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Role of Ethylene in Avocado Fruit Development and Ripening

II. ETHYLENE PRODUCTION AND RESPIRATION BY HARVESTED FRUITS

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ABSTRACT

Avocado (*Persea americana* Mill.) fruits were harvested at successive development stages during a period of 10 months. Ethylene production and respiration were determined during the post-harvest period.

Detached immature fruits were found to have a preclimacteric increase in ethylene production and respiration without any signs of ripening. In fruits larger than 20 g a second phase of climacteric ethylene production and respiration, associated with ripening, ensued.

The preclimacteric ethylene was produced mainly by the seed coat. It is suggested that the high ethylene production potential of the seed coat may serve as a means for inducing abscission in young fruits.

INTRODUCTION

The respiration rate in mature climacteric fruit such as the avocado usually decreases after detachment from the mother plant until the climacteric rise in ethylene production and respiration in the detached fruit. Non-climacteric fruits show a slow continuous decline in respiration after harvest (Biale, 1960; Biale and Young, 1962; McGlasson, 1970). Only isolated instances of different respiration patterns in detached mature fruits have been described (Biale, 1941; 1960; Pharr and Kattan, 1971).

Young fruits behave differently: a temporarily increased respiration rate after harvest was found in both citrus and pineapple, which are non-climacteric (Aharoni, 1968; Dull, Young, and Biale, 1967; Eaks, 1970; Trout, Huelin, and Tindall, 1960), and in apples, plums, and tomatoes, which are climacteric (Kidd and West, 1945; Krotkov, 1941; McGlasson, Dostal, and Tigchelaar, 1975; Roux, 1940). In citrus, production of considerable amounts of ethylene was associated with the rise in the respiration rate (Aharoni, 1968; Eaks, 1970). However, ethylene production of a detached climacteric fruit during the preclimacteric period, with its rise in respiration rate, has either not been investigated (Kidd and West, 1945; Krotkov, 1941;

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Roux, 1940) or was invariably found to be very low (McGlasson *et al.*, 1975). The suggestion that increased ethylene production and respiration rate are associated with normal ripening processes in citrus was disputed (Aharoni, 1968; Eaks, 1970; Rhodes, 1970), and it seems all the more in doubt with regard to climacteric fruits.

In the present work we studied ethylene production and respiration of harvested avocado fruits picked at different stages of their development.

MATERIALS AND METHODS

Uniform-sized cv. Hass fruits (*Persea americana* Mill.) were tagged about 1 month after fruit set at a weight of about 2 g. Thirteen times during the development period (Adato and Gazit, 1977), 10 fruit samples were picked and their ripening behaviour was studied. The harvested fruits were kept at 21 °C and about 90% r.h.; ethylene and CO_2 concentrations were below 0·1 parts 10^{-6} and 0·05%, respectively (Adato and Gazit, 1974). Ethylene production and respiration were determined about 1 h after harvest and every day throughout the storage period (Adato and Gazit, 1974). Ten individual fruits were examined at each date. Another 10 fruits, chosen daily at random after their ethylene production rate had been determined, were bisected longitudinally and separated into pericarp, seed coat, endosperm, and an intact embryo. The tissues were sealed immediately in glass containers and after 15 min the ethylene content inside the container was determined.

Fruits of cv. Fuerte and those from a seedling of the 'West Indian' race were also examined at two different developmental stages.

RESULTS

Ethylene production and respiration in whole fruits

Avocado fruits cv. Hass. The study started with fruitlets weighing 2·2 g and ended, 10 months later, with mature fruits weighing over 200 g. Ethylene production and respiration of typical fruits during the course of their storage period are presented in Fig. 1. The typical fruits chosen represent the 10-fruit sample, picked at the same date, both considering the pattern as well as the absolute ethylene production and respiration rates.

Ethylene production 1 h after harvest was always less than 0·08 μl h^{-1} kg^{-1} fr. wt. Fruits weighing 2·2 g started to produce ethylene at a detectable rate as early as 24 h after harvest. These fruits attained their peak of ethylene production within 3 d after harvest, and then production declined to nil within 6 d after harvest (Fig. 1). During this period there were no external signs of fruit ripening. Similar results were obtained with fruit weighing 5·5 g, although in these fruits a second slight increase in ethylene production could be detected. Here, too, there were no signs of ripening. Commencement of fungus infection was found 6 d after harvest in 2·2-g fruit and 12 d after harvest in 5·5-g fruit, and then examinations were terminated.

