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ABSCISSION AND ETHYLENE PRODUCTION IN MANGO (MANGIFERA INDICA L.) FRUIT CV. TOMMY ATKINS[1]

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Additional index words. fruit drop, fruit set, seedlessness, parthenocarpy, explants.

Abstract. **Rates of fruit drop and remaining fruited panicles were monitored in the field for 96 days beginning on April 1, 1983. More than 90% of total fruit drop occurred within the first 4 wk, and final fruit set was 0.61%. Percentage of fruited panicles remained constant for the first 3 wk, decreasing sharply to 40% by the 6th week, and ending at 11.7% at harvest. Of the fruit which reached maturity, 42% were seedless. Samples of seeded and seedless fruit collected during the high drop period showed different abscission patterns in the laboratory. All seeded fruit separated within 72 hr after harvest, where as 22% of the seedless fruit were still attached 95 hr after harvest. Abscission of seeded fruit was accompanied by a rise in ethylene production, while parthenocarpic fruit abscised without an increase in the level of this hormone. In the field, the observation that seedless and seeded fruit are shed throughout the entire period of fruit development indicates that physiological factors occurring after pollination and/or ovule fertilization are involved in fruit abscission and consequently affect the final yield in mango.**

The mango is a tropical fruit crop which has a pronounced tendency to shed fruit at all stages of development until harvest (12). Monoembryonic types show this behavior more intensely than polyembryonic ones, a fact attributed to the development of nucellar embryos which apparently influence a greater retention of fruit (15).

The problem of low fruit set by mango trees has been well documented through the years. In Florida, the monoembryonic cultivar, 'Edward', had 3.8% fruit set in an 18-wk study of 160 panicles (15). The 'Haden' mango of Florida is well known for its high unfruitfulness and erratic bearing habits. Young (17) showed that only a small fraction of the perfect flowers normally set and mature fruit, which is attributed to a high percentage of fruitlets that drop early in the season due to abortion of ovules. In a study by Naik and Rao (8), mango panicles produced 2000 to 4000 flowers, with only 1 to 35% being hermaphroditic. Furthermore, 13 to 28% set fruit and only 0.1 to 0.25% reached maturity. Some cultivars have been noted to develop one fruit to maturity of 150 apparently fertilized flowers, particularly with a heavy fruit set (7).

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Abscission of flowers and young fruitlets is maximum during the first 3 to 4 wk after pollination (13), reaching levels of 90% or more (7). Among the biological factors suggested to be associated with such high rates of early abscission are inadequate pollination and/or fertilization (13) resulting from high proportion of male flowers and high ratios of style length to stamen length. Environmental factors such as inadequate soil fertility, insufficient soil moisture, diseases, and low temperatures at time of bloom may also favor the incidence of fruit drop (14, 18). In general, a degeneration of the reproductive apparatus resulting in ovule or embryo abortion seems to play an important role in the abscission process at these early stages (12, 18), as evidenced by the shrivelling and blackening of ovules sometimes observed in young abscised mango fruitlets (12). Nucellar senescence is also correlated with abscission in avocado fruit (5).

More recent research on the physiology of abscission in mango fruit revealed a higher production of ethylene by abscised fruit of 'Haden' as compared to normal fruit, although such difference was not significant in 'Sensation' (16). The 'Haden' mango is considered as having higher abscission rates than 'Sensation', which may indicate ethylene is important in the high pre-harvest fruit drop rates in some mango cultivars.

Use of explants has been invaluable in studies of the basic physiology of abscission (1). Flowers, stems, cotyledons, leaves and fruitlets, among other organs, have been widely used for this purpose. Further, extrapolation of data from explants to the natural condition is considered valid since no major differences have been reported in the biology of the 2 systems (11). When natural abscission is preceded by senescence, there is a decrease in the flow of auxin to the abscission zone concomitant with an increase in ethylene production (9). Explants have shown similar changes; auxin may decrease by removal from the plant, while ethylene synthesis may increase in response to damage by excision (6).

The present work is part of a research project which intends to contribute information on the physiology and biochemistry of pre-harvest fruit abscission in mango. Field observations of fruit setting habits of 'Tommy Atkins' in the current season are discussed. Emphasis is given to establishing an experimental methodology for the study of mango fruit abscission under controlled laboratory conditions. The 'Tommy Atkins' mango originated in Florida and is currently the most important cultivar in the region (2).

