British Mycological Society promoting fungal science

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

Effect of ultraviolet radiation A and B on growth and mycotoxin production by *Aspergillus carbonarius* and *Aspergillus parasiticus* in grape and pistachio media

Esther GARCÍA-CELA, Sonia MARIN, Vicente SANCHIS, Ana CRESPO-SEMPERE, Antonio J. RAMOS*

Applied Mycology Unit, Food Technology Department, University of Lleida, UTPV-XaRTA, Agrotecnio Center, Av. Rovira Roure 191, Lleida 25198, Spain

ARTICLE INFO

Article history:
Received 27 July 2014
Received in revised form
14 November 2014
Accepted 15 November 2014
Available online 25 November 2014
Corresponding editor:
Marc Stadler

Keywords:
A. carbonarius
A. parasiticus
Aflatoxins (AFs)
Climate change
Ochratoxin A (OTA)
Ozone depletion

ABSTRACT

The effects of two exposure times per day (6 and 16 h) of UV-A or UV-B radiation, combined with dark and dark plus light incubation periods during 7–21 d on fungal growth and mycotoxins production of *Aspergillus* species were studied. *Aspergillus carbonarius* and *Aspergillus parasiticus* were inoculated on grape and pistachio media under diurnal and nocturnal temperatures choosing light photoperiod according to harvest conditions of these crops in Spain. Ultraviolet irradiation had a significant effect on *A. carbonarius* and *A. parasiticus* colony size (diameter, biomass dry weight, and colony density) and mycotoxin accumulation, although intraspecies differences were observed. Inhibition of *A. carbonarius* fungal growth decreased when exposure time was reduced from 16 h to 6 h, but this was not always true for ochratoxin A (OTA) production. OTA reduction was higher under UV-A than UV-B radiation and the reduction increased along time conversely to the aflatoxins (AFs). Aflatoxin B_1 (AFB_1) was the main toxin produced by *A. parasiticus* except in the UV-B light irradiated colonies which showed a higher percentage of AFG than AFB. Morphological changes were observed in colonies grown under UV-B light.

Introduction

The last report from the World Meteorological Organization (WMO) highlighted that human emissions of chlorofluorocarbons (CFCs) and other chemicals have an important role in the atmosphere changes by damaging the stratospheric ozone layer that filters out harmful ultraviolet radiation (UV) (WMO 2013). The ozone depletion has a strong link with climate change, as the physics and chemistry of the Earth's atmosphere largely determine our climate, inasmuch changes in ozone can induce changes in climate, and *vice versa* (McKenzie *et al.* 2011). For example, changes in atmospheric circulation resulting from climate change can induce regional differences in ozone, leading to increase in UV radiation in some regions and reduction in others (Hegglin & Shepherd 2009). The United Nations Environment Programme reported that the average of total ozone values for 2006–2009 of about 3.5 % and 2.5 % below than the

* *Corresponding author*. Tel.: +34 973 702908; fax: +34 973 702596.
E-mail address: esther.garcia@tecal.udl.es (E. García-Cela).

http://dx.doi.org/10.1016/j.funbio.2014.11.004
1878-6146/

1964–1980 averages, for 90°S-90°N and 60°S-60°N, respectively (UNEP 2010). Ground-based UV reconstructions and satellite UV retrievals, supported in the later years by direct ground-based UV measurements, show that erythemal ('sunburning') irradiance over midlatitudes has increased since the late 1970s, which is correlated with the observed decrease in column ozone (UNEP 2010). Solar UV radiation transmitted through the earth's atmosphere has three primary streams of incoming radiant flux depending on their wavelength range: (i) UV-C (100–280 nm) is the higher energetic portion of the UV spectrum, which does not reach the ground surface as it is completely absorbed by the ozone layer and other atmospheric constituents; (ii) UV-B (280–315 nm) still reaches ground level but it is strongly absorbed by stratospheric ozone; (iii) UV-A (315–380 nm) is only slightly absorbed by ozone layer making up most of the UV irradiance at the ground level (CIE 1987).

