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Effects of *Bacillus subtilis* strain QST 713 and storage temperatures on post-harvest disease development on greenhouse tomatoes

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ABSTRACT

Tomato plants in two commercial greenhouses were treated with Rhapsody (*Bacillus subtilis* strain QST 713, rate of 1.45%) once every 4 weeks during 2012–2013 to determine effects on post-harvest fruit infection. Populations of *Bacillus* and disease incidence were monitored weekly from harvested fruit over an 18-week period. Population levels of *Bacillus* ranged from 75 to 110 × 10^4 colony forming units (cfu) cm^{-2} of fruit surface area one week after application to 25–30 × 10^4 cfu cm^{-2} of fruit surface area 4 weeks after application. Disease incidence on harvested fruit incubated at 21 °C for 7–10 days was variable, due to variation in inoculum levels within the greenhouse as well as variable environmental conditions. Both disease incidence and severity were significantly reduced on Rhapsody-treated fruit, especially in the 1–2 week period following application. Post-harvest storage temperature (13 °C vs. 21 °C) and incubation time (12 vs. 16 days) had a significant effect on final disease severity. Rhapsody-treated fruit incubated at 13 °C had an average of 1–2% fruit infection compared to up to 20% infection on untreated fruit at 21 °C. The most frequent pathogens affecting fruit quality were *Penicillium* sp. and *Rhizopus stolonifer*. Rhapsody applications made every 4 weeks maintained sufficiently high populations of *Bacillus* on the fruit surface to prevent spread of these fungi onto the fruit, resulting in significant post-harvest disease control on fresh market tomatoes. When combined with storage at 13 °C for no more than 12 days, disease was reduced to negligible levels.

1. Introduction

Tomatoes (*Solanum lycopersicum* L.) are grown worldwide for fresh market consumption and for processing into paste, sauces and juice. Production of fresh market tomatoes in greenhouses yields high quality fruit year-round in controlled environments that utilize reduced or pesticide-free crop production practices. The greenhouse tomato industry in Canada generates around $500 million in sales annually. In British Columbia, about 62 million kg of tomatoes, valued at $141 million, are produced using 116 ha of greenhouse growing space (Anonymous, 2011). The tomatoes are marketed as “tomato-on-the-vine” or “vine-ripened” and sold locally or exported to the USA and Asia. Most commercial greenhouses use soil-less (hydroponic) systems and, wherever possible, management of pest and disease problems relies on the implementation of biological control agents (Anonymous, 2011). Post-harvest fungal pathogens cause significant losses on fresh-market tomatoes both in commercial greenhouses as well as under field conditions (Bartz et al., 2002; Blancard, 2012; Howard et al., 1994; Jones et al., 1991). Infection of the fruit may occur during crop production or at harvest, and disease symptoms are manifested during storage, transport or at the retail outlet. Frequently, fruit appear healthy at harvest but bear latent infections that develop under storage conditions that favor fungal growth. Fruit should ideally be rapidly cooled after harvest and kept in a temperature controlled environment (13 °C) with 70–75% relative humidity (Bartz et al., 2002; Blancard, 2012; Howard et al., 1994; Jones et al., 1991). At warmer temperatures and higher humidity levels, disease development can progress rapidly. One of the challenges to managing post-harvest fungal diseases is that the time during crop production when fruit infection may occur is unpredictable, necessitating the frequent application of disease control products. In addition, the lag time between when infection may have taken place and the appearance of disease symptoms may be 10–14 days. Therefore, seemingly healthy-appearing fruit may succumb to post-harvest decay after a period of storage.