Materials and Methods

Selection of plant material. A commercial 4-acre grove in Homestead, Florida, was the source of the plants used in this study. Initially, 1,961 individual fruitlets were monitored on 60 panicles distributed in 9 trees. The grove was subjected to a strict pest control and fertilization program;; therefore trees and fruitlets had a healthy external appearance. Trees were approximately 16 yr old and were selected according to their uniformity and as being representative of the entire grove. Panicles were uniformly distributed around each tree and individually tagged. They were randomly selected when the trees were in heavy bloom, at a stage when most fruitlets measured less than 1 cm in length and some dry flowers still remained attached. Initially, fruitlets appeared to be distributed randomly throughout the panicle.

Recording of remaining fruit and fruited panicles. The initial number of fruit on each panicle was recorded on April 1, 1983, and the numbers of fruit remaining were recorded at 10 different times for 96 days until the fruit were harvested on July 5.

Collection of fruitlets for laboratory studies. The observation in the field that abscised fruitlets consisted of large proportions of seeded and seedless (parthenocarpic) fruit led us to question whether they followed the same abscission patterns or mechanisms. Dissection of many individual fruitlets in the field indicated that there was a higher concentration of parthenocarpic fruitlets on the tip of the panicle, while very frequently the seeded ones developed along the apical half but closer to the middle of the panicle. This information allowed the collection of samples of both types of fruit, which could then be taken to the laboratory for further observation.

Experiments with fruitlet explants. A total of 316 parthenocarpic and 247 seeded fruitlets were collected from various trees in the grove and immediately upon excision were transported to the laboratory. Fruitlet explants were individually prepared by leaving a peduncle of at least 5 cm long. The excess peduncle was cut off under a flow of cold water to delay or prevent dehydration. Small clusters of approximately 15 fruitlets were placed in 100 ml Erlenmeyer flasks which contained sufficient water to cover the excision cut. Care was taken that water did not directly contact the abscission zone, located between 3 and 5 mm from the base of the fruitlets. To further protect against dehydration, the flasks thus arranged were enclosed in a 60-liter plexiglass chamber which was equipped with a flow-through system of humid air at a constant rate of 1 liter/min (Fig. 1). This supplied adequate humidity inside the chamber while also removing unwanted gases such as ethylene and CO_2 from the chamber. The chamber was kept at a constant temperature of 26°C. Additionally, water in the flasks was changed every 24 hr.

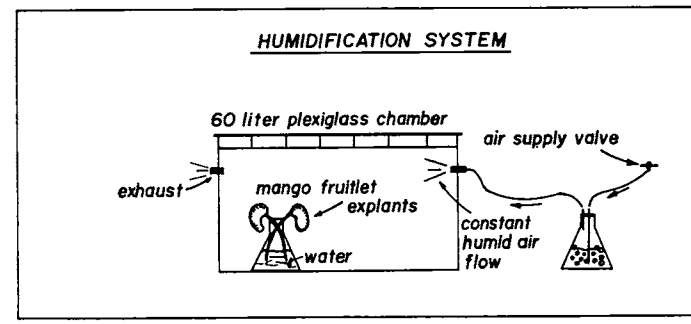

Fig. 1. Diagram illustrating the enclosure of mango fruitlet explants in the humidified plexiglass chamber to study abscission under controlled laboratory conditions.

The entire operation of fruitlet collection and final enclosure in the chamber took approximately 2 hr. At this point, and at subsequent 12-hr periods, the strength of the abscission zone was tested by a gentle and uniform tug on each fruitlet. Rates of abscission were recorded at each period, and abscised fruitlets were removed from the chamber after each test.

Ethylene measurement during abscission. In a complementary experiment, ethylene production by entire fruitlets of both types was measured. Sixteen fruitlets of each type were individually enclosed for 1 hr every 12 hr in 80 ml glass beakers sealed with Saran film (which is impermeable to ethylene and also does not produce it) and tightened with a rubber band. Preliminary trials done to evaluate wound-ethylene determined that an enclosure time of 1 hr at the beginning of each 12-hr period was appropriate. A 1 ml gas sample was extracted from each beaker with a gas-tight syringe. The sample was analyzed in a Varian 3700 Series gas chromatograph equipped with 80-100 alumina mesh in a 183 cm x 3.1 mm stainless steel column and flame ionization detector. Fruitlets were kept in the humidified chamber between sampling periods.

Results

Abscission rates in the field. The rate of fruit drop was maximum during the first 4 wk of the evaluation period. After 25 days, only 7.7% of the initial fruit remained attached and after 40 days this amount gradually decreased to nearly 2% until a final 0.61% of the original fruitlets reached horticultural maturity and were harvested on July 5 (Fig. 2). Parthenocarpic fruit comprised 42% of this proportion. Also, only 12% of the original panicles developed fruit to maturity, indicating that many panicles gradually lost all their fruitlets. By harvest, each fruited panicle had retained an average of 1.7 mature fruits (Table 1).

