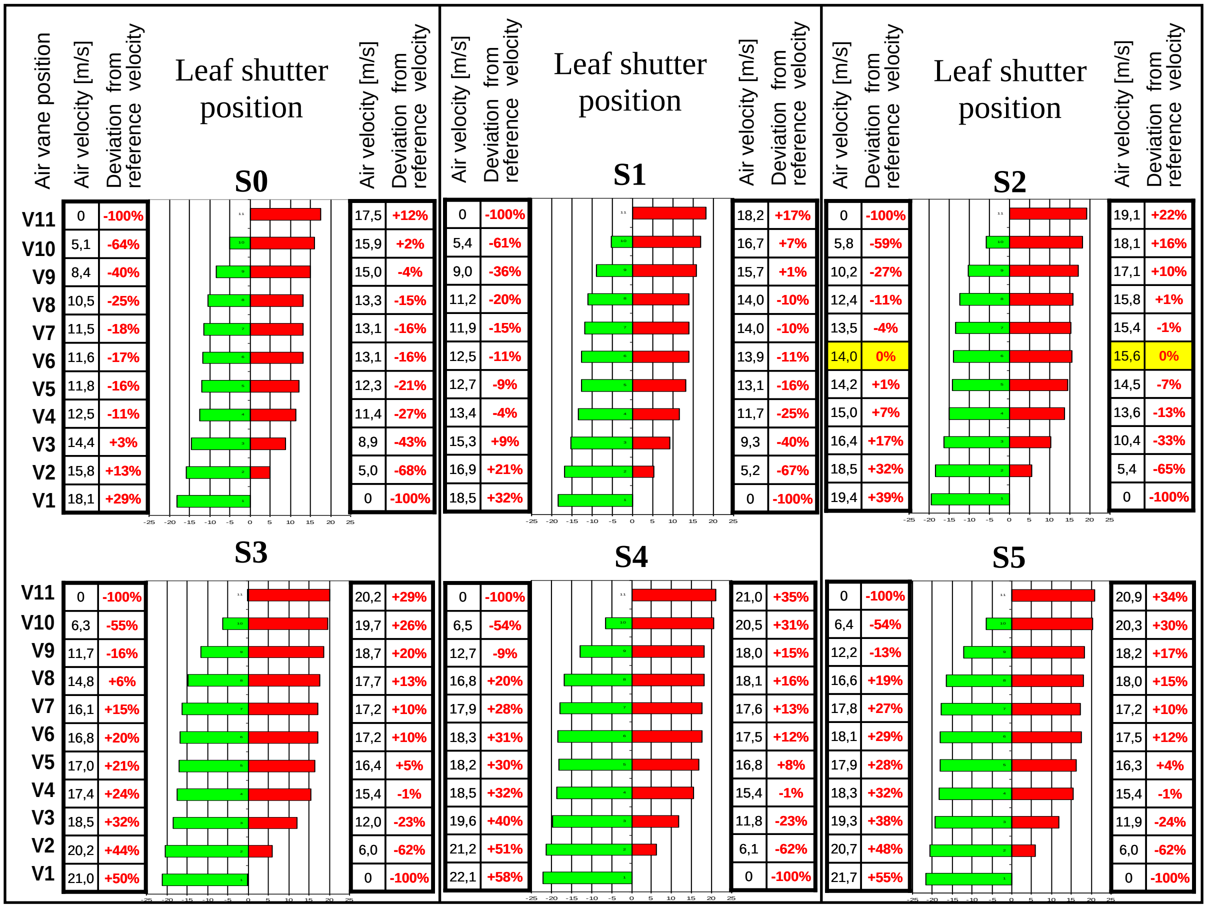

Figure 3. Average airflow velocities (m/s) measured for LEFT and RIGHT air spout sections and air velocity deviations (%) from the reference setting (S2/V6) for different positions of diaphragm leaf shutter on the fan inlet and air vane in the air collector of EDAS sprayer model (average of 8 air spouts in 5 replications)

4. 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 is integrated with the CHS and CIS sub-systems to meet the objectives of the CASA system to the full extent.

The current works within the ISAFRUIT project (spring-autumn 2009) focus on carrying out field experiments to evaluate the effects of EDAS controlled applications on spray treatment quality (spray deposition and distribution within tree canopies), and reduction of environmental pollution (spray drift).

5. ACKNOWLEDGEMENTS

Thanks go to Tadeusz Jędrachowicz, Marek Bernyś, and Grzegorz Kubica for contribution to the EDAS concept and software development.

This research was financially supported by the 6th Framework Programme EU Project ISAFRUIT. The ISAFRUIT Project is funded by the European Commission under Thematic Priority 5 – Food Quality and Safety of the 6th Framework Programme of RTD (Contract No. FP6-FOOD-CT-2006-016279).

6. REFERENCES

Balsari, P., G. Doruchowski, P. Marucco, M. Tamagnone, J.C. Van de Zande, and M. Wenneker. 2007. The development of a Crop Identification System (CIS) able to adjust the spray application to the target characteristics. Proc. SuProFruit 2007 – 9th Workshop on Spray Application Techniques in Fruit Growing. Alnarp, Sweden 12-14 September. p. 17-18.

Doruchowski, G., R. Holownicki, A. Godyn, W. Swiechowski, T. Jedrachowicz, P. Balsari, P. Marucco, J.C. Van de Zande, V. Achten, and M. Wenneker. 2007. Environmentally Dependent Application System (EDAS) for adjusting the spray application parameters according to the environmental circumstances in orchards – ISAFRUIT project. Proc. SuProFruit 2007 – 9th Workshop on Spray Application Techniques in Fruit Growing. Alnarp, Sweden 12-14 September. p. 15-16.

Doruchowski, G., P. Balsari, and J.C. Van de Zande. 2009. Development of a Crop Adapted Spray Application System for Sustainable Plant Protection in Fruit Growing. Acta Horticulturae 824, eds. L.G. Albrigo and R. Ehsani, Proc. IS on Appl. of Precision Agric. for Fruit and vegetables. p. 251-259.

ISAFRUIT. 2006. www.isafruit.org

Salyani, M., N. Pai, and R.D. Sweeb. 2007. On-the-go changing of sprayer airflow based on tree foliage density. Proc. SuProFruit 2007 – 9th Workshop on Spray Application Techniques in Fruit Growing. Alnarp, Sweden 12-14 September. p. 63-64.

Van de Zande, J.C., M. Wenneker, J. Meuleman, V. Achten, P. Balsari, and G. Doruchowski. 2007. Development of a Crop Health Sensor to minimise spray applications in apple. Proc. SuProFruit 2007 – 9th Workshop on Spray Application Techniques in Fruit Growing. Alnarp, Sweden 12-14 September. p. 13-14.