VRT air jet system for orchard sprayers

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Abstract

Conventional air-assisted sprayers with hydraulic nozzles are the most commonly used in fruit growing. They are not very costly, easy to operate and effective in chemical control of pests and diseases. They were developed when big trees with wide and dense canopies were most commonly grown. These sprayers generate a large radial spray plume which results in large off-target losses and require a high power consumption (12-20 kW). It is not uncommon to see these machines treating dwarf orchards, where the spray losses at the full leaf stage may over 80% of applied spray volume. Therefore, it is necessary to develop more precise “environmentally friendly” spray application methods.

Significant decrease of spray losses can be obtained with target oriented air-flow adjustment. There were only a few concepts of sprayers developed, which allowed the adjustment of these parameters to respond to the changing weather conditions and morphological characteristics of tree canopies. The objectives of the presented studies were to develop an energy saving Variable Air-flow Discharge system (VAD) with continuous adjustment of air volume independent on right and left side of the sprayer. The Variable Air-flow Discharge system is based on a double axial fan system which allows the remote adjustment of air volume produced separately on the right and left side of the sprayer. The functional model of the VAD system powered by the electric motor was designed for indoor laboratory tests. The preliminary results seem to meet objectives. The calculated nominal air output of 20000 m³ h⁻¹, typical for dwarf and semi-dwarf orchard was obtained with 6 kW power consumption. The air volume can be continuously adjusted (+/- 40%) and the obtained air-flow profiles, on both the right and the left sides are very close to symmetric.

Key words: orchard sprayer, air-jet system, VRT, precision agriculture

1. Introduction

The air-jet parameters (air-volume & direction) considerably influence both on off-target losses and spray deposit uniformity. Earlier experiments showed that enhancing the air volume not only increased the spray deposit uniformity but also additionally increased spray
losses blown through the tree canopy. The opposite effect is observed when decreasing the air volume (Doruchowski, at al., 1997; Holownicki, at al., 2000).

Additional reduction of spray losses can be obtained by deflecting the air-jets backwards to extend the spray passage distance within the tree canopies. Such a settings increase the droplet catch efficiency by enhancing the filter efficacy of the tree canopies. In extreme situations the spray loss can be reduced by over 50% using the same air flow parameters (Holownicki et al., 2000b, 2004) with air jets perpendicular to the tree line.

Most of the sprayers currently used in fruit growing were developed many years ago when big trees with wide and dense canopies were very common. They generate a large radial spray plume which results in large off-target losses and require a high power consumption (12-20 kW). These machines are still commonly used for treating even dwarf orchards with small and open tree canopies. Spray application in such orchards is a very inefficient process, because even more than 80% of applied spray volume is lost (Holownicki et al., 2000b). Cross-flow fan sprayers, directed air-jet sprayers with horizontal or adjustable air discharge systems, which were developed and commercialised at the end of the last century, made significant progress in spray application. However, these more precise air-discharge systems were introduced in recent years and utilised in commercially available sprayers, did not lead to any significant progress in decreasing the spray losses in orchards. Even, if these sprayers offer more possibilities of air-jet adjustment (volume, direction), than conventional fans with radial air-jet emission, the adjustments of these parameters cannot be realised in real time because the lack of existing VRT (Variable Rate Technology) technical solution.

The innovative VRT air-jet adjustment system applied in EDAS (Environmentally Dependent Application System) sprayer was proposed by Doruchowski, at al. 2011, which was designed based on a double rotor radial fan allowing the automatic management of the air flow rate independently on both sides of the sprayer. In order to minimise the emission of spray towards sensitive areas, the assisting air jets (Left and Right) produced by the fan were adjusted individually for the left-hand and right-hand sections of the sprayer by manipulation of the airflow area on the inlet of the fan. However, the assumptions and performances of the EDAS sprayer were positively verified in commercial machines, the experiments on the new VRT systems are being continued at the Research Institute of Horticulture, Skierniewice (Poland). They are focussed not only on the wide adjustment possibilities of air volume and directions, but also on decreasing the power consumption.

The objectives of the presented studies were to develop energy savings and a Variable Air-flow Discharge system (VAD) with continuous asymmetric adjustment of air volume independent on both the right and the left side of the sprayer.
2. Materials and methods

VAD is an air-jet discharge system for spraying the deciduous fruit trees in dwarf orchards with variable adjustment of volume and air direction. The system is dedicated for intelligent sprayers operating in accordance with the rules of precision agriculture. The discharge system principle is based on maximising the natural filter efficiency of the tree canopies. Therefore, the air-jets produced by the sprayers fan will be self-adjusted to the local wind conditions and tree morphology characteristics with the use of special sensors.

