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Design of a Flow Rate Adjustement System Related to Tree Foliage Surface Estimation by Using Ultrasonic Sensors (Smart Spraying Machine)

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Abstract: The changes in the shape and size of crops in orchards during growing season require a continuous adjustment of applied dose to optimise spray application efficiency. Ultrasonic sensors can be used for measurement of crop width and adapting the applied dose. A four arms multi-nozzle air-blast sprayer was fitted with four ultrasonic sensors to measure canopy volume in real time, in relation to the variability of crop width. Crops are divided to four parts for measurements.
There is a significiant differences between four parts of trees in the term of canopy volume. Highest density in the trees are detected at the 3.Zone of trees s expected. Lowest density in trees are detected at the 1.Zone of canopy, the highest place of the tree.
Licor AM300 leaf area meter was used to measurement of leaf area and this measurements are used to determine Leaf Area Index(LAI). Results of leaf area meter showed similarity with ultrasonic sensor measurement
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Key words : Orchard, spraying, distance measurement, electronic control, tree volume, ultrasonic, sensor

INTRODUCTION

Apple fruit orchards are sprayed mainly with axial fan ‘mistblower’ orchard sprayers, because the fan is effective in a wide range of orchard types and under a wide range of conditions. Simple and robust structure, relatively low cost of purchase and operation of these sprayers, make them good choice for farmers. But these sprayers are prone to spray drift because of axial air stream., thus large losses to the atmosphere and ground occur (Cross et al., 2001) and (Eberlinc et al., 2008). It is not easy to adapt the characteristics of air stream generated by axial fan sprayer to different tree canopies are quite limited.

A number of systems for adjusting the applied dose of plant protection products according to tree structure have been developed in the past decades. One widely accepted is the Tree Row Volume (TRV) dosing system initiated by (Byers et al., 1971). In this system, the dose applied to an orchard is varied by varying the spray volume at constant pesticide concentration in proportion to the TRV. The TRV (m3 ha-1) is the volume of the tree canopy per unit of ground area (= 10000× crown height × crop width / row spacing). The

TRV spray volume adjustment system has been adapted and tested for low volume spraying in several European countries [(Heijne et al., 1997) to Sutton ve Unrath, 1984) In contrast to the TRV model, (Pergher et al., 1997) and (Pergher and Petris, 2008) proposed the use of leaf area measurements to improve the correlation between deposits given by different types of spraying equipment and types of hedgerow vineyards. However, different shapes and sizes of tree canopies, even among the same variety in the orchard, require continual calculation of TRV and adjustment of the applied dose of pesticide to optimize the spray application efficiency (Solanelles et al., 2006).

For these reasons that in the last decade measurement of crop structure has been simplified by the development of a range of non-invasive optical and ultrasonic sampling techniques. In particular, the development of a compact, tractor-mounted light and range detection system (LIDAR) has made it possible to take quick and detailed readings of crop structure (Wangler et al., 1993). These are suitable for computational processing to calculate a wide range of summary parameters based on a probabilistic interpretation of light transmission and crop interception characteristics (Walklate et al., 2002). Such a system employs a pulse time-of-flight ranging method, with separate apertures (side-by-side) for an infrared laser diode transmitter and a matched diode light receiver.

Contrary to the expensive radar system, (Gil et al., 2007) suggested the use of ultrasonic sensors and proportional electro-valves with the corresponding software and automation, which allowed real time modification of the sprayed flow rate adapted to the crop structure of the vineyard. In response to changes in the shape and size of the vines during the growing season, this system reduced the spray volume and the use of pesticides by up to 57%, while maintaining coverage and penetration rates similar to those from conventional spraying methods.

However, since the ultrasonic sensors were originally designed to measure distances in industrial environments, where objects are rigid, and the surface is perpendicular to the direction of the ultrasonic wave, their utility in orchard measuring might be negligible (Sutton and Unrath, 1984). Some of the deficiencies of standard sensors can be overcome by modern sophisticated ultrasound signal processing algorithms (Jeycic et al.,2011).

The purpose of our study was to develop an crop volume estimation with the measurements of ultrasonic sensors. The results of experiments in the apple orchard and ultrasonic sensor measurement datas are presented in the following sections.

MATERIALS and METHOD

1.1 General Experiment Information

The experiments carried out in the research orchard of Namik Kemal University (40094′N, 27044′E).

The experiments were performed on spindle trained 5-year old 'Gala' and 'Granny Smith' apple trees, shown in Fig. 1, planted at 1 m inter tree spacing and an inter row spacing of 3 m. The average height of the trees was 2.5 m.

