Revista Iberoamericana de Tecnología Postcosecha
ISSN: 1665-0204
ISSN:
reginaldo.baez@gestagro.com.mx
Asociación Iberoamericana de Tecnología Postcosecha, S.C.
México

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Revista Iberoamericana de Tecnología Postcosecha, vol. 24, núm. 1, 2023
Asociación Iberoamericana de Tecnología Postcosecha, S.C.
Disponible en: https://www.redalyc.org/articulo.oa?id=81376287002

Generales

Postharvest decay control fungicides for citrus

FUNGICIDAS PARA CONTROLE DE APODRECIMENTO PÓS-COLHEITA DE CITROS

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Recepción: 05 Abril 2023
Aprobación: 16 Mayo 2023
Publicación: 30 Junio 2023

Acceso abierto diamante

Abstract

The reduction in the percentages of citrus fruit with symptoms of the main postharvest decay organisms may be achieved via fungicide spray treatments in packinghouse procedures. However, one of the limitations for a successful control is the reduced number of molecules registered for postharvest use in most countries that are frontrunners in citrus production and export. Moreover, upsurges of resistant pathogen strains of postharvest pathogens point towards the need of effective control measures not only after harvest but also along the production periods. For those reasons, the conscientious use of chemical control to reduce the incidence of pathogens is imperative.

Keywords: *Penicillium* spp, disease control, fludioxonil, imazalil, thiabendazole.

Resumo

A redução das percentagens de frutas cítricas com sintomas dos principais patógenos de pós-colheita pode ser alcançada com aplicação de fungicidas nos procedimentos de packinghouse. Todavia, uma das limitações para um controle com sucesso de agentes causais de podridões é o reduzido número de moléculas registradas para uso após a colheita na maioria dos países expoentes em produção e exportação de cítricos. Além disto, o surgimento de raças resistentes destes agentes causais aponta para a necessidade de medidas efetivas de controle não apenas após a colheita, mas também durante os estádios de desenvolvimento das culturas. Por estas razões o uso consciencioso do controle químico para reduzir a incidência de doenças pós-colheita é indispensável.

Palavras-chave: Penicillium spp, controle da doença, fludioxonil, imazalil, tiabendazol.

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INTRODUCTION

World fruit production between 2000 and 2019 increased 54%, from 572 million tons to 883 million tons (FAO 2021). According to that same source, fruits and vegetables accounted in 2019 for roughly 20% of a total of food exports of about U$ 1.4 trillion. World production of the main citrus species was estimated to be of 103.2 million tons (USDA 2022) harvested from about 7.5 million hectares (YARA BRASIL 2020).

Citrus fruit are shipped all over the world, but mostly from the southern hemisphere to the northern countries (Figure 1). According to FAO (2020), world citrus exports were in the range of 17.5 million tons. Brazil exported about 137.5 thousand tons.

Postharvest diseases, such as green and blue molds (*Penicillium digitatum* and *P. italicum*, respectively) are severe constraints for distribution of citrus fruit for fresh consumption. Other fungi such as *Lasiodiplodia theobromae, Alternaria alternata* amongst other genera, depending on the citrus species, may also cause serious economic losses to fruit shipping businesses to supply distant markets.

