Evaluation of flight directions and other canopy coverage characteristics from aerial spraying, using Remotely Piloted Aerial Application Systems (RPAAS aka drones), in a high-density linear olive grove*

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Abstract

The use of Remotely Piloted Aerial Application System (RPAAS, aka drones) for applications of various plant protection products, fertilizers, biostimulants, air seeding and air-fertilization is becoming the most effective way for to provide sustainable solutions in all crop species. It is also the faster developing agricultural technology and very much accepted and used by farmers and other stake holders. However, few studies exist to evaluate precisely the overall effectiveness and efficacy of these systems. The RPAAS Currently used mainly in field crops and not much on tree production systems. This study was established to specifically evaluate the flight direction (parallel vs. perpendicular to planted lines) in a linear and high-density olive grove, at the premises of the Perrotis College/American Farm School, Thessaloniki. The olive grove adapted for mechanical harvesting, was established in 2011 and consists of two varieties used in these systems (Arbequina and Koroneiki), three planting densities a Super high Density (SHD), a High Density (HD) and a Medium Density (MD) with 1670, 1000 and 500 trees/ha, respectively, spaced at 4 m between the rows. The traditional olive systems use ca. 250-350 trees/ha spaced in orthogonal systems. These density systems represent a much more dense plant canopy than the traditional olive groves and it is a unique case to evaluate penetration studies with aerial spraying systems. The drone used two Flight Directions (FD), a parallel (Par FD) and a perpendicular (Per FD) to the planted lines, using various flight settings (volume, height and speed). The percent Canopy coverage (PC%) and other droplet characteristics were recorder with Water Sensitive Papers (WSP) in all three planting Densities and in three heights (low –medium –high) within each olive tree replicated. The overall results indicated that the Perpendicular flight (Per FD) provided a better coverage and also planting densities and tree profile, were not shown to significantly vary among all three densities These results can be used by users of RPAAS to achieve better canopy coverage in foliar applications. Therefore, using the same volume of spraying, a higher coverage can be achieved. The results presented in this study are only applicable to the specific type of high-density olive linear systems and should not be extrapolated directly to other linear systems such as vineyards, fruit trees, due to the differences in plant canopy, geometry and density and to traditional olive groves. Comparative aerial spraying studies between high and traditional olive densities and in vineyards are in progress at Perrotis College/American Farm School.

Keywords

RPAAS, UAS, spraying drones, high density olive, flight direction evaluation

1. Introduction

The development of new agricultural technologies immediately used by the famers and other end-users is advancing with a fast rate. More specifically the area of robotics (ground and aerial) is re-shaping the agricultural management strategies and presents a one-way direction for the future.

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The focus of this study is the aerial applications by remotely piloted domes (RPAAS Remotely Piloted Aerial Application systems aka spraying drones). These devices are not only used for spaying but also for air-seeding, air-fertilization with granular or pelleted type fertilizers, and other agricultural related uses.

The many advantages of drones have been outlined in numerous studies. A study [1] outlined a thorough comparison among a variety of ground and aerial (drones) sprayers systems. The recent development in RPAAS produced new knowledge and belter functionalities. Their potential for spraying over net covered crops [2] is very importance for crop protection, in lieu on the climate change which has among other issues, increased significantly the occurrence of hail events in Greece and globally. The objective of this study was to evaluate two flight directions, in parallel and vertical flight of the drone above a high-density olive grove system. There is very limited work [3] on these special olive linear systems and the knowledge generated is expected to facilitate the most efficient on the two flight paths. A study in Spain in vineyards and traditional spaced olives [4] reported that the aerial efficiency is much higher for UAV sprayers. Also, the aerial drone sprayers require a lower cost of water and products. The RPAAS have a number of additional advantages over the conventional ground systems, such as lower cost in spraying olives for the olive fruit fly [5] and other crops [6], safety for the farmers and the environment and an overall higher efficiency in pest management [7]. It should be mentioned that the technological models presented in this study, already represent somehow "relative older" models. The developments in this technological area have a very short tech life, approximately 12 months and the new models entering the EU agricultural market by the next years are much superior in terms of capacity and software. The introduction of artificial intelligence (AI) in the software is already producing more efficiency and accuracy. The use of RPAAS in Precision Agriculture (PA) has been proven to be one of the most efficient and friendly user technologies, immediately available to end users (farmers, and sprayers). It remains for the EU to finally update the EU legislation about aerial spraying systems (RPAAS), which remains unchanged literally from 2006. There is too much conclusive evidence supporting the change. Recent comparative studies showed that although major steps have been done forwards, there are still deficiencies that should be overcome [8].