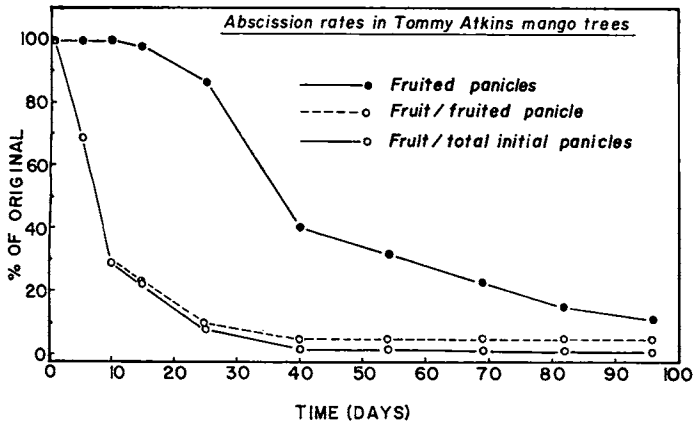

Fig. 2. Friut abscission rates and percentage of fruit per fruited panicle and per total initial panicles as observed in 'Tommy Atkins' mango in the field.

Abscission patterns and ethylene production in the laboratory. Parthenocarpic and seeded fruitlets showed different abscission patterns while enclosed in the humidified plexiglass chamber. All seeded fruitlets separated from the peduncle within 72 hr after harvest, while only 78% of the parthenocarpic sample had abscised 95 hr after harvest (Fig. 3). Fruitlets from both samples that abscised within the first 72 hr of enclosure retained sufficient turgor to exude a small amount of sap when separated from the peduncle, indicating that dehydration had been kept to a minimum. This was further confirmed by the fact that their initial and final weights were comparable. After 95 hr, the remaining parthenocarpic fruitlets had softened and begun to shrivel, yet the strength of the abscission zone did not diminish. At this point, the final percentage of abscission was recorded and fruitlets were discarded.

Parthenocarpic fruitlet explants show an entirely different pattern of ethylene production as compared to seeded ones; there is no gradual increase in ethylene levels, paralleling increases in abscission rates. Synthesis levels were below

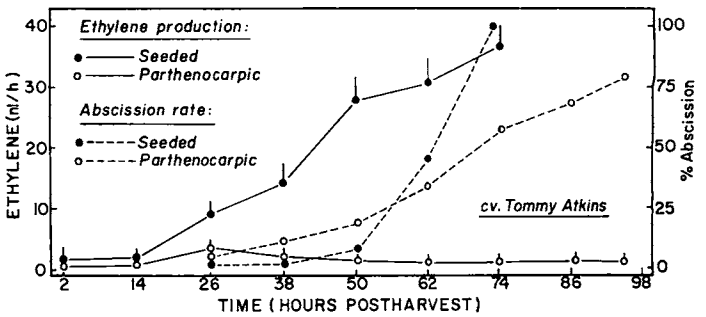

Fig. 3. Abscission rates and ethylene production as observed in seeded and parthenocarpic fruitlets under laboratory conditions. Vertical lines represent one half of the mean standard error.

5 nl/hr at all times, while seeded fruitlets had already exceeded this level only 14 hr after harvest.

Field observations in relation to fruit setting habits. The following observations were consistently noted in the field and may be valuable clues for further detailed studies on the factors affecting fruit set and abscission of mango:

1. Repeated sampling in the field revealed abscission of seeded and parthenocarpic fruitlets occurring throughout the entire period of fruit development.
2. Embryonic or ovular deterioration did not always occur in the abscised seeded fruitlets. In fact, at the stage when the liquid endosperm had acquired a gelatinous consistency, the majority of these fruitlets contained seeds of a uniform white color, only occasionally showing a darkening at the chalazal end.
3. After approximately 7 wk, there was a clear distinction in size between fruitlets of both types. Parthenocarpic fruitlets were notably smaller, about one-third the size of the seeded ones. Also, when the panicle contained both types of fruitlets, almost invariably the parthenocarpic ones would be located on the apex of the panicle while the seeded would develop along the apical half but towards the middle of the panicle. Fruit rarely developed along the basal half of the panicle. When panicles developed only one fruit, it was usually on the apex regardless of fruit type. Parthenocarpic fruitlets usually had a smoother sinus (concave portion of the fruit), and had a rounder shape. This is also a common observation in the 'Haden' mango (15).

