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Seasonal changes in the abscission site in bunch tomatoes and differential response to 1-methylcyclopropene

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Abstract

Cherry tomatoes harvested as bunches are susceptible to abscission during storage. Two abscission zones are present in the bunch: the joint (AJ) in the middle of the pedicel and the receptacle (AR), which connects the fruit to the pedicel. It is demonstrated in the present study that during the temperate winter, after storage at 12 °C abscission commences through the AJ and that during the spring there is a transition to AR. Fruit harvested in the summer mostly underwent the AR type. It has been shown that 1-methylcyclopropene (1-MCP) can prevent abscission in cv. R-819. It is now shown that in early winter lower doses of 1-MCP are required to suppress abscission than during the warmer season. Of three cultivars tested, cvs. Shiren and Conchita had less abscission after storage than R-819, and 1-MCP could suppress abscission in all of them to various extents. Exposure of cv. Shiren to 50 $\mu l\,l^{-1}$ of ethylene for 3 h did not induce abscission whereas 1-MCP reduced both AJ and AR abscission, and delayed ripening, as indicated by fruit color and firmness. Delay of red color development required lower doses of 1-MCP than inhibition of abscission. The variability in abscission of bunch tomatoes during the season indicates that multiple environmental signals determine the final quality of the produce.

Keywords: Postharvest; *Lycopersicon esculentum*; Bunch tomatoes; Ethylene; 1-Methylcyclopropene; Joint; Calyx; Pedicel

1. Introduction

Cherry tomatoes harvested as bunches (Kagan Zur and Mizrahi, 1993) are subject to abscission during storage, and this is a significant commercial problem with this product. After harvest, the bunches are stored at 12 °C and, unlike single tomatoes, the end of their shelf life is defined by the separation of the fruit from the bunch. The shelf life of bunch tomatoes is highly variable and can range from 1 to 3 weeks. The primary objective of this study was to gain an understanding the factors involved in this process.

The indeterminate tomato genotypes facilitate continuous production of new inflorescences and bunches and it allows tomato growers to harvest the fruit throughout the season, which can last 6 months or more. This in turn creates a situation in which the fruit are exposed to very variable conditions during their development. Another feature of bunch tomatoes is the anatomy and genetics of the vegetative parts of the bunch. Typically, the bunch is composed of a major stem from which peduncles bearing the fruit are arranged in one plane. Joints located in the middle of the peduncle change the orientation of the fruit with respect to the axis of the peduncle and they constitute the first abscission zone (AJ). The tip of the peduncle bears the sepals and the fruit is attached to it through the receptacle, so creating the second abscission zone (AR). Thus, fruit abscission can occur at the AJ or at the AR and the differing anatomy and physiology of these two zones can lead to variable consequences for the shelf life

Abbreviations: AJ, abscission from the joint; AR, abscission from the receptacle; AZ, abscission zone; 1-MCP, 1-methylcyclopropene; AVG, aminoethoxyvinylglycine; STS, silver thiosulfate

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of the bunch. It has been reported that in tomato cv. Loica, flowers and undeveloped fruit abscised from the AJ whereas ripe fruit abscised from the AR (Biain de Elizalde, 1980). This situation is reminiscent of the multiple abscission zones in citrus fruit (Greenberg et al., 1975), *Nicotiana glauca* (S. Meir, personal communication), and peach peduncles, which have three abscission zones (Rascio et al., 1985). In peach it was suggested that the proximal abscission zone, AZ-1 is responsible for shedding the buds, flowers and young fruit in early June, whereas AZ-2 and the distal AZ-3 are activated in mid and late June, respectively.

The effect of ethylene on abscission has been documented in many systems (Osborne, 1989). The evidence for its involvement derives primarily from the capability of the exogenous hormone to promote abscission and of inhibitors of ethylene action, such as silver thiosulfate (STS) and 1-MCP, or inhibitors of ethylene synthesis such as aminoethoxyvinylglycine (AVG), to delay this process. Other lines of evidence rely on the timing of endogenous ethylene secretion and mutants in the ethylene pathway (Whitelaw et al., 2002). STS is widely used to prevent senescence and abscission in cut flowers, but it cannot be applied to edible produce, and 1-MCP has been shown to delay ripening, senescence and abscission in many agricultural products (Sisler and Serek, 1997; Blankenship and Dole, 2003). A number of studies have shown the effect of 1-MCP on tomato fruit ripening (Hoeberichts et al., 2002; Wills and Ku, 2002; Younes et al., 2003; Mir et al., 2004). These studies demonstrated consistent inhibition of ripening by 1-MCP, expressed mainly as delay in carotenoid accumulation. The mature green fruit represent the stage that is most sensitive to 1-MCP, and application of the treatment to immature green tomatoes can prevent proper ripening. The efficacy of the treatment is reduced as ripening proceeds to the red stage and a second application after storage can resume the inhibitory effect of 1-MCP.