Previous research on various biological control approaches to

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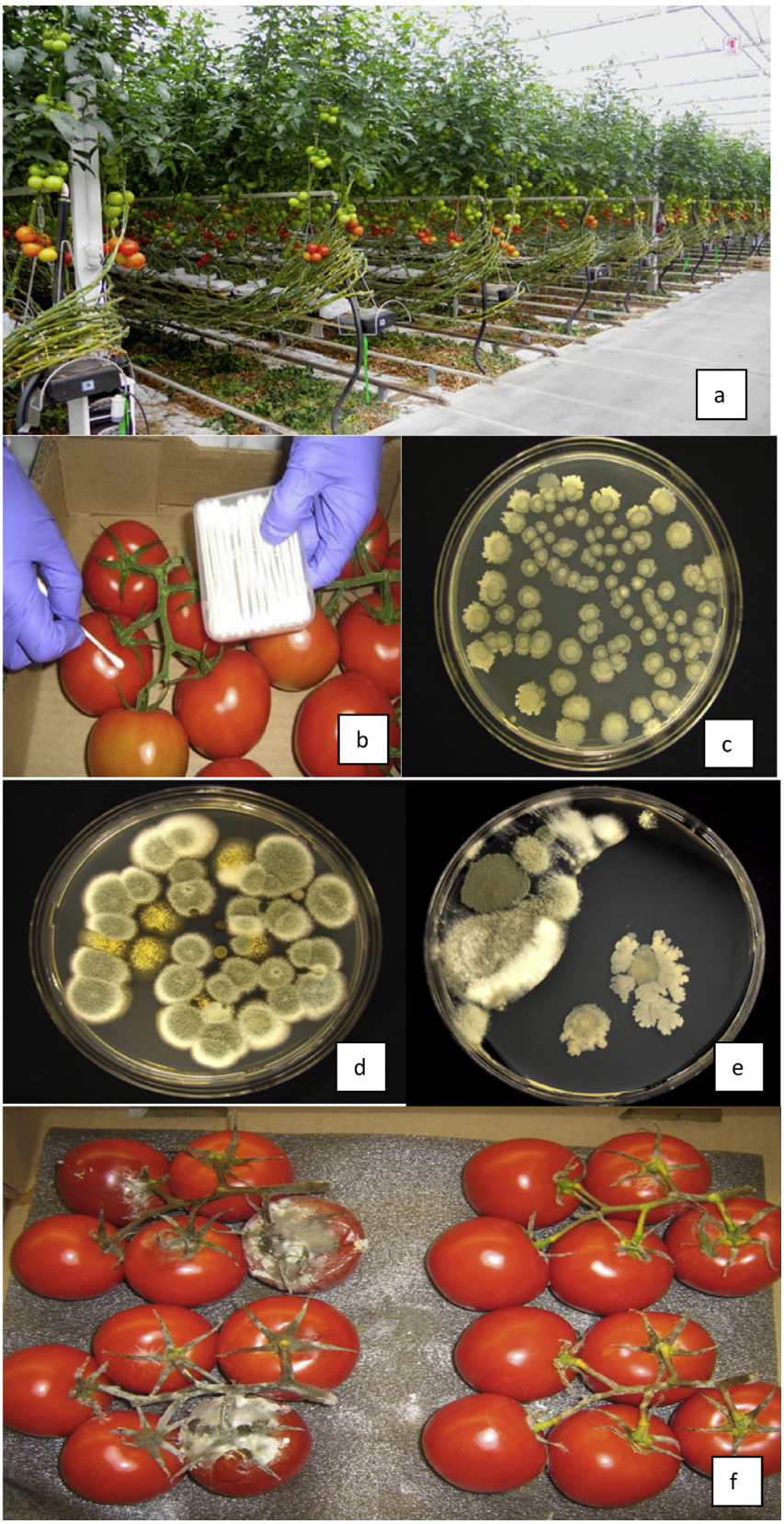

Fig. 1. Populations of *Bacillus subtilis* on tomato fruits following application of Rhapsody. (a) Rows of plants on which treatments were made. (b) Sampling of a cluster of 5 fruits to determine fruit surface populations using the swab technique. (c) Colonies of *Bacillus* recovered from treated fruit. (d) Colonies of fungi (mostly of *Penicillium*) recovered from control fruit after streaking onto potato dextrose agar. (e) Inhibition zone formed by *Bacillus* colonies (lower right) against growth of fungal colonies (top left). (f) Comparison of disease development on control fruits (left) with Rhapsody-treated fruits (right) after 12 days of incubation at 21 °C.