In fruit picked from 26 June up to 4 September (weighing from 27 to 140 g), it was possible to distinguish clearly between two phases of post-harvest ethylene production. In the first preclimacteric phase, which occurred until the 9th–14th day after harvest, ethylene production levels were lower than in the younger fruits (Fig. 1). The fruit stalk abscised on the 6th–8th day, but no external signs of ripening could be seen at the end of this phase. The second climacteric phase culminated in a high peak that was associated with characteristic signs of ripening. In fruit

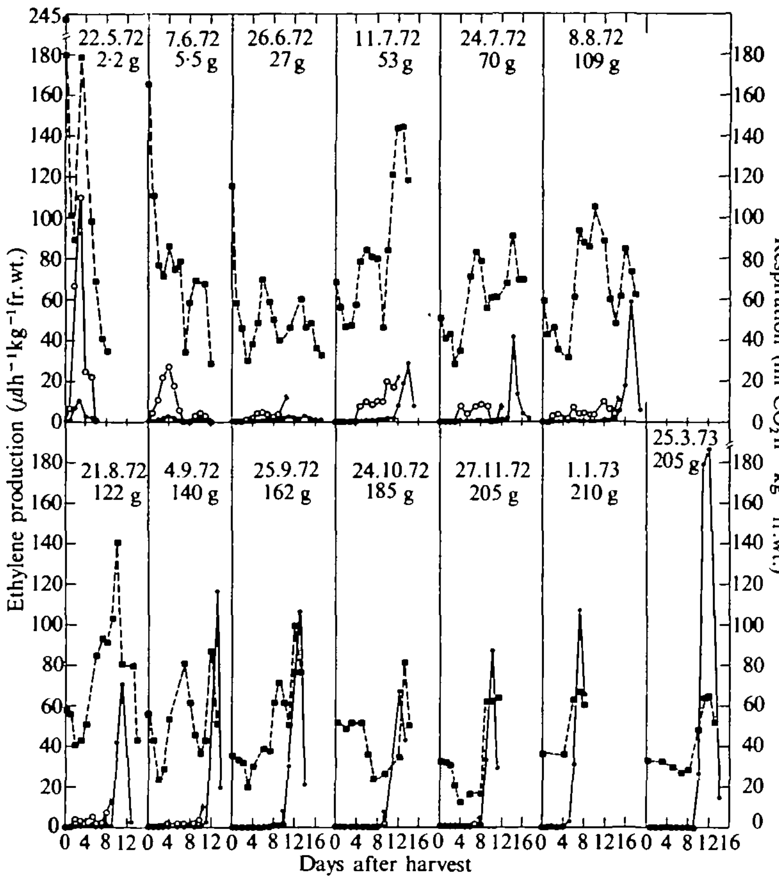

FIG. 1. Patterns of respiration rate (■) and ethylene production (●) of harvested 'Hass' avocado fruits during their development. (The low values for ethylene production at the preclimacteric phase are also shown as a 10-fold magnification (○).) Each curve represents a typical fruit chosen from 10 replicates.

weighing 27 g, ripening was only partial, appearing as irregular red patches as well as softening of the pericarp around the stalk only, while the remainder of the fruit blackened and hardened. In fruits weighing 53 g and over, fruit softening and colour development were characteristic of normal ripening, and began to appear 1 d after the second ethylene production peak.

In respiration rate, too, it was possible to distinguish between a preclimacteric peak and a climacteric peak (Fig. 1). The preclimacteric and climacteric peaks of ethylene production and respiration rate are closely synchronized, but there is no quantitative correlation between the two processes: the intensity of the preclimacteric respiration is high in relation to the low ethylene production in this phase, in comparison with that obtained in the climacteric phase (Fig. 1).

In the same type of determinations made with cv. Hass fruits in the course of an additional season, similar results were obtained with regard to the patterns and quantities.

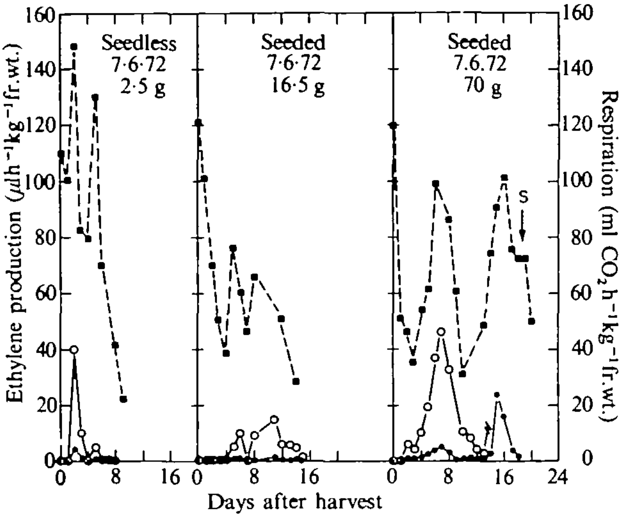

FIG. 2. Patterns of respiration rate (■) and ethylene production (●) of detached seeded and seedless 'Fuerte' avocado fruits at two harvest dates. (The low values for ethylene production at the preclimacteric phase are also shown as a 10-fold magnification (○).) Each curve represents a typical fruit chosen from 10 replicates. The 'S' arrow indicates soft fruit.

'Fuerte' and 'West Indian' avocado fruits. Preclimacteric ethylene production was found in both seeded and seedless 'Fuerte' young fruits (Fig. 2) as well as in young fruits from a seedling of the West Indian race.

