Abscission of Mango Fruitlets as Influenced by Enhanced Ethylene Biosynthesis

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ABSTRACT

Experiments were conducted on developing fruitlet explants of two mango (Mangifera indica L.) cultivars to establish the source and dynamics of ethylene production prior to and during fruitlet abscission. Abscission of all fruits in the samples occurred at approximately 86 and 74 hours postharvest in ‘Keitt’ and ‘Tommy Atkins’, respectively. Increased abscission began 26 hours from harvest and was preceded by enhanced ethylene synthesis. Enhanced ethylene production initiated approximately 48 hours prior to abscission and increased to a maximum near the time of fruitlet abscission. The seed produced the highest amount of ethylene on a per gram fresh weight basis. The pericarp, however, was the main source of ethylene on an absolute basis, since it represented more than 85% of total fruitlet weight. Pedicels containing the abscission zone produced no detectable ethylene prior to or at the moment of abscission. Fumigation of ‘Tommy Atkins’ fruitlets with 1, 15, or 100 microliters per liter ethylene accelerated abscission by 24 to 36 hours in comparison with unfumigated controls. Diffusion of ethylene from distal fruitlet tissues to the abscission zone triggers the events leading to separation of the fruit from the tree.

Shedding of immature fruits occurs in many mango cultivars (11, 12, 17, 18, 19). Abscission occurs at all stages of fruit development but is particularly high during the first 3 to 4 weeks after pollination (12, 14). Fruit drop at these early stages can account for over 90% loss of originally set fruitlets (6, 12), and has been associated with ovular and embryonic degenerations which hinder normal fruit development (13). Factors involved in abscission of apparently normal fruit have not been elucidated. Anatomical studies revealed that the abscission zone in mango fruit is formed in the pedicel at the flower initiation stage and is composed of irregular rows of small meristematic cells (13).

The notion that ethylene is involved in abscission of most plant organs is well established (9). Furthermore, evidence exists to indicate that ethylene is capable of inducing preabscission changes in fruit as well as strongly accelerating fruit abscission (2, 8). The suggestion that ethylene is involved in abscission of young mango fruit has been made on the basis that abscised fruit produced significantly higher amounts than did normally develop-
ration but remained slightly adhered due to the sticky latex secretation at the abscission zone (4). Abscised fruitlets were removed from the chambers after each check.

The experiment was repeated three times with 'Tommy Atkins' fruitlets and twice with 'Keitt' fruitlets. Each experiment was performed with approximately 250 explants.

Fumigation. To observe the effect of exogenous ethylene application on the dynamics of fruitlet abscission, 'Tommy Atkins' explants were enclosed in plexiglass chambers and fumigated with 1, 15, or 100 μL/L ethylene in a continuous flow system. Because of time limitations, these concentrations were evaluated this research season only to establish a cause, effect, and time relationship between ethylene and abscission as opposed to determining a specific response threshold. Each concentration was applied to approximately 120 explants. The desired ethylene concentration in the humidified, incoming air stream was achieved by utilizing a fine-metering valve connecting a 5% ethylene container to the in-line humidifier flask. The desired ethylene concentration was verified by analyzing 1 ml samples of the air-ethylene mixture entering and leaving the chamber.

The lid of the chamber, sealed with a nonethylene-producing paste prepared from Play Doh modeling compound (Kenner Products Corp.) and silicone stop-cock grease, was removed every 12 h to record abscission rates. The appropriate amount of pure ethylene was injected into the entering air stream to quickly regain the concentration being tested immediately after each reclosure.

RESULTS

Ethylene Biosynthesis and Abscission of Whole Fruitlets. Continuous monitoring of ethylene production by individually enclosed whole fruitlets revealed marked differences in synthesis levels between cultivars (Fig. 1). Ethylene production was substantially higher in 'Keitt' than in 'Tommy Atkins' explants.

On an absolute basis, maximum synthesis in 'Keitt' fruitlets occurred at 50 h, reaching nearly 140 nl/h, while 'Tommy Atkins' fruitlets reached their peak production, 35 nl/h, 74 h after collection. Ethylene production on a per unit weight basis was also higher in 'Keitt' fruitlets, which peaked at 50 h with 4.4 nl/g-h, while 'Tommy Atkins' fruitlets reached their highest level, 1.6 nl/g-h, at 74 h. Ethylene production prior to abscission appeared as gradual but variable increments at each sampling period (Fig. 1). Ethylene synthesis levels at each 12-h period were more variable (as evidenced by the standard errors of the means) in 'Keitt' fruitlets than in 'Tommy Atkins.' The highly variable results obtained using 'Keitt' explants did not appear to be caused by any remarkable diurnal fluctuation in ethylene production because data from individual fruits did not show such fluctuation. It was apparent, however, that ethylene produced from fruitlet to fruitlet was highly variable as was the time of onset of ethylene synthesis after harvest, particularly in 'Keitt' (data not shown). These two factors were compensated (Fig. 2) by transforming the mean production rates into mean relative rates based upon maximum production by individual fruitlets (postharvest).