Figure 1. ***A prototype sprayer during the experiment in the orchard;***

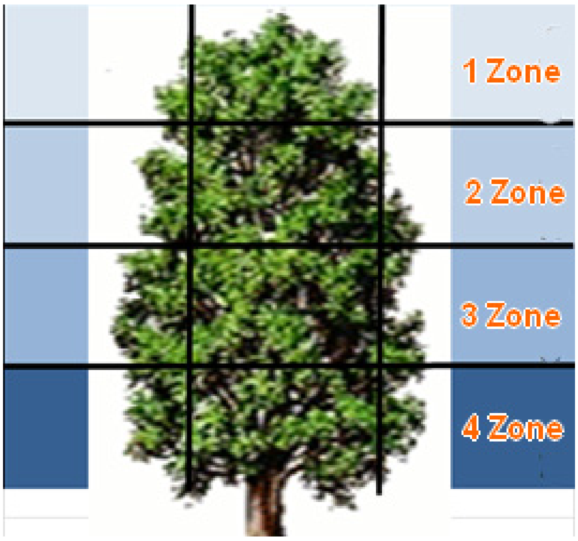

Figure 2. Measuring positions on the tree

The experiment was arranged in a single row, from which a 100 m long part was selected to ensure constant guiding and meteorological conditions. Any passing to other tree rows would immediately cause additional variability. During the tests the following values for the meteorological conditions were recorded: temperature 25.3 to 32.2 °C, relative humidity

69.8 to 73.8%, wind speed 1.3 to 1.7 ms^{-1} and wind direction 20 to 42 deg deviation from perpendicular direction of the sprayer track.

1.2. Sprayer

The prototype sprayer was developed by modification-upgrading of a mounted air- assisted sprayer TA 1200 Piton (TARAL, Turkey), equipped with a piston pump and a 1200 l tank, a pressure-limiting valve, a blower unit with an axial fan, four arms in each side with air outlet and one nozzle at every arm (Fig. 3).

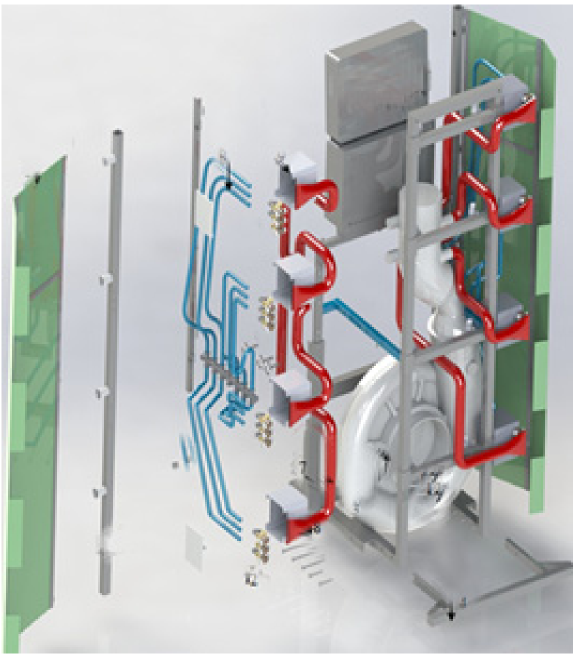

Figure 3. A prototype mounted air-assisted sprayer;

The prototype was fully operative on one side. There were 4-nozzle sections with three electric valves mounted in each one. Four ultrasonic sensors were placed 100 cm in front of the nozzle plane in the direction of travel, at 50,

100,150 and 200 cm above the ground (Fig. 4).

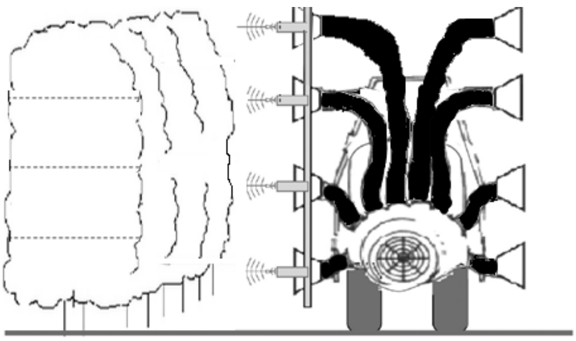

Figure 4. Position of ultrasonic sensors ultrasound acquisition and analysis system.

The measurement was performed at forward speed of 0.83 ms^{-1} (3.00 km h^{-1}) for both spraying modes.

1.3 Control System for Executing the Sensor Measurement

The measurement procedure by ultrasonic sensors is explained in more detail below.

System operation included the triggering of ultrasonic transceivers, a calculation of distance using transceivers' own electronics, processing and time delaying of data from transceivers. Same transceivers were used for sending and receiving. The triggering of transceivers was used to prevent unwanted false detections that could arise from the signal being detected on the selected transceiver immediately after another transceiver produced a sound burst.

System control was provided by a control unit consisting of a Arduino UNO microprocessor unit and SD card for datalogging. Control system was protected and mounted to the electric box (Fig. 1a).

Ultrasonic transceivers used were Maxbotixx

LV-MaxSonar-EZ0 ultrasonic rangefinder. The sensors were equipped with a horn with 25 mm length and 22° angle (Fig. 5).

