CO$_2$ assimilation of developing fruiting shoots of cv Hass avocado (*Persea americana* Mill)

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ABSTRACT

The dynamics of fruit drop and CO$_2$ assimilation of fruiting spring shoots of cv Hass avocado were studied for the first 76 days after bud break. Individual leaves showed a net gain in CO$_2$ assimilation after reaching 80% of full expansion. There was a net CO$_2$ assimilation loss from developing shoots for the first 27 days after bud break during which 60% of the initial fruits which set dropped. A further 22% of the initial fruit set was lost during the following 15 days when the youngest leaves on the shoots were still strong sinks. Fruit loss stabilised when shoots reached their maximum CO$_2$ assimilation capacity 60 days after bud break.

INTRODUCTION

The study of CO$_2$ assimilation of ageing leaves and leaf x environmental interactions has been the focus of much research, yet few have addressed the assimilation dynamics of a growing shoot. Notable exceptions are the work of Kriedemann (1968) with peach and apricot shoots and Davis and Sparks (1974) with pecan shoots. This paper reports on CO$_2$ assimilation flux of the fruiting spring shoot of cv Hass avocado and relates this to fruit loss.

MATERIALS AND METHODS

The CO$_2$ assimilation ('A') measurements were carried out on seven-year-old cv Hass trees (grafted to seedling Edranol root-stocks), in their fourth cropping cycle, growing in a commercial orchard at Nelspruit, South Africa (latitude 25°S, altitude 660 m). The area has a mild subtropical climate with mean rainfall of 1 000 mm/pa and a mean max/min temperature of 29,1/18,6°C in January and 23,3/6,5°C in July. The trees were growing in a sandy loam soil and flood irrigation was scheduled using a Class 'A' Evaporation Pan.

Three indeterminate flowering terminals on the northern side of each of five trees were

selected at the completion of anthesis and each leaf was tagged and dated as it emerged from the vegetative bud. The first leaf position on the new flush generally fails to develop normally so was not used in this experiment. The second leaf position on the shoot was designated the first leaf for the purposes of the study. Approximately ten days after each leaf emerged its area was measured with a portable LiCor Model LI-3000 leaf area meter and the CO_2 exchange determined with a LiCor LI-6200 portable photosynthetic meter using an LI-6000-11 1ℓ chamber. All CO_2 exchange measurements were made at or above photosynthetic photon flux densities (ppfd) of 600 µmole quanta m^{-2} s^{-1} (saturating ppfd 500 µmole quanta m^{-2} s^{-1}, Scholefield *et al*, 1980), between 08:30 to 10:30 — a low stress time of day. Photosynthetic rates were derived from Software 2,00 (Sept 1987) installed in the LI-6200 photosynthetic meter. Following the initial readings, leaf area measurements were taken every four to eight days, depending on weather conditions, until leaves stopped expanding (about 32 days after emergence). CO_2 exchange measurements followed a similar schedule until the 'A' of the youngest leaf reached a plateau (76 days after bud break). The net 'A' of the developing shoot was calculated at each point of measurement.

Ten days after bud break fruit set on the tagged indeterminate flowering terminals was counted. Counting was repeated at seven to 14 day intervals for a period of 76 days after bud break. Abscised fruit were recovered and examined for the presence of an embryo.

Data were plotted, using mean values (n = 15) of the various parameters measured, and the best fitting regression curves used for data projections.
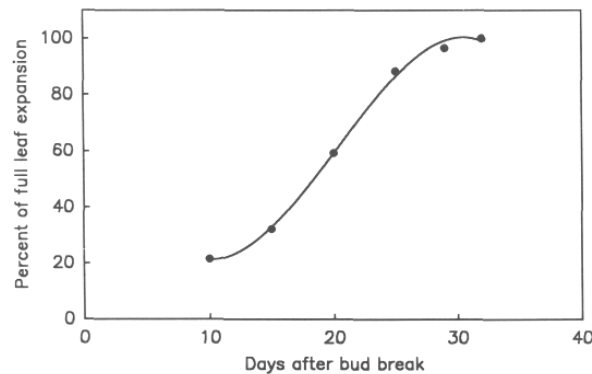