2. Materials and Methods

The study took place in the Educational-Research-Demonstration high density olive grove adapted for mechanical harvesting at Perrotis college/American Farm School in Thessaloniki, Greece. Two varieties (Arbequina nand Koroneiki) are arranged in linear systems at three planting densities - PDs (Super high, High and Medium, corresponding to 1670, 1000 and 500 trees /ha). Two different technological drones were tested for a number of flights over the olive grove and Water sensitive Papers (WSPs) were placed in each one of the three PD and in Koroneiki variety plants. Also at each tree, papers were placed in a profile to evaluate the vertical distribution of droplets the Upper-Middle and Low part of the tree. The two Flight Direction (FDs) were Parallel and Vertical to planted lines (Fig.1).

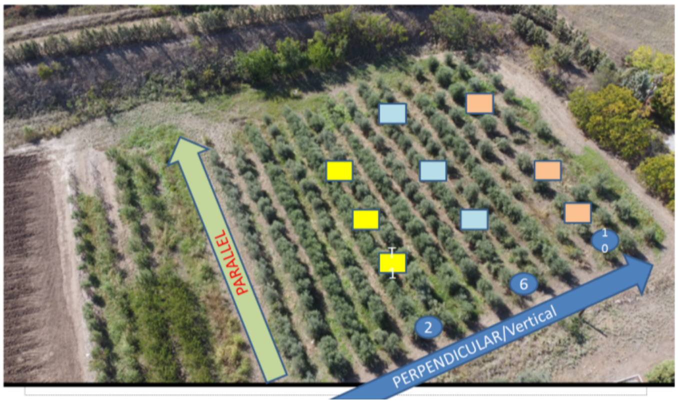

Figure 1: The Flight Directions and the position of WSPs in the high density olive grove.

All flights conducted using two different model drones. The Topxgun (16 L tank capacity) uses four conventional nozzles and the EA Vision Hercules EA -30 XP with 30 liters tank capacity uses two centrifugal type nozzles (Fig. 2). The same settings in speed, height above canopy, dosage were used by all models and flights. The percent plant coverage (PC%) and other droplet characteristics were measured using the Deposit Scan software [https://www.ars.usda.gov/midwest-area/wooster-oh/application-technology-research /engineering/ depositscan/].