We have previously shown that 1-MCP is capable of inhibiting abscission in cherry tomatoes cv. R-819 (Beno-Moualem et al., 2004). This study also documented the effects of various treatments on expression of six tomato endo-1,4-β-glucanase genes in the AJ during storage and identified the critical genes that may be involved in this process. In the present study, we examined how abscission was divided between AJ and AR throughout the season, what were the effects of different concentrations of 1-MCP on each type of abscission, and how different cultivars compares with one another in these respects.

2. Materials and methods

The cherry tomato (*Lycopersicon esculentum*) cultivars used were 'R-819' and 'Shiren' (Hazera Genetics, Israel, developed by the groups of N. Kedar, H. Rabinowitz and E. Kopielevitz, the Hebrew University, Faculty of Agriculture, Rehovot, Israel) and 'Conchita' (DeReuters, distributed by Semco, Israel). Bunch tomatoes were routinely obtained from commercial net houses which were 3.5 m in height with polycarbonate on top and walls made of 50 mesh white net. The net houses were equipped with passive screen type ventilation. The plants were grown at a density of 2000–2500 plants per dunam in paired rows and high wire support training. The plants were grown on either tuff:pit (2:1, v/v, experimental net house Fig. 2C and D), or perlite in soiless medium (comparison of different cultivars, Figs. 4 and 5), or sand (Fig. 6). The plants were typically fertigated with an N:P:K composition of 4:2.5:6. Bunches were harvested according to commercial practice, the bunches contained a minimum of six fruit, of which the proximal pair were at the light red stage and the distal pair at the turning stage or at the pink stage with substantial areas of green pericarp. The fruit were transported in an air-conditioned van as bulks of 7–14 kg. Immature, green, over-ripe and cracked fruit and non-uniform bunches were removed. Unless otherwise specified, three or four bunches, weighing a total of 400–500 g were placed in ventilated polycarbonate packages, each of which constituted a replicate, and a minimum of five replicates were used for each treatment. 1-Methylcyclopropane (1-MCP, SmartFresh, Rohm and Hass Co., Philadelphia, PA, kindly provided by Rimi Ltd., Israel) was applied at a calculated final concentration in either 32- or 200-l gas-tight containers at 12 °C. The powder, which contained 0.14% active ingredient was dissolved in warm water (at 40 °C) in a tube that was placed in the bottom of the container and opened, after which the container was sealed immediately. The concentration of 1-MCP in the container was determined with a gas chromatograph (GC). The GC (Varian 3300) was equipped with flame ionization detector GC–FID operating at 150 °C, and a stainless steel column, packed with 20% Carbowax 20M, 80–100 mesh. The injection and column temperatures were 55 and 45 °C, respectively, and helium at 30 ml/min was used as a carrier gas. The amount of 1-MCP was calculated by comparison with a standard of 1 $\mu l\,l^{-1}$. After 20–22 h at 12 °C all the containers were opened and the packages were stored at 12 °C. Unless otherwise specified, relative humidity (RH) in the storage room was maintained at 90 ± 2% (monitored by a Hygrolog datalogger, Rotronic AG, Bassersdorf, Switzerland).

The abscission mode was classified according to the site of detachment: abscission in the joint located in the middle of the peduncle was designated as AJ and that in the connecting tissue between the peduncle and the fruit as AR. Fruit abscission was evaluated manually by shaking the bunches vertically downward, twice, for approximately 1 s. The color of the fruit was determined with a CR-300 chromometer (Minolta, Japan) and was displayed as hue angle (h°) on the Lab scale (McGuire, 1992), or by counting the number of fruit that contained any portion of green pericarp. Firmness was determined on a sample of 15 fruit with a digital force gauge (Chatillon, USA) equipped with a 12-mm flat probe that measured the maximal compressive force of the fruit in newtons.