Fig 1 Leaf expansion of cv Hass leaves in relation to their age represented by the regression curve: $y = 98, 32 — 17,17x + 1,13x^2 — 0,02x^3$ (r = 0,99). Data are means of three leaves from each of five trees.
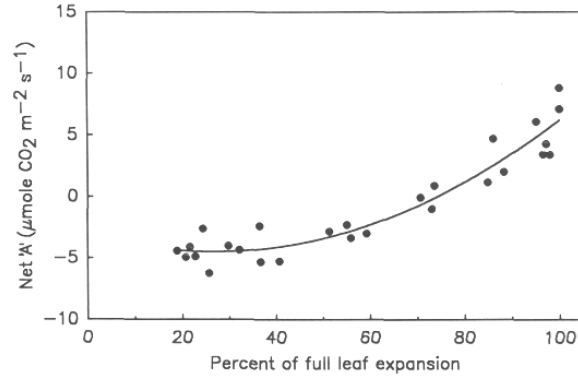
Fig 2 Net assimilation rate of expanding avocado leaves represented by the regression curve: $y = -3,10 - 0,105x + 0,0019x^2$ $(r = 0,96)$. Data are means of three leaves from each of five trees.
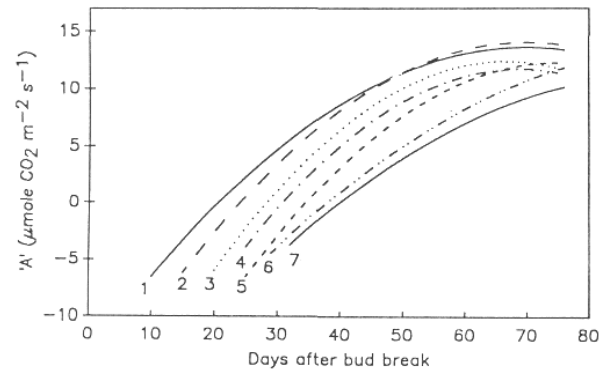

Fig 3 Net assimilation of ageing leaves from different positions along the shoot. $r \geq 0,92$ for all curves.
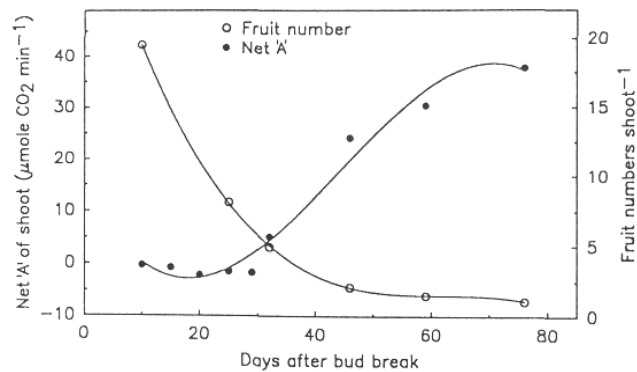

Fig 4 The relationship between fruit loss represented by the regression curve: $y = 31,9 - 1,47x + 0,024x^2 - 0,00013x^3$ $(r = 0,99)$; and net assimilation of the shoot represented by the regression curve: $y = 14,96 - 2,16x + 0,075x^2 - 0,00057x^3$ $(r = 0,99)$. Data are means of three shoots from each of five trees.

RESULTS

The mean number of leaves and mean leaf area per fruiting shoot were $6,9 \pm 1,1$ and $496,4 \pm 141,0 cm^2 (n = 15 \pm se)$ respectively. Leaf growth followed a sigmoidal curve

(Figure 1) reaching 50% of full expansion after 20 days with maximum size 30 days after bud break.

A net gain in 'A' was not recorded until individual leaves had reached 80% of their full expansion, i.e. about 25 days old (Figures 1 and 2). The maximum 'A' for each leaf was recorded when it reached approximately 60 days old (Figure 3). The net 'A' for the spring shoot followed a sigmoidal curve (Figure 4). There was a net CO_2 loss from the shoot during the first 27 days from the vegetative bud break of the indeterminate shoot, with 'A' reaching its maximum after 70 days.