A second curve in this figure represents these relative production rates during the time prior to abscission of individual fruitlets rather than time from harvest (preabscission). Ethylene synthesis levels were derived from the nl/h value for each fruitlet; however, a similar transformation using the nl/g-h values produced an almost identical trend.

Percent of absced 'Keitt' fruitlets increased sharply from 12% at 62 h postharvest to 50% at 74 h postharvest. Similarly, abscission in 'Tommy Atkins' fruitlets increased sharply from 6% at 50 h postharvest to 44% at 62 h postharvest. Total abscission was observed 12 h later in 'Keitt,' since 97% of remaining fruitlets absceded 86 h postharvest, while 100% of 'Tommy Atkins' fruitlets had absorbed at 74 h postharvest. Abscission of mango fruitlets was thus preceded by an increase in endogenous ethylene synthesis which began approximately 48 h prior to abscission and peaked near the time of abscission.

Ethylene Biosynthesis by Fruitlet Tissues. The dynamics of ethylene production by the pericarp, seed, and pedicel-peduncle (abscission zone) of fruitlets of both cultivars was compared (Fig. 3). The pericarp of each fruitlet synthesized most of the ethylene produced from both cultivars at all sampling times. At 48 h prior to abscission of 100% of the fruitlets, when abscission rates were below 5% in both cultivars, pericarps were producing substantially more ethylene than seeds and pedicels combined. At the moment of abscission, pericarps produced 74 and 34 nl/h (74 and 92% of total ethylene) in 'Keitt' and 'Tommy Atkins' fruitlets, respectively. Developing seeds showed slight increases in ethylene production; however, synthesis did not exceed 20 nl/h in 'Keitt' or 5 nl/h in 'Tommy Atkins' at any point. Pedicels containing the abscission zone produced negligible ethylene throughout the entire abscission process.

Analysis of ethylene biosynthesis on a per unit weight basis was also made to compare the synthesis potential of tissues from fruit of each cultivar (data not shown). Whereas the temporal trends in ethylene production were similar, seeds had a higher ethylene production per unit weight than did pericarps or pedicels for both cultivars. Seeds of 'Keitt' reached a maximum synthesis rate of 18 nl/g-h at 62 h postharvest, while seeds of 'Tommy Atkins' reached their peak production (15 nl/g-h) at 50 h postharvest. Percarps from both cultivars produced less than 6 nl/g-h, while the trend was only a slight increase starting 14 h.
FIG. 2. Fruit abscission rates and relative ethylene production rates by whole fruitlets of two mango cultivars. Data represent mean % of maximum individual nL/h synthesis rate. Postharvest ethylene production curve from rates beginning at harvest. Preabscission ethylene production curve from rates at times prior to abscission. SE bars are shown.

postharvest. Pedicels containing abscission zones showed a very low capacity to synthesize ethylene, since they never exceeded 0.5 nL/g·h in either cultivar.

Effect of Ethylene Fumigation on Abscission. Fumigation with exogenous ethylene showed that constant atmospheres of as low as 1 µL/L dramatically accelerated the abscission process in 'Tommy Atkins' fruitlets (Fig. 4). Abscission of the entire population was induced 50 h postharvest, 24 h sooner than in controls, under the 1 µL/L ethylene concentration. Higher ethylene concentrations showed even stronger effects, as both 15 and 100 µL/L caused 100% abscission at 38 h postharvest. The 100 µL/L atmosphere had already induced 60% abscission as early as 26 h postharvest, while at this time, both 1 and 15 µL/L had caused less than 10% abscission. As shown earlier (Fig. 1), controls exposed to only the humid air flow took 74 h to reach 100% abscission, while their abscission rate was below 10% (between 38 and 50 h postharvest) when the fumigated treatments had abscised completely.