Figure 5. Ultrasonic rangefinder

The sensors were configured in such a way that the operational range was from 6 to 150 cm.

Ultrasonic sensor measurements were simultaneously recorded to the SD card. After the measurements, information was retrieved from the recorded data.

RESULTS and DISCUSSION

Recorded measurements of ultrasonic sensors are given below. Highest density in the trees are detected at the 3.Zone of trees s expected. Lowest density in trees are detected at the 1.Zone of canopy, the highest place of the tree (Fig 6).

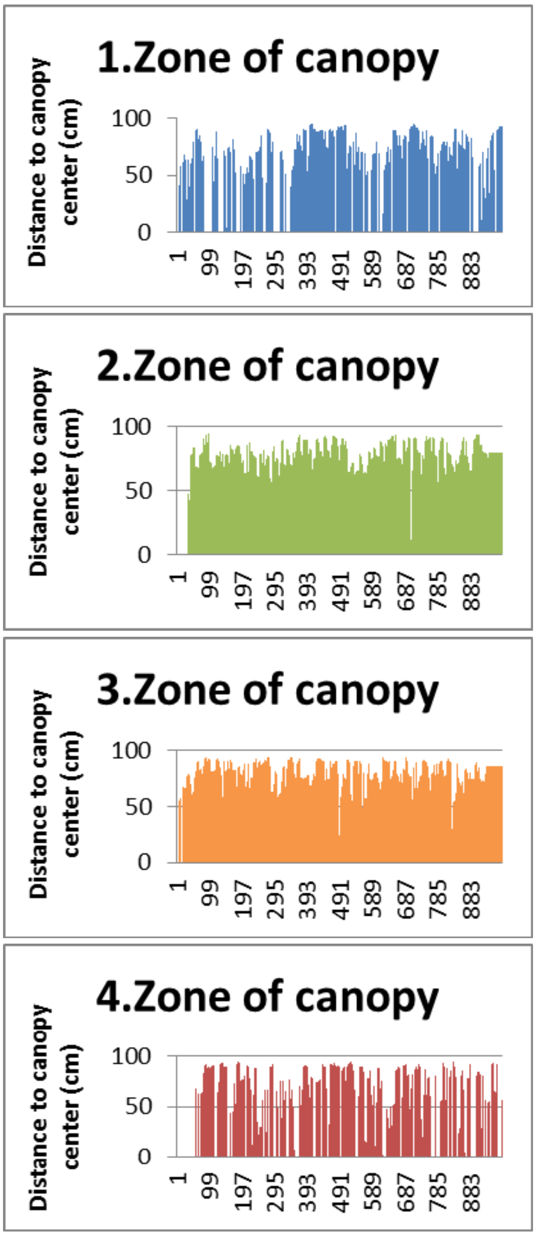

Figure 6. Ultrasonic sensor measurements

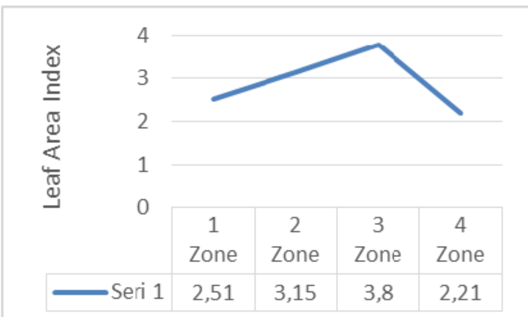

Figure 7. Leaf Area Index measured by LICOR AM300

Licor AM300 leaf area meter was used to measurement of leaf area and this measurements are used to determinde Leaf Area Index(LAI). Highest LAI values are detected at 3.zone of canopy and lowest LAI values are detected at 1.zone of canopy (Fig 7).

CONCLUSIONS

Assessment of ultrasonic electronic control system for measuring tree canopy volume was showed correlation between leaf area index measurements.

Four ultrasonic sensors were used in our experiments.;

It is well known that in the present development stage ultrasonic sensors can not distinguish very small and dense structures of the canopy, orchard supports and broad less dense canopies. For this reason and for the reason that most of the ultrasonic echo is formed on the canopy outer layer, the ultra sound sprayer guidance system operated by standard ultrasonic sensors, unlike the radar guidance systems, is not able to provide the information about the tree structure deep inside the tree crown.

Sensors detection should be evaluated regarding the tree structure and canopy properties. Sensors used in this experiment, provided only information in the form of presence of the target and its distance. Small very dense targets performed similar to large less dense targets. There might exist an opportunity for a further upgrade of sensors electronics to distinguish between both mentioned cases. Potential further improvement of our prototype system can be achieved by modifying the ultrasonic sensors so they could detect the tree structure selectively according to the different reflection from the leaf density in the middle of the crown and give a better discrimination of tree crown and the background also in the lower section of trees.

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