The mean number of fruits set on each shoot was greatest (19,5 + 6,8; n = 15 + se) when first recorded ten days after bud break (Figure 4). Fruit numbers fell rapidly as the shoot aged with a mean of 1,5 + 0,6 (n = 15 + s e) fruit per shoot remaining 76 days after bud break. Of the abscised fruit recovered 97% had formed apparently normal embryos.

DISCUSSION

Leaves grew quickly reaching full size after 30 days. This is similar to the 28 days reported for the West Indian cv Peterson (Schaffer *et al,* 1990) and the Mexican cv Fuerte (Blumenfeld *et al,* 1989). Although a net gain in 'A' was recorded at 80% of full leaf expansion (25 days old), ^{14}C studies by Blumenfeld *et al* (1990) suggest that the leaf does not become an effective source until fully expanded, i.e. when about 28-30 days old. Wolstenholme (1990) states that the sink-source transition can occur in deciduous fruit tree leaves at one third to half of full expansion. With citrus leaves Kreidemann (1969) reported that the sink-source transition did not occur until full size was reached.

The twofold increase in leaf 'A' from reaching full expansion to their maximum 'A' at 60 days, was similar to that reported by Schaffer *et al* (1990) for West Indian cultivars. The maximum 'A' of leaves recorded in this experiment (13,1 μmole CO_2 m^{-2} s^{-1}) is considerably higher than that reported previously for the Guatemalan cv Edranol (9,1 μmole CO_2m^{-2} s^{-1}, Bower *et al,* 1978) the Mexican cv Fuerte (6,2 μmole CO_2 m-^{2} s^{-1} Scholefield *et al,* 1980) and the West Indian cv Peterson (5,5 μmole CO_2 m-^{2} s-^{1}, Schaffer *et al,* 1990). The higher 'A' in this experiment may be due to more favourable environmental conditions during measurements, or the effect of sink strength from the developing fruit on these shoots (Hansen 1970; Ghosh, 1973: Fujii & Kennedy, 1985). It is interesting to note that the previously highest reported net 'A' was with Edranol, a cultivar belonging to the same ecological race as Hass.

The greatest loss of fruit was concomitant with the period during which the shoot was a strong sink (ie net 'A' loss) with 60% of the initial fruit set falling during the first 27 days after bud break. The youngest leaves on the shoots were sinks for another 15 days (42 days after bud break) during which time a further 22% of the fruit set was lost. Fruit retention stabilised at the time that the spring shoot reached maximum source strength. It has also been shown that dry matter gain of individual fruit is minimal during the period of net leaf 'A' loss but becomes substantial as the spring shoot approaches maximum source strength (Whiley, 1990). Previous research with avocado has

suggested that the fruit and shoot components of the spring growth are competitive sinks for available assimilate (Biran, 1979: Blumenfeld *et al*, 1983; Köhne and Kremer-Köhne, 1987; Wolstenholme *et al*, 1990). Recently completed ^{14}C studies with developing avocado shoots (Whiley & Schaffer, unpublished) confirm expanding leaves as strong sinks. This experiment further supports the concept of competitive vegetative sinks during the first 42 days after bud break. It is suggested that the size of the assimilate pool (storage and current from existing mature leaves) and the strength of the shoot sink (ie vigour of growth) largely determines the success of fruit retention and growth during the first 60 days after bud break. While initially competitive, renewal shoot growth during the spring is necessary for the secondary development of avocado fruits. Wolstenholme *et al* (1990) demonstrated that with severe retardation of spring shoot growth of Hass with paclobutrazol sprays, fruit dry mass at flush maturity was significantly reduced compared to other treatments giving less growth suppression. This was reflected in lower yields at fruit maturity. Similar results are reported by Quinlan & Preston (1971) from shoot tipping and removal studies with apples. Despite the necessity of shoot growth the opportunity remains to manipulate the vegetative-reproductive balance to a more favourable economic yield. Whiley & Wolstenholme (unpublished data) have shown that a low concentration foliar spray of paclobutrazol (Cultar®) at full bloom, which slightly suppresses shoot growth of cv Hass, significantly increases fruit yield. Correct timing of fertilisation with nitrogen can also assist in controlling spring flush vigour thus favouring greater fruit retention and yield (Whiley *et al*, 1988).

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