The target and the wind parameters will be continuously monitored during the treatment. Target dimensions will be measured by ultrasonic sensors. Air velocity and direction, as a vector value of atmospheric wind and travel velocity of the sprayer, will be identified by the wind direction and velocity sensors assembled on the sprayer. Referring to the transferred signals the microprocessor controller will set the most suitable air volume produced by the sprayers’ fan. It will assure also the deflection of air outputs in horizontal plane independently on both the left and the right side of the sprayer fan. Finally, these corrections will optimise the air volume parameters to reach satisfactory spray penetration, at a minimal spray loss caused by blowing spray droplets through the tree canopy.

The objectives of the experiments was focused on choosing the most suitable:
- shape and configuration of the fans’ deflector to optimise the air-flow vertical uniformity at a minimal power consumption,
- type of impeller to achieve the most diverse range of air volume adjustment.

The VAD (Variable Air-flow Discharge) is an air-jet system designed and constructed on an axial fan. In general it requires a lower power consumption to produce the same volume of air than a radial fan. The functional model of the system powered by an electric motor was designed for indoor laboratory tests. The system consists of double, independent operated air-jets systems, equipped with an axial fan which allows the remote adjustment of air volume produced separately on both the right and the left side of the sprayer. The whole studies were divided into on two steps. Firstly the shape and configuration of the fans’ deflector was optimised and power consumption was measured, then in the second step the air distribution was measured for the two different methods of air flow adjustment. In the first method the air flow was controlled at a constant number of shaft revolutions with the use of an impeller with adjustable blades. The principle of the second adjustment method of air-flow was based on the use of an impeller with the fixed blades working at a variable revolution rate of the impeller shaft.

3. Results

In the first part of the experiment the shape of the fan deflector was optimised to obtain the highest vertical air distribution uniformity using the lowest possible power consumption.
The measurements of air-flow distribution with the use of hot wire anemometers and fast data loggers were made using various configurations of the fan deflector at every 0.1 m of the air duct outlet (Fig. 1). Though, the vertical air distribution was not perfect, the first obtained results seem to be promising, in that the assumed shape of the air-flow velocity profile was similar to that recommended for the evaluation of spray distribution and measured on a vertical paternator using in a relatively wide range of the fan capacity.

The significant decrease of power consumption in comparison with existing commercial fans, was also observed. The air volume (20 000 m$^3$ h$^{-1}$), necessary for effective spray application in typical semi-dwarf orchard, can be reached a power consumption of only 6 kW and is three times lower than for conventional sprayers. It can be explained by the use of a novel air-discharge system, which consists of two separate units responsible for producing air jets directed only to one side of the sprayer. The use the separate fans facilitates the air distribution and makes it more effective in comparison with the conventional single impeller solutions, because inside correcting blades and vanes to improve the air distribution are no longer required, these kinds of devices not only produce excessive noise, but also lose a lot of energy. It can be expected that two twin units will produce almost perfect symmetric air-flow distribution on both sprayers sides without any correcting devices.

In the second stage of experiments the air distribution was measured for the two different methods of air flow adjustment. In the first one, the air flow was controlled with the use of the impellers with a constant number of shaft revolutions and pneumatically adjustable blades within the regulation range 20-45$^\circ$. The air volume range produced by the fan equipped with adjustable blades reached only 18.6-25.9 m$^3$ h$^{-1}$, at a power consumption 3.9-18.2 kW. It means that adjustment range from the nominal positioning (settings) of impeller blades (32$^\circ$) can’t be wider than +/- 20% (Fig. 1).

The second applied method of an air adjustment based the use of a conventional impeller with fixed blades at a variable revolutions rate of its shaft is a more suitable method for VAD system, which can be confirmed by a wider (+/- 35%) range of air volume regulation (16.3-35.0 m$^3$ h$^{-1}$) at a lower power consumption (1.8-14.0 kW) (Fig. 2).

4. Conclusions

The first results showed that the VAD air-jet system brings new possibilities for spray application in fruit growing. The use of two twin fan units results almost perfect symmetric air-flow distribution on both of the sprayer sides, using three times less power when compared with the conventional air-jet systems. It also gives the unique technical possibilities of independent remote adjustment the direction of air-jets, on both the right and on the left, as well as the air volume to optimise the filter efficacy of a tree canopies during treatments in orchards. A though, the system was dedicated for intelligent machines, which operate in accordance with the rules of precision agriculture, the VAD system can be also assembled in
conventional sprayers. A wider regulation range was reached using the impeller with fixed blades at a variable revolutions rate when compared to using adjustable blades at constant number of shaft revolutions. Further studies will be focused on measurements of air-flow profile, which will be carried out in apple orchard at different growing stages.

6. References


Fig 1. Air velocity profile for the VAD (Variable Air-flow Discharge) system
- impeller with adjustable blades at constant revolution rate

Fig 2. Air velocity profile for the VAD (Variable Air-flow Discharge) system
- fixed blades at variable revolution rate of the impeller