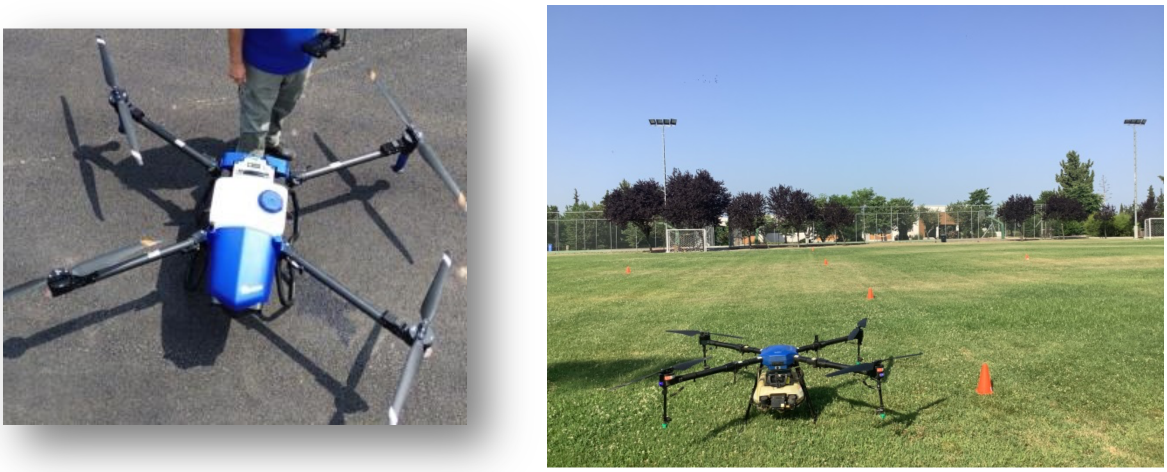

Figure 2: LEFT the Hercules EA-30 XP model and RIGHT the Topxgun 16 drone

3. Results and Discussion

The first flight conducted by the Topxgun 16 L drone has shown that Vertical flight has statistically significant higher percent coverage than the parallel flight and there was no differences among the three PDs and the three positions in each tree (Table 1).

The additional two flights conducted by the Hercules model, showed very similar results with the previous flight by the other drone model (Tables 2 and 3). The overall results validate the higher efficiency of the Vertical flight direction, while justifying the overall efficiency of the fine droplets generated by both drones across the different PDs and also the tree profile. The uniformity of PC% is very critical when spraying crops from above and this is due by the strong downward and turbulent flow generated by the four propellers of the drones. Special droplet characteristics analyzed (size and distribution) have also verified and supported the conclusion drawn by the PC%.

This type of olive linear production system represents a unique canopy architecture for aerial spraying drone evaluation, The density of the canopy is much higher (also an evergreen plant species) than all other linear production systems (i.e. vineyards, kiwi, apple, pear, etc. fruits) and therefore is a good indicator for evaluation of spraying efficiency.

Table 1

One-way Analysis of PC% by TOPXGUN model (1st flight)

By Flight Direction		
Level	Mean	PC%
Vertical	A	1.022
Parallel	B	0.526
By Planting Density (PD) (pooled data)		
Level-PD	Mean	PC%
MD	A	2.412
SHD	A	1.807
HD	A	1.395
By Position in the Tree (pooled data)		
Level-Position in the Tree	Mean	PC%
UPPER	A	2.208
LOW	A	1.980
MIDDLE	A	1.582

Levels not connected by same letter are significantly different.

Table 2

One-way Analysis of PC% by Hercules EA-30 Xp model (2nd flight)

By Flight Direction		
Level	Mean	PC%
Vertical	A	1.317
Parallel	B	0.631
By Planting Density (PD)		
Level-PD	Mean	PC%
MD	A	1.390
SHD	AB	0.867
HD	B	0.563
By Position in the Tree		
Level-Position in the Tree	Mean	PC%
UPPER	A	1.208
LOW	A	0.980
MIDDLE	A	0.582

Table 3

One-way Analysis of PC% by Hercules EA-30 Xp model (3rd flight)

By Flight Direction		
Level	Mean	PC%
Perpendicular	A	1.160
Parallel	B	0.578
By Planting Density (PD)		
Level-PD	Mean	PC%
HD	A	1.364
MD	B	0.663
SHD	B	0.577
By Position in the Tree (pooled data)		
Level-Position in the Tree	Mean	PC%
LOW	A	1.044
UPPER	A	0.994
MIDDLE	A	0.566

4. Conclusions and recommendations

The results from three flights and the two different drone models demonstrated in all cases that the perpendicular/vertical to line flight is more efficient than the parallel in terms of overall percent canopy cover. This should be considered from those using aerial sprayings in such a linear system. However, and cautiously interpreted, the results presented in this study are only applicable to the specific type of high-density olive linear systems and should not be extrapolated directly to other linear systems such as vineyards, fruit and nut trees (almonds, apples, pears, peaches, kiwi fruits etc.) due to the differences in plant canopy, geometry and density and to traditional olive groves for which no such data is available. It was very interesting also to conclude that the spraying uniformity across three quite variable planting densities as well as for within the vertical tree profile was not affected by the overall spraying in both directions This was true in pooled data but also within each FD (not shown here). Comparative aerial spraying studies between high and traditional olive densities and in vineyards and other fruit systems are in progress at Perrotis College/American Farm School and in collaborating farmers.

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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