Young, seeded 'Fuerte' fruits weighing about 16·5 g apparently produced only preclimacteric ethylene during the first 15 d after harvest; no signs of ripening were seen in these fruits (Fig. 2). In 70-g fruit, both preclimacteric and climacteric ethylene production and respiration were observed; full softening of the fruit took place 2–3 d after the climacteric peak. Seedless 'Fuerte' fruits showed preclimacteric respiration and an ethylene production pattern (Fig. 2) similar to that of 5·5-g 'Hass' fruit (Fig. 1).

'West Indian' avocado fruits, at two harvest dates (in 4-g and 38-g fruits), showed similar ethylene production and respiration patterns.

Preclimacteric ethylene production in separate tissues of the developing fruit

During the preclimacteric phase of ethylene production in young fruits, the seed coat produced ethylene at a very high rate, while production by the pericarp was quite low. The combined ethylene production of these two tissues made up the production of the whole intact fruit (Fig. 3). The intact embryo and the cut endosperm did not produce ethylene during their post-harvest period in any of the fruit development stages. The timing and quantities of ethylene produced by the seed coat are well correlated with the preclimacteric ethylene production of the whole fruit (Figs 1, 3). Consequently, we can conclude that the seed coat is the main contributor to the preclimacteric ethylene production of the whole fruit.

DISCUSSION

A preclimacteric rise in respiration and ethylene production was found in harvested young avocado fruits of cv. Hass and cv. Fuerte and of the 'West Indian' race (Figs

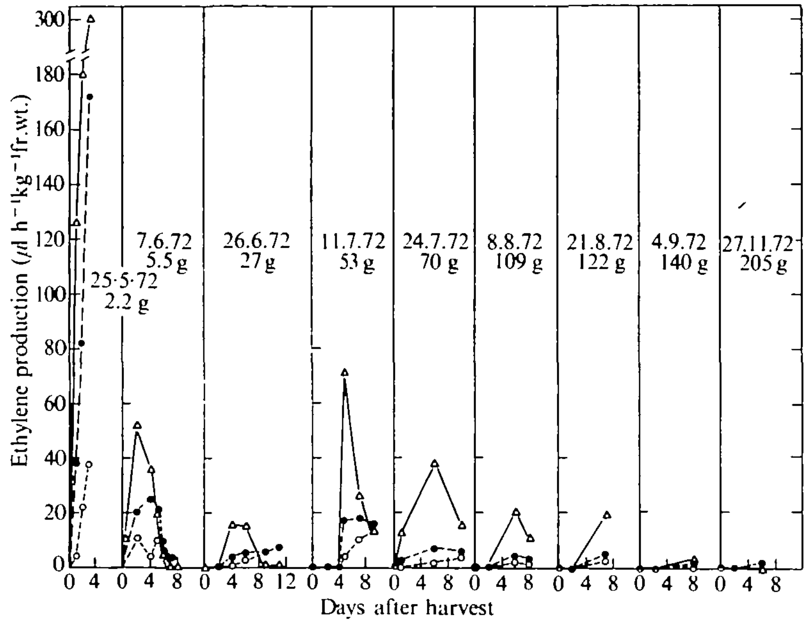

FIG. 3. Patterns of preclimacteric ethylene production in whole fruits (●) (magnified 10-fold), pericarp (○) (magnified 10-fold), and seed coat (△) of harvested 'Hass' avocado fruits in the course of their development. Each curve represents a typical fruit chosen from 10 replicates.

1, 2, 3). It can therefore be assumed that this is a general occurrence in detached avocado fruits.

This is the first time that a close link has been demonstrated in a climacteric fruit between the rate of respiration and that of ethylene production in a non-climacteric phase (Fig. 1). A similar correlation was found in citrus (Aharoni, 1968; Eaks, 1970), and it seems that the immature avocado fruit has much in common, during its pre-climacteric phase, with the non-climacteric citrus. Our data indicate that usually the increase in ethylene production precedes the respiratory preclimacteric rise (Fig. 1). This situation is in accordance with the postulate that increased ethylene production is the primary factor responsible for the rise in respiration of detached young citrus fruits (Aharoni, 1968; Eaks, 1970).

The tissue found to be responsible for ethylene production at the preclimacteric phase is the seed coat (Fig. 3), although a preclimacteric rise in ethylene production was also found in seedless fruits (Fig. 2). We suppose that in seedless fruits some other tissue plays a role analogous to that of the seed coat.

Preclimacteric ethylene production is confined to immature fruits which have a viable seed coat (Adato and Gazit, 1977) and does not seem to have any direct role in fruit ripening. These facts apparently indicate that the significance of the pre-climacteric ethylene production must be sought elsewhere. The avocado seed coat seems to serve in the tree-attached fruit both as a vital constructive tissue—due to its high levels of all growth promoters (Blumenfeld and Gazit, 1971, 1972; Crane, 1964, 1969; Nitsch, 1950), and as a destructive tissue—due to its ability to produce ethylene at a very high rate. This tissue apparently plays a central role both in fruit growth and development and in fruit abscission, as indicated also by the fact that fruit growth rate decreases and fruit abscission stops when the seed coat withers (Adato and Gazit, 1976; Blumenfeld and Gazit, 1971). We believe that this dual and antagonistic role of the seed tissue is not accidental.

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