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Pest management control of olive fruit fly (*Bactrocera oleae*) based on a location-aware agro-environmental system

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ABSTRACT

This paper investigates the effectiveness of a mobile agro-environmental Location Aware System (LAS) in ground spray applications against olive fruit fly, under real conditions. It aims to the specific needs of pest management control, by means of combining the olive fruit fly population dynamics, the meteorological conditions during the sprayings, the spatiotemporal characteristics of the spraying areas, as well as the environmental sensitive and inhabitant areas located near the spraying areas. From a moderate-scale field experiment conducted for evaluation purposes, the duration of sprays, the amount of spray solution applied and efficacy were statistically analyzed. Results show that the LAS is able to reduce the amount of spraying solution by performing sprays only when and where are really needed. The protection of environmental and inhabitant areas is also achieved, by avoiding off-target sprays. The LAS is able to decrease the duration of the sprayings, minimizing their cost and the possibility of canceling a spray application due to meteorological conditions. The acquisition of the spatiotemporal data during the sprays is able to provide agrotraceability systems with useful information about the olive products. In conclusion, the proposed LAS is shown to be a useful tool for olive farmers, scientists or organizations that can increase the efficacy and decrease the cost of moderate scale pesticide treatments from ground and avoid effects on environmental protected or domestic areas.

1. Introduction

1.1. Discussion of the problem

Olive fruit fly (*Bactrocera oleae* or *Dacus oleae* (Gmelin), Diptera: Tephritidae) is the most serious insect pest of the cultivated olive (*Olea europea* L.) fruits in the world (Economopoulos, 2002) and affects the olive tree cultivation causing serious qualitative and quantitative consequences with economic impacts and monetary losses (Neuenschwander and Michelakis, 1979; Economopoulos et al., 1986). Without treatment and under optimum climate conditions for the development of the olive fruit fly, the insect is able to infest more than 90% of olives in untreated orchards (Athar, 2005; Kapatos and Fletcher, 1984). Olive fruit flies survive best in more humid climates. Also, they infest fruits in olive trees that are grown in dry regions. According to Kapatos and Fletcher (1986) the olive fruit fly survives best in cooler coastal climate, but is also found in hot, dry regions. The optimum temperature for the insect development is between 20 and 30 °C. In practice, the air temperature during the spraying process must be between 12 and 28 °C and the wind speed must be less than 28.8 km/h. High wind speed inhibits the insect flights. Because of this, the olive fruit flies are not fed by the sprayed solution and survive.

The control of *B. oleae* remains almost exclusively based on insecticides, particularly organophosphates (OPs) (Roessler, 1989). Bait sprays with OPs from the ground have the ability to inflict high insect mortality rapidly, and are the most common and effective form of treatment in cases that the insect is very noxious. Dimethoate is an OP used in bait-pesticide sprays in order to control adult olive fruit fly populations. However, it is harmful and irritating to humans, dangerous for the environment, very toxic to bees (*Apis mellifera* L.), harmful to animals, birds and aquatic organisms. Nowadays, bait sprays cover large areas and can be applied by high-pressure sprayers, mounted on tractors. In theory, ground spot sprays are performed once every 2, 3, or even 4 rows of trees. Baits are developed for spray application on a small part of foliage, "spot spraying" (Haniotakis, 2005). However, in practice, a large portion of the tree canopy is sprayed as tractors move between rows of trees. People, wildlife, and the environment are exposed to the spray drift from off-target sprays, leading, to health and environmental effects and property damage. This paper focuses to the prevention of inappropriate sprays,

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to the minimization of the pesticide applied and to the reduction of olive fruit fly population.

The extensive use of insecticides and off-target sprays lead to environmental and public health problems. Inappropriate sprays may occur for many reasons. For example, during the spray applications, the sprayer attendants may not be able to memorize the areas to be sprayed, and/or may not be aware of the areas that must not be sprayed (i.e. domestic or environmentally protected areas, biological cultivations). Air temperature, wind speed and air humidity levels in the spraying area are critical for the continuation of the spraying. During spray applications the values of these critical parameters should not exceed a certain threshold. If a parameter exceeds the optimal threshold in local level, then the adult flies, which are the target of the spray applications, can fly and seek nearby locations. Although the above issues that arise during spray applications are well known to the sprayer attendants, in practice and without the aid of computer and communication technologies, there is limited chance to avoid them. Usually, the sprayings cover large areas. Thus, it is difficult for the tractor attendants to memorize their spraying areas, and as a result over or under spraying may occur. In addition, the spraying attendant cannot determine the spray volume per area and is not aware of the areas which must not be sprayed. As a result, over, under or off-target sprayings can be performed, leading to quality reduction of olive oil and table olives and producing negative consequences to the environment, and to humans.

