Scientia Horticulturae 165 (2014) 295–302

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Effect of ultraviolet-C radiation on "Kumagai" guavas infested by *Ceratitis capitata* (*Diptera—Tephritidae*) and on physical parameters of postharvest

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ARTICLE INFO

Article history:
Received 17 June 2013
Received in revised form 25 October 2013
Accepted 13 November 2013

Keywords:
Fruit fly
Quarantine treatment
Radiation
Commodity treatment
Post-harvest treatment

ABSTRACT

Physical quarantine methods are being developed to replace fumigants to control arthropods and microorganisms during post-harvest management of fruit and vegetables. This study aims to evaluate the use of UV-C radiation to disinfest guava with *Ceratitis capitata* (Wied.) eggs and evaluate the quality of fruit irradiated at two different storage temperatures. For the *in vitro* test, one-day old *C. capitata* eggs were exposed to increasing doses of UV-C radiation and stored in a B.O.D. chamber. Applying *in vivo* tests, 'Kumagai' guavas were exposed to artificial infestation by medfly. After infestation, the fruits were subjected to an increasing intensity of UV-C radiation and stored in a B.O.D. incubator at $23.0 \pm 0.2\,^{\circ}C$ for about 20 days. *In vitro* tests indicated that 1.383 kJ m^{-2} UV-C on *C. capitata* eggs was capable of preventing the eclosion of larvae. However, guavas infested by medfly eggs needed 16.0 kJ m^{-2} of UV-C to prevent pupation. The guavas subjected to treatment with UV-C radiation and stored at a temperature of $8 \pm 0.2\,^{\circ}C$, obtained much better responses in terms of quality indices than those stored at $22 \pm 0.2\,^{\circ}C$, which lends credence to the storage temperature being a key factor in maintaining fruit quality.

1. Introduction

Brazil boasts the highest production of guava in the world and the plants are grown either in large commercial orchards or as a dooryard fruit. As a commodity, Brazilian guava exports are destined for the European market, without any post-harvest treatment. For other markets, the products suffer restrictions due to fruit fly (*Tephritidae*) infestation.

Insects from the *Tephritidae* family cause major financial losses in the fruit growing industry, by attacking the reproductive organs of plants, fruits and flowers. Some *Tephritidae* are quarantine pests, which affect the international trade of fresh vegetables (Raga et al., 2005; Aluja and Mangan, 2008). Among the 235 species of *Anastrepha*, 104 have been recorded in Brazil, in addition to the medfly *Ceratitis capitata* (Wiedemann) (Uchôa-Fernandes and Nicácio, 2010; Raga et al., 2011). Another factor that limits international trade is the lack of appropriate post-harvest mitigation treatment to deal with these pests (Duvenhage et al., 2012).

C. capitata is an invasive species found on all five continents, where they easily adapt to different climates, biomes and host plants, with a high capacity to reproduce. Medfly attacks 58 host plants in Brazil (Zucchi, 2001) and has spread to new fruit-producing areas. Raga et al. (2005) reported *C. capitata* infestation and seven species of *Anastrepha* in guavas collected in the Brazilian state of São Paulo.

Sometimes the commodities that carry a significant risk of harboring pests such as fruit flies that cannot be only managed in the field, may still be marketable with disinfestation treatment during post-harvest processing (Heather and Hallman, 2008). Due to restrictions on the use of chemical fumigants on fruit destined for export, pest disinfestation by physical methods is being widely investigated as an alternative to quarantine treatment (Vieira, 2004; Vicente et al., 2006; Lopes et al., 2008; Raga, 2010; Arévalo-Galarza and Follett, 2011). The concept of quarantine treatment on fruit flies is based on procedures developed by Baker (1939), in order to achieve a mortality rate of 99.9968% (Probit 9),

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0304-4238/$ – see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.scienta.2013.11.015

equivalent to the survival of 32 individuals in a population of 1000,000 insects treated. The criteria are based on the assumption that the level of infestation in the fruit to be treated is extremely high. Thus, the large guava orchards whose production is destined for export must employ appropriate monitoring and integrated pest management (IPM) tactics such as the earlier individual bagging of fruit to prevent fruit fly infestation (Raga, 2010).

Quarantine treatment should eliminate, sterilize or kill regulatory pests in exported commodities to prevent their introduction and establishment in new areas. The increasing restriction on international trade to only non-infested fruit has prompted the search for new quarantine techniques. When precisely and rigorously applied, quarantine methods have reduced the risk of the global spread of pests, especially fruit flies (Follet, 2007).

Ultraviolet radiation is an effective technique in the disinfestations of fungal infection and to keep fruit and vegetables processed to a minimum, due to the germicidal properties, the destruction of microbial DNA and protein denaturation, resulting in an increased shelf life (Artés et al., 2009). This technique has a potential use as quarantine treatment for the disinfestation of commodities, without risk to consumers and the environment. According to Guerrero-Beltrán and Barbosa-Cánovas (2004), UV-C disinfestation technology should be studied further in relation to the effectiveness of penetration into plant materials and at the light levels applied, since the effects of radiation are variable, depending on the target organisms, and even among populations of the same species.

