Computers and Electronics in Agriculture 121 (2016) 135–140

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Monitoring spray drift in aerial spray application based on infrared thermal imaging technology

Leizi Jiao, Daming Dong *, Haikuan Feng, Xiande Zhao, Liping Chen *

National Research Center of Intelligent Equipment for Agriculture, Beijing Academy of Agriculture and Forestry Sciences, China

ARTICLE INFO

Article history:
Received 1 September 2015
Received in revised form 28 October 2015
Accepted 16 December 2015
Available online 30 December 2015

Keywords:
Aerial spray application
Spray drift
Infrared thermal imaging
Water-sensitive paper

ABSTRACT

The pesticide drift in aerial spray applications is harmful both to environment and human beings but hard to be measured. We demonstrated a new method for real-time evaluation of pesticide drift which used infrared thermal imaging technology to detect the thermal differences before and after spraying process and then measured the range and concentration distribution of droplets. The drift distribution and spray range are detected using infrared thermal imaging system combined with image processing algorithms. The experiments were carried out in both ground spray and aerial spray applications. The results showed that this method had the ability to detect the tiny thermal differences during spray application and thus to monitor the aerial drifts. Furthermore, the testing results using this method had well agreement with the water-sensitive paper method. Therefore, it is verified that infrared thermal imaging method combined with infrared image processing algorithms can be used to monitor the pesticide drift in aerial spray application with advantages of fast, non-contact and able to realize real-time measurement.

1. Introduction

Although environment pollution caused by pesticides has been widely concerned, pesticides as the most effective tool for crop pest-control were still popular among farmers (Panneton et al., 2005). Because of the low cost and efficient performance, spraying was the most common way for pesticide application (Giles et al., 2008). However, the quantity of the spray deposited on crops was significantly less than that released from sprayer (Salyani et al., 2007). The quantity of spray deposited on the target was no more than 55% of the sprayed volume while 45% of spray deposited on the ground or lost as small airborne droplets (Panneton et al., 2001).

Although it is impossible to avoid spray drift, the optimal management can minimize the spray drift. In optimal management measures, the selections of suitable nozzle, shield, spraying pressure, spraying volume in unit area, spraying speed and weather conditions are important (Felsot et al., 2011). In order to reduce the contamination on the non-target area during spray application, buffer zones were arranged between target areas and non-target sensitive areas which mainly include water ways, wetlands, woodlands and schools. The width of buffer zone could be properly adjusted with fluorescence tracers and biological calibration technology (Longley and Sotherton, 1997; Robinson et al., 2000; Sinha et al., 1990; Woods et al., 2001). The spray drift would be reduced by adding drift adjuvants according to the appropriate proportion in the aerial spray application (Carlsen et al., 2006). The results obtained from the wind tunnel experiments for measuring surface tension, viscosity, evaporation rate and spray droplet density indicated that dynamic surface tension was one of the most important factors and spray drift was reduced obviously through increasing the droplet viscosity by adding the drift adjuvant (Hanks, 1995). The appropriate spraying method might also reduce the spray draft. Spraying technology department of USDA Agriculture Research Institute found that mechanical shield spray as a cheap and simple method could effectively reduce spray drift (Ozkan et al., 1997).

In the aerial pesticide application the controllable parameters, such as buffer zone width, spray pattern, sprayer parameters and pesticide adjuvant proportion, and uncontrollable factors including weather conditions and atmospheric stability were both considered (Balsari et al., 2008). The optimization of these parameters and the assessment of spray quality have become one of the study hotspots in recent years (Prokop and Veverka, 2006; Zhu et al., 2011). Water-sensitive paper was one most popular artificial object for evaluating spray quality (Hill and Inaba, 1989; Fox et al., 2003). it was widely used to study droplet size, deposit rate, spray deposition features between air induction nozzle and traditional nozzle, size distribution on the object, droplet covering quality in different operating variables of the sprayer and spray

* Corresponding authors.

http://dx.doi.org/10.1016/j.compag.2015.12.006
0168-1699/

distribution patterns in aerial spray application. Spray quantity evaluation and sprayer parameter optimization were accomplished through combining water-sensitive paper with fluorescence technology and optical analysis method (Salyani et al., 1987; Salyani and Fox, 1999; Holownicki et al., 2002; Fritz et al., 2007, 2014; Guler et al., 2007; Zhu et al., 2008; Derksen et al., 2010; Khot et al., 2011; Ozkan et al., 2011). Water-sensitive paper can change its color under the condition of high humidity and is effective only in the relatively dry environment. The spray quality assessment experiments with water-sensitive paper were carried out under the dry sunny weather conditions.