1.2. Related work

Location aware (LA) systems are nowadays popular in multiple everyday applications (Raper et al., 2007). In agriculture, LA systems have not yet attracted the necessary attention and their use is rare. Instead of LA systems, GIS, ES and DSS have been used in agriculture applications to assist farmers in their work.

Several attempts have been made to develop decision support systems (DSS) and ES for optimizing agriculture operations. DSS and ES systems have been developed for weed control (Macé et al., 2007), irrigation (Srinivasan et al., 1991; Lilburne et al., 1998; Bergez et al., 2004), fertilization (Lewis et al., 2003; Bonfil et al., 2004) and pest management (Ellison et al., 1998; Mahaman et al., 2002; Wharton et al., 2008).

In a similar weed spraying system Zaman et al. (2011) have developed an automated prototype variable rate (VR) sprayer boom for site-specific application of agrochemicals on weeds. This type of VR sprayer does not use prescription maps, but relies on sensors to provide real-time weed detection information which is used to dispense correct agrochemical rates for the weeds. In a similar system, Loghavi and Behzadi Mackvandi (2008) developed a target oriented weed control approach by integration of differential global positioning system (DGPS), GIS, and solenoid-activated spray nozzles in response to signals generated by a displacement sensor. Targeted weed patch herbicide application resulted in 69.5% saving compared to the conventional application (uniform spraying).

In a pest management problem similar to the olive fruit fly problem, Cohen et al. (2008) developed a spatial decision system for monitoring the Mediterranean fruit fly (*Ceratitis capitata* (Wied), Diptera: Tephritidae) on citrus. Their system provides recommendations to the coordinators' decisions in order to reduce the number of unnecessary spray actions and the number of sprayed plots. However, this system does not solve the problems that may arise during the spraying process.

Spraying applications against olive fruit fly depend on meteorological conditions that are rapidly alternated during time; in these cases GIS, ES or DSS are inadequate to provide a solution. The involved personnel should be informed constantly about the meteorological conditions of their area of application. In addition, if spraying of an area has been performed even 1 min ago by another person, the current personnel should be informed and aware. To avoid the aforementioned problems during the spraying control of olive fruit fly, Pontikakos et al. (2010) proposed a mobile agro-environmental Location Aware System (LAS) for ground spray applications against olive fruit fly. The above paper focused mainly to the software and database architecture and included limited experimental results. In this paper, we continue the research of Pontikakos et al. (2010) in order to evaluate the efficacy of the LAS, the pesticide solution application and the spraying process.

1.3. Aim of the project

The main objective of this paper is to investigate under real conditions, the effectiveness of the LAS proposed by Pontikakos et al. (2010), towards environmental and pest management optimization. The general components of the concept of the agro-environmental LAS are described below:

- *Efficacy and low cost*: Efficacy increase and cost reduction of spray applications from ground against olive fruit fly can be achieved by limiting sprays to a minimum requisite. Monitoring regularly the olive fruit fly population as well as the meteorological conditions, the infestation risk per olive cultivation area can be determined. Thus, applying the insecticides accordingly, the infestation risk ensures the optimum sprayings performance, mainly because over or under spraying is avoided.
- *Environmental protection*: During spray applications, the necessary safety precautions should be followed in order to avoid spraying environmentally sensitive areas such as water courses and protected ecosystems.
- *Inhabitant protection*: During spray applications, the necessary safety precautions should be followed in order to avoid applications near domestic areas such as hospitals or playgrounds.
- *Agro-traceability considerations*: Traceability adds value to the overall quality management system by providing the communication linkage for identification, verification and isolation of non-compliance sources to agreed standards and customer expectations. Agro-traceability simply refers to the collection, documentation, maintenance, and application of information related to all processes in the supply chain in a manner that provides guarantee to the consumer on the origin, location and life history of a product. In the case of spraying applications against the olive fruit fly, traceability refers to the ability to identify the specific farms or the olive trees where sprayings were conducted.

The developed framework is based on regulations concerning the agricultural practices, focuses on the integration of these regulations with new technologies and facilitates the collaboration of the users who participate in the spray applications. This framework also adopts today's Integrated Pest Management (IPM) framework, by means of an effective and environmentally sensitive approach that relies on a combination of common-sense practices. IPM programs monitor pests and identify them accurately, so that appropriate control decisions can be made in conjunction with action thresholds. In the case of olive fruit fly, McPhail traps (McPhail, 1937) with various baits are the standard traps for monitoring insect populations (Burrack et al., 2008). This monitoring and identification, removes the possibility of using the wrong pesticide, or a pesticide that is not really needed. The general concept of the developed agro-environmental LAS for ground spray applications against olive fruit fly is illustrated in Fig. 1.