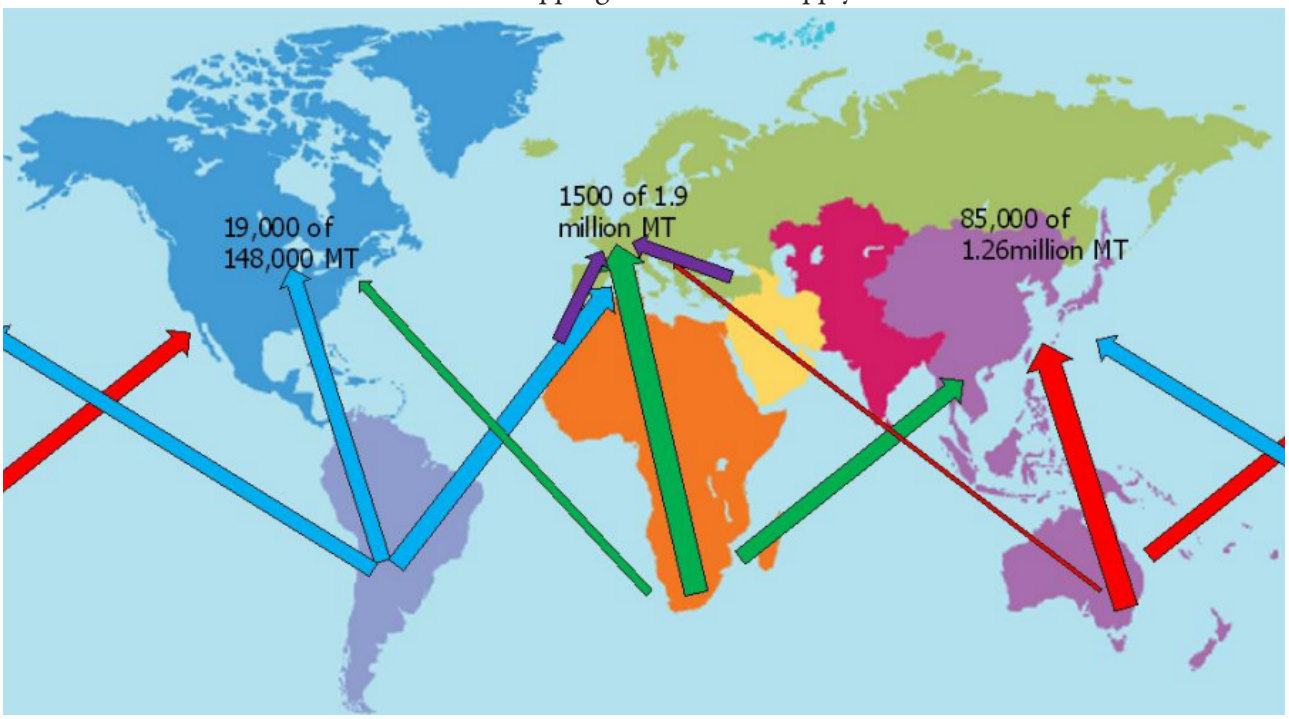

Figure 1

International routes of citrus shipments from production areas to consumer countries

Source: https://www.asoex.cl/seminario-citricos-abril-2011/finish/35-seminario-citricos-abril/263-la-industria-del-citrico-en-australia-y-sud-africa.html

As the fruit progress ripening and at storage temperatures above the ideal limits, susceptibility to decay incidence builds up. Mechanical injuries to the fruit at harvest and succeeding procedures along the postharvest handling chain are also grounds to boost infections (Panebianco et al., 2015). According to the authors, in most, if not all, citrus producing countries, fungicides containing the active ingredients imazalil and thiabendazole are the primary decay control measures. However, not all fungi species are effectively controlled by those active ingredients. Sour rot (*Geotrichum citri-aurantii*) common to citrus fruit in all regions is not controlled by the registered molecules imazalil and thiabendazole and, as well, is not controlled by pyrimethanil and fludioxonil (Wang et al., 2020). Other active ingredients with more effectiveness against citrus postharvest diseases, such as sodium ortho-phenylphenate (SOPP) and guazatine are not registered in all citrus producing countries.

The literature does not present the complete lists of active ingredients registered for after harvest use in the major citrus producing and exporting countries. Therefore, we decided to search the official

agrochemical registration offices of these countries and list these active ingredients available for use and compare to what the Brazilian growers are allowed by the Ministry of Agriculture, Livestock and Supply (MAPA) to apply to control postharvest decay on citrus fruit.

The molecules registered for use as postharvest treatments for decay control on citrus fruit were retrieved from public systems of agrochemicals registration offices of Argentina, Australia, Mexico, South Africa, Spain and Uruguay. In all countries and alike to Brazil, distinct directorates of the respective Ministries of Agriculture are in charge of technical evaluations of the required documents for the approval and registration of active ingredients for agricultural use. In Argentina, the Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA) is in charge of the technical evaluation of the required documents for the approval and registration of active ingredients. In Australia, a public chemical registration information system is available for search at the Australian Pesticides and Veterinary Medicines Authority. In Mexico, the authorization of agrochemicals for agricultural use is in charge of the Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria (Senasica). In South Africa the Department of Agriculture, Land Reform and Rural Development has that responsibility. In Spain the registration of phytosanitary products is operated by the Ministerio de Agricultura, Pesca y Alimentación and the database is updated weekly. In Uruguay, the Direccion General de Servícios Agrícolas of the Ministerio de Ganaderia, Agricultura y Pesca is in charge of the registration of phytosanitary products. In Brazil, the registered agrochemicals for use on citrus fruit may be looked up at the Agrofit/Ministry of Agriculture, Lifestock and Supply site.