Given the lack of information in the literature on the potential for disinfestation via UV-C radiation on insects, economically important to the trade of fresh food, the aim of this study was to evaluate the effects of UV-C radiation on *C. capitata* eggs *in vitro* and *in vivo* in guava fruits and also on the post-harvest quality of the fruit, by means of an analysis of the quality parameters during the period of storage, at two different temperatures.

2. Materials and methods

2.1. Colonies

C. capitata eggs were obtained from colonies kept at the Laboratory of Economic Entomology, Biological Institute, in Campinas, located in the state of São Paulo (Brazil), since 1993. Medfly colony was reared using artificial means described by Raga et al. (1996). After emerging, adults were fed a mixture of yeast extract and white sugar in a ratio of 1:3 (w/w) and distilled water.

2.2. UV-C radiation equipment

The irradiator utilized in this study is located in the Post-harvest Laboratory of the School of Agricultural Engineering at UNICAMP, in Campinas (SP). The equipment consists of a wooden structure and iron angle bars, 1.66 m high × 1.14 m long by 0.6 m wide, equipped with four wheels at the base to allow movement. Within this framework, there are iron angle bars fitted as lateral supports for the removable shelves, permitting a similar distance between the light source and the treated material. One shelf is placed in the middle, which is intended for the placing of the fruit. We used twelve Philips 30W UV-C germicidal lamps (mercury vapor at low pressure, and a wavelength of 254 nm), permitting six at the top and six at the bottom (Fig. 1). Electrical equipment and two Qualitas Q90SA3 exhaust fans were installed on each side.

The intensity of the UV-C lamps was determined before each test, using a Newport Optical Power Meter 1830-C digital radiometer. The mW cm^{-2} data were transformed into kJ m^{-2} to provide better comparison with other studies.

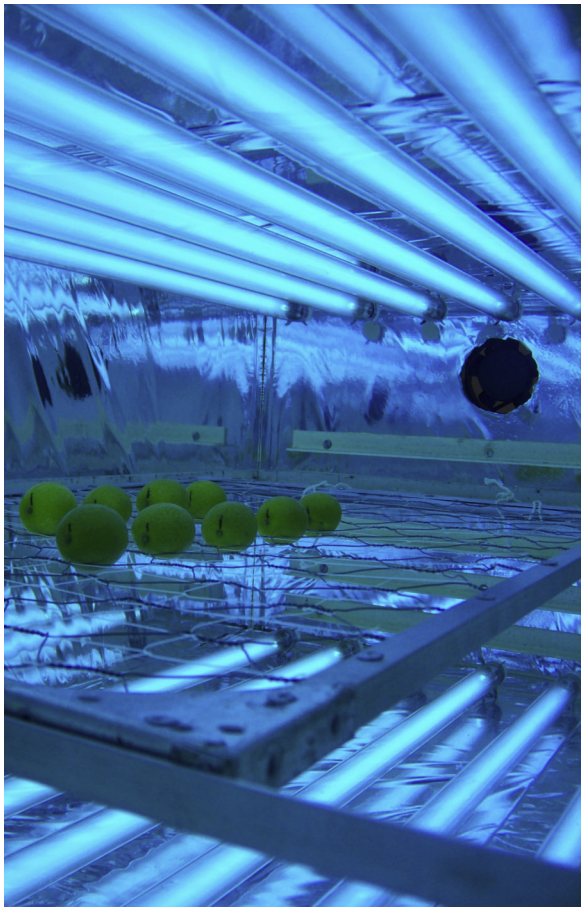

Fig. 1. Irradiated fruits arranged on the middle shelf in UV-C equipment in the laboratory.

2.3. Evaluation of the mortality of C. capitata eggs subjected to UV-C radiation (in vitro)

Each treatment consisted of ten replications and each plot had 20 one-day-old eggs. The eggs were counted using a Carl Zeiss Jena Citoval 2 stereoscopic microscope at a magnification of 40×, and were then transferred to Petri dishes 10 cm in diameter by 1.5 cm high, containing 20 ml of distilled water. After the application of the treatments, they were stored in a B.O.D. type (Biochemical Oxygen Demand) incubator at 25 ± 0.2 °C to provide better development of the *C. capitata* eggs. The treatments were as follows: control (without UV-C radiation—T1); 0.087 (T2); 0.261 (T3); 0.348 (T4); 0.461 (T5); 0.691 (T6); 0.922 (T7); 1.383 (T8); 4.150 (T9); 5.534 (T10) and 8.301 kJ m^{-2} (T11). The mortality of the *C. capitata* eggs was evaluated 24 h after treatment.

2.4. Assessment of the effects of UV-C radiation in preventing pupation based on irradiated "Kumagai" guavas containing C. capitata eggs

Physiologically mature, white-pulp "Kumagai" guavas (*Psidium guajava L.*) were used, as per normal commercial standards. The fruit originated from an area of production that used an individual fruit-bagging system, free from insecticide applications, located in Campinas (SP). The guavas were placed in laboratory rearing cages containing 500 pairs of 12 day-old *C. capitata*, for an infestation session lasting 7 h. After the infestation, the guavas were placed in the UV-C radiation equipment, on a shelf arranged at a distance of eight centimeters from the light source. The following treatments