Discussion

Fruit drop in the 'Tommy Atkins' mango showed characteristics similar to that of other cultivars. More than 90% of fruitlets abscised within 4 wk of the initial count and final fruit set was 0.61% (Table 1). High percentages of fruitless panicles and parthenocarpic fruit reaching maturity (Fig. 2) may have resulted from unusually low temperatures

Table 1. Numbers and percentages of remaining fruit, remaining fruited panicles, fruit per fruited panicle and fruit per total initial panicles in 'Tommy Atkins' mango, from April 1 to July 5, 1983.

Variable	Days after initial count									
	0	5	10	15	25	40	54	69	82	96
Remaining fruit	1961	1351	561	410	151	38	32	24	17	12
(%)	(100)	(68.9)	(28.6)	(20.9)	(7.7)	(1.94)	(1.63)	(1.22)	(0.87)	(0.61)
Remaining fruited panicles	60	60	60	59	52	24	19	14.0	9	7
(%)	(100)	(100)	(100)	(98)	(86.7)	(40.0)	(31.7)	(23.3)	(15.0)	(11.7)
Fruit/fruited panicle	32.7	22.5	9.4	6.9	2.9	1.6	1.7	1.7	1.9	1.7
(%)	(100)	(68.9)	(28.6)	(21.1)	(8.9)	(4.9)	(5.2)	(5.2)	(5.8)	(5.2)
Fruit/total panicle	32.7	22.5	9.4	6.8	2.5	0.63	0.53	0.40	0.28	0.20
(%)	(100)	(68.9)	(28.6)	(20.8)	(7.7)	(1.9)	(1.6)	(1.2)	(0.87)	(0.61)

and high rainfall experienced during the blooming period. High percentages of parthenocarpic fruit were also produced in many other mango cultivars in the area during this year, as compared to "typical" years (C. W. Campbell, personal communication). On the other hand, the fact that hermaphrodite flowers open earlier in the season (4, 17) may explain the typical distribution of parthenocarpic fruit on the panicle. Apical flowers may have opened earlier and been pollinated but not fertilized due to cold damage to the pollen tube and/or egg apparatus (10). In contrast to other cultivars, mature parthenocarpic fruit of 'Tommy Atkins' did not develop to the full size of the seeded fruit (10). The observation in the field that abscission of parthenocarpic and seeded fruit continued until harvest indicates that other factors, not necessarily related to original reproductive degenerations, may be involved in the induction of abscission. Explants studied under controlled laboratory conditions revealed marked differences in the abscission patterns of seeded and parthenocarpic fruit (Fig. 3). There is an association between ethylene production and increases in abscission rates of seeded fruit; yet, parthenocarpic fruit appears to abscise independently from a rise in ethylene. Moreover, a small fraction (22%) of these fruit did not attain the separation stage even after 95 hr of enclosure. In accordance with the current notions that developing mango seeds are a source of auxin (3), and that a decrease in endogenous auxin promotes abscission (1), it is possible that the experiments with seeded explants reflect a condition which occurs in the field when abscission is preceded by senescence. A decrease in auxin favors an increase in ethylene and events conducive to separation. This contention is supported by the observation that mango fruitlets which were destined to abscise showed an inhibition of growth about 1 wk prior to actual detachment (14). The causal factors involved in such inhibition and subsequent senescence are still unknown, yet consideration has been given to environmental stresses (3, 14, 18).

The situation observed in parthenocarpic fruit is a paradoxical one which suggests that interactions with other factors, perhaps hormonal, are involved in abscission of this type of fruit.

Results and field observations from this study suggest that the mechanism of pre-harvest abscission in mango is not identical in seeded and parthenocarpic fruit, and that seeded fruit may abscise in the field in response to factors different from reproductive degenerations, perhaps environmental stress(es) which may stimulate the synthesis and action of ethylene in the events leading to abscission. Further work in the physiology of abscission in mango, as well as in the relations between developing parthenocarpic and seeded fruit appear to offer valuable information towards a horticultural manipulation of this process in the field.

Acknowledgements

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IMPORTANCE OF IRON TO PLANTS GROWN IN ALKALINE SOILS[1]

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Abstract. **Iron nutrition in cultivated plants grown in calcareous soil in Dade County is discussed along with various strategies used to correct iron chlorosis. A preliminary evaluation of the potential of various chelated iron products in limestone soils is presented. Results suggest that Miller Ferriplus 138 and Geigy Sequestrene Fe 138 are the best suited products for use in these soils.**

Additional index words. chelates, limestone, chlorosis.

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Iron is an important element required by all plants to