DISCUSSION

The involvement of ethylene in abscission of young mango fruit was suggested by Van Lelyveld (15, 16). Ethylene production by abscised young fruit was significantly higher than that of normally developing fruit in 'Haden,' although this difference was not detected in 'Sensation' fruit (16). The observation in

FIG. 3. Time course from harvest to abscission of ethylene biosynthesis per unit fruitlet by isolated tissues from fruitlets of two mango cultivars. Each point in A is the mean of 15 samples (five from each of three experiments); each point in B is the mean of 10 samples (five from each of two experiments). Each sample composed of tissues from 13 explants. SE bars are shown.

FIG. 4. Abscission rates (% of abscised fruitlets from the original population) of developing mango fruitlets as influenced by ethylene fumigation under laboratory conditions. Each treatment applied to approximately 120 explants.

'Haden' suggested a role for ethylene in the abscission process; however, since the fruit were collected after separation from the trees, the dynamics of ethylene production prior to and during the process remained unclear. In the present experiments, fruitlet abscission of explants occurred with relative synchrony after excision in the field. The
procedure allowed a periodic monitoring of ethylene evolution for correlative comparison with abscission rates. Abscission and ethylene biosynthesis patterns showed similar trends in 'Keitt' and 'Tommy Atkins' mango fruitlets, although 'Keitt' fruitlets consistently produced substantially more ethylene than did 'Tommy Atkins.' It is likely that the amount of ethylene produced by fruitlets of both cultivars far exceeds the threshold levels required to induce abscission. The source of variability expressed in the 'Keitt' data (Figs. 1–3) was not correlated with fruit size, as indicated by similar results expressed on a per fruit or per unit weight basis. It was, however, a result of variation in ethylene production from fruitlet to fruitlet. Postharvest, time-course analysis showed that virtually all explants abscised within 86 h (cv Keitt) and 74 h (cv Tommy Atkins) from collection, and that ethylene production was maximum during the last 24 h in both cultivars. At present, we have no specific explanation for the variability exhibited or the difference in the timing of abscission in the two cultivars. The observed earlier timing of 'Tommy Atkins' fruitlet abscission could reflect a greater sensitivity of the abscission zone cells to ethylene and, therefore, a more rapid induction of the abscission process. On the other hand, the amounts and rate of hydrolytic enzyme synthesis in the abscission zone cells could influence the time required for separation to occur and may be different in the two cultivars.

Seeds from fruitlets of both cultivars produced higher amounts of ethylene on a nl/g.h basis than did pericarp and pedicel- peduncles; however, it is important to note that they only represent 10 to 15% of total fruitlet weight. Furthermore, seed tissue is spatially separated from the abscission zone. The fact that the pericarp accounts for over 85% of total fruitlet weight indicates that this tissue is the major source of ethylene within the fruitlet. In contrast to mango, the major source of ethylene in avocado fruitlets originated from senescing seed-coat tissues (3). Although shriveling and blackening of ovules has been reported to occur in young abscised mango fruit (11), newly abscised fruitlets in the present experiments did not visually indicate any tissue deterioration, suggesting that tissue senescence may not be a prerequisite for abscission, as has been found in avocado (3).

Due to the virtually undetected ethylene production (limit of detectability was 5 nl/L), at the abscission zone (Fig. 3), ethylene originating mainly in the pericarp presumably diffuses into the pedicle and abscission zone to trigger the synthesis of hydrolytic enzymes which initiate formation of the separation layer (10). Abscission of sweet and tart cherries was similarly not observed to be preceded by ethylene production in the abscission zone (1). However, the contrary was observed in citrus, where pedicels from detached fruit produced higher ethylene concentrations at or close to the moment of abscission (5).

Although ethylene production by mango pedicels is negligible, the involvement of this hormone in abscission is further supported by the accelerating effect that exogenous ethylene fumigations exerted on abscission rates (Fig. 4). In similar experiments with harvested avocado fruitlets, 100% abscission of unfumigated controls occurred 96 h postharvest, while fumigation with 100 and 500 μl/L ethylene caused 100% abscission only 24 h postharvest (3).

The present results support the contention that ethylene produced by the pericarp is involved in abscission of mango fruitlets. Production of ethylene leading to explant abscission in a predictable time frame originated as a result of excision from the tree. An extrapolation of the phenomenon under laboratory conditions to the natural field condition seems valid since no major biological differences have been detected when abscission occurs under both conditions (10). The abscission layer in mango fruits can be formed at any stage of fruit development since fruits possess a predetermined abscission zone (13). Slight abnormalities in the fruit or pedicle have been correlated with fruit abscission (13).

In conclusion, our results indicate a key role for ethylene in abscission of mango fruitlets, but the events responsible for induction of ethylene biosynthesis in vivo are unknown at the present time.

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