Certain groups of filamentous fungi can produce harmful secondary metabolites called mycotoxins. The major groups of mycotoxins, derived from polyketide metabolism, are present in a wide range of foodstuffs: aflatoxins (AFs), fumonisins (FBs), ochratoxin A (OTA) and zearalenone (Gallo *et al.* 2013). Although the ecological role of mycotoxins is far from being elucidated, several studies indicate the mycotoxin biosynthesis is induced under certain stress conditions (Schmidt-Heydt *et al.* 2008). Moreover, Cary & Ehrlich (2006) suggested that AFs production could be a strategy of fungi to prevent from UV damage. Also, citrinin has been considered as a light protectant, since citrinin producing colonies grew better under red and blue light than non-producing colonies (Schmidt-Heydt *et al.* 2012). However, the effect of UV radiation in mycotoxin biosynthesis is unknown, and to our knowledge there are no publications on this topic.

Some previous works have studied the effect of UV radiation on fungal spore germination, growth, and sporulation, showing that the effect is dependent of time and wavelength of UV exposure (Table 1) (Fourtouni *et al.* 1998; Moody *et al.* 1999; Osman *et al.* 1989; Wu *et al.* 2000). Fungal spores of *Aspergillus flavus* and *Penicillium chrysogenum* are much more resistant to the lethal effects of UV than the vegetative mycelium (Osman *et al.* 1989). UV-A irradiation stimulated fungal growth of several species while in others species it had no influence on radial growth or dry mass (Fourtouni *et al.* 1998; Moody *et al.* 1999; Osman *et al.* 1989). The UV-B irradiation not only reduced the germination and sporulation in most of the fungi tested but also reduced the colony diameter (Aylor and Sanogo, 1997; Fourtouni *et al.* 1998; Moody *et al.* 1999). This contrast between the responses of fungi to these two different parts of the UV region can be explained by the fact that shorter wavelength radiations are more deleterious to biological systems as they carry more energy per photon than longer wavelengths (Moody *et al.* 1999).

The aim of this study was to assess the effect of UV-A and UV-B radiation on fungal growth and mycotoxin (OTA/AFs) production of two *Aspergillus* species commonly isolated in foodstuffs: the OTA producer *Aspergillus carbonarius* which is present mainly in vineyards around the world and the AFs

Table 1 – Previously published studies regarding the effects of UV-A and UV-B radiation in fungi in laboratory conditions.

Microorganism	Wavelength (nm) Range	Wavelength (nm) Peak	Irradiance ($mW \cdot cm^{-2}$)	Exposure time per day	Irradiance ($KJ \cdot m^2 \cdot day^{-2}$)	Days of exposure	T (°C)	Culture médium	Ref.
Aspergillus flavus *Penicillium notatum*		366	0.04	20-40-60-120-240 min	0.5-5.8	1	24-25	Czapek	1
Aspergillus fumigatus *Cladosporium cladosporioides* *Leptosphaeria coniothyrium* *Marasmius androsaceus* *Mucor hiemalis* *Penicillium hordei* *Penicillium janczewskii* *Penicillium purpurogenum* *Penicillium spinulosum*	315-400		3.056-5.556	3 h	330-600	16	20	PDA	2
Trichoderma viride *Ulocladium consortiale* *Verticillium state* *Alternaria alternata* *Botytis cinerea* *Cochliobolus sativus* *Epicoccum nigrum* *Khuskia oryzae* *Ulocladium botytis*	292-350		<0.001-0.019		0-2.1				
Alternaria solani	315-360	366	0.051-0.167	12 h	21.9-72.3	7	25	PDA enriched	3
	290-315	313	<0.001-0.194	12 h	0.3-83.6	7	25	with glucose	
Bremia lactucae	200-400	340-350	0.600-1.250	2-4-8-12 h	43.2-540	1		Lettuce leaves	4
	280-315	305-310	0.150-0.700	2-4-8-12 h	10.8-302.4	1			

Data were obtained from the following references: (1) Osman *et al.*, 1989, (2) Moody *et al.*, 1999, (3) Fourtouni *et al.*, 1998 and (4) Wu *et al.*, 2000.