The presence of residues and the occurrence of resistant fungal strains to some fungicides compels for efforts for appropriate chemical use and for the development of effective alternative measures to control diseases. According to Holmes & Eckert (1999), in California, the proportion of isolates that were resistant to three fungicides (imazalil, thiabendazole and SOPP) increased from 43% in 1988 to 74% in 1994. Bus (1992) reported the occurrence of several *Penicillium* isolates from different geographical regions of the world with reduced sensitivity to thiabendazole, imazalil and benomyl. Benomyl's use, though, was prohibited in 2001 (Pearson & Miller, 2014) while imazalil and thiabendazole are still available in many citrus producing countries. In packinghouses of the state of Sao Paulo/Brazil, Fischer et al. (2009) reported that 39% of *Penicillium digitatum* isolates were resistant against thiabendazole and already 1% resistant to imazalil. Vinas et al. (1993) reported that 85% of a number of tested strains of *Penicillium* spp, were tolerant to imazalil at concentrations up to 11,000 μg/mL in apple packinghouses of Spain.

The upsurge of resistant strains of fungi species, which cause postharvest decay depends on several factors. Insensitivity or a reduction in sensitivity to an active ingredient results from an inherited adjustment of the fungus to that molecule either due to single or multiple genetic mutations (Brent & Hollomon, 2007). Therefore, according to the authors, resistant strains derive somewhat from a natural rate of genetic mutation of the pathogen, though the frequency of use of a single compound over the years should also not be ignored. Fischer et al. (2009) pondered that the high number of thiabendazole field sprays is a possible cause of the resistance of *P. digitatum* determined in citrus packinghouses in the state of São Paulo, Brazil.

Due to the limited availability of registered molecules for postharvest use (Table 1), it is imperative that these fungicides be used sparingly and according to technical recommendations to avoid the emergence of resistant strains, as already indicated by authors such as Holmes & Eckert (1999) and Kinay et al. (2007). Besides, whenever possible in order not to depend exclusively on after harvest treatments with fungicides or other alternative treatments, rotation of active ingredients in field sprays is necessary to limit the possibility of development of resistant strains (Fischer et al., 2011).

Table 1

Registered active ingredients for postharvest use in export-driven citrus producing countries.

Brazil	Uruguay	Argentina	South Africa	Australia	Mexico	Spain
Imazalil	Imazalil	Azoxystrobin + Fludioxonil	Azoxystrobin	Fludioxonil	Azoxystrobin + Fludioxonil	Fludioxonil
Thiabendazole	Prochloraz	Benomyl	Imazalil	Guazatine	Imazalil	Fosetyl-Al
Azoxystrobin + Fludioxonil	Propiconazole	Carbendazim[2]	Fludioxonil	Imazalil	Thiabendazole	Imazalil
	Pyrimethanil	Fludioxonil	Pyrimethanil	SOPP		Propiconazole
	SOPP [1]	Imazalil	Propiconazole	Thiabendazole		Pyrimethanil
	Thiabendazole	Prochloraz	Thiabendazole	Imazalil + Pyrimethanil		SOPP
		Propiconazole	2,4-D	Propiconazole + Fludioxonil		Thiabendazole
		Thiabendazole	SOPP			

In Brazil, the risk of emergence of resistant strains is high, as there were, for years, only two molecules registered for use on citrus after harvest, unlike countries like Spain and the Mercosul partners that contribute in the supply of the Brazilian domestic market and have an availability of a much larger number of molecules. Only recently, in the year 2020, a formulation of azoxystrobin and fludioxonil had its registration completed at the Brazilian Ministry of Agriculture, Lifestock and Supply.

Even if a molecule is registered for use in a specific country, when that country exports it is of utmost importance for growers and exporters to look up the respective regulations of the importing country regarding restrictions on the use of molecules and the presence of residues. Those restrictions may be more limiting than the tolerances of presence of maximum residue limits (MRL) indicated by the legislation of the country of origin or of the Codex Alimentarius to which most countries comply to.

The diversity of post-harvest diseases arising from latent and/or active infections suggests the need to employ more effective control measures during the production and postharvest procedures. Grove management during fruit development to reduce the inoculum of causal agents and alternation of active ingredients is also mandatory to lessen the chances of emergence of resistant strains of decay fungi.

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