Infrared thermal imaging technology can convert thermal radiation into thermal images and has a unique advantage in measuring temperature differences (Gowen et al., 2010; Vadivambal and Jayas, 2011). The infrared thermal imaging technology has not been used in the spray application assessment. In the aerial pesticide application under dry weather conditions, the temperature differences may exist between the environment and droplets released from the nozzle. Based on the existing temperature difference, the infrared thermal imaging technology can be used to monitor and assess the aerial spray pesticide application. However, it was still unknown whether the infrared thermal imaging technology could be used to detect the temperature differences and had a good dynamic imaging performance for the aerial spray application with high speed.

This paper aims to verify the feasibility of monitoring and assessing the aerial pesticide application using infrared thermal imaging technology.

2. Materials and method

2.1. Materials

Hand-push centrifugal mist spraying machine with the atomized particle size of 20–60 μm was used in the early pilot experiment. This experiment was carried out in the National Demonstration Base of Precision Agriculture located at Xiaotangshan Town, Changping District, Beijing. Thrush 510G plane manufactured by the Thrush Aircraft Inc. was used in this aerial application experiment. This experiment was carried out in the experimental field of Beidahuang General Aviation Company located at Jiamusi City, Heilongjiang Province, China. AU-5000 atomizer on the Thrush 510G was made by the MicronAir Company. Water-sensitive paper with the scale of 76 ∗ 26 mm was provided by the Beidahuang General Aviation Company. FLIR SC620 manufactured by the FLIR company was used to acquire clear images of thermal radiation. Its detector type was uncooled microbolometer and IR resolution was 640 ∗ 480 pixels. Its noise equivalent temperature difference was less than 40 mK and spectral range was 7.5–13 μm. Nikon D5100 was used as a visible light camera to acquire the visible light images. Tripods were used to fix thermal infrared imager and visible light camera.

2.2. Methods

In the early pilot experiment weather parameters were not measured. Hand-push centrifugal mist spraying machine was placed in suitable location and the required quantity of water was added. In order to guarantee enough field of view for monitoring the spraying process, thermal infrared imager was fixed at the appropriate locations with the tripod according to the position of hand-push centrifugal mist spraying machine. The distance between the thermal infrared imager and hand-push centrifugal mist spraying machine was 23 m. The spraying process lasted for about 10 s and thermal images of the spraying process were stored in the SD card embedded the thermal infrared imager.

Schematic diagram of monitoring aerial spraying process in the experimental field was shown in Fig. 1. Thrush 510G plane flied into the experimental field against the wind. When the plane reached on the marking flag, pilot turned on the AU-5000 atomizers and began to spray. 21 water-sensitive paper test points were used. The 11th point was located at the marking flag location and the others was uniformly distributed on the right and left of marking flag. The distance between every two points was 3 m. These points were arranged in a straight line perpendicular to the direction of flight. In order to guarantee enough field of view, the thermal infrared imager was fixed in front of the flag and 180 m away from the flag. Considering the high speed of the plane, the sequence images with frame frequency of 30 Hz were captured using the ResearchIR software. Visible light camera was placed near the thermal infrared imager for convenience operation (see Fig. 2).

The parameters of the aerial spray application were shown in Table 1. The weather parameters downloaded from the airport control tower were shown in Table 2. Therefore, the weather conditions in Table 2 were suitable for aerial spray application.

MATLAB and ResearchIR software was used to process thermal images. The background thermal image was acquired before

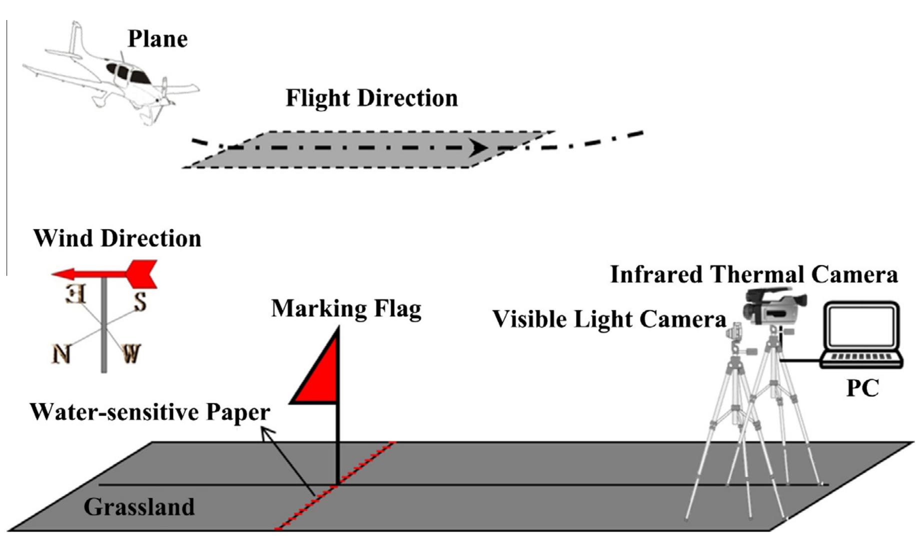

Fig. 1. Schematic diagram for monitoring of aerial spay application in the test field of Beidahuang General Aviation Company.