

DETERMINATE VERSUS INDETERMINATE INFLORESCENCES OF THE 'HASS' AVOCADO

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Abstract

The relative productivity of determinate versus indeterminate inflorescences of the 'Hass' avocado (*Persea americana* Mill.) under California conditions is not known. Thus, the present study was undertaken as part of a multi-year field trial to characterize the potential of both types of inflorescences to set fruit that survive to harvest in "on" or "off" years. Scanning electron microscopy was used to determine when stomata were formed and stomatal densities for both flowers and inflorescence leaves. Respiration or photosynthesis, and transpiration were assessed for both organs during the course of inflorescence development in the field to identify the transition of the leaf from sink to source and to quantify the difference in water flux through the two inflorescence types in relation to anthesis and fruit set.

1. Introduction

'Hass' avocado trees (*Persea americana* Mill.) are outstanding with respect to the large number of flowers they produce (> 1 million per tree) relative to the low number of fruit harvested (about 300 per tree). Thus, fruit set represents only about 0.03 % of flowers (Bergh, 1985). Flowers are borne on two types of inflorescences: (i) determinate inflorescences, exclusively floral shoots terminating with a **flower**; or (ii) indeterminate inflorescences, floral shoots terminating with a **vegetative shoot**, which under California conditions flushes at the time of anthesis and fruit set.

The relative productivity of the two types of inflorescences under California conditions and the underlying physiological mechanisms is the subject of an international research collaboration between Isa Bertling (Germany, plant growth regulators), Michael Blanke (Germany, eco-physiology), Samuel Salazar-Garcia (Mexico, reproductive biology), and Carol Lovatt (California, USA-host laboratory, whole tree physiology and production management strategies). Thus, the present study was undertaken as part of a multi-year, multi-grove field trial to characterize the potential of determinate versus indeterminate inflorescences to set fruit that survive to harvest in both "on" and "off" years of a biennial bearing cycle.

2. Material and methods

2.1 Avocado trees

Seven-year-old cv. Hass avocado (*Persea americana* Mill.) trees grafted to Duke 7 rootstock growing in an irrigated commercial grove on the campus of the University of California, Riverside (UCR) were used. The trees flowered during the last two weeks of March through the first two weeks of April 1995.

2.2 Scanning electron microscopy

Avocado inflorescences were examined by SEM in the Department of Biology, UCR within 2 h of sampling (Blanke and Lovatt, 1993). Mounted specimens were gold-coated in an EMSCOPE SC 500 sputter coater and examined in a Philips SEM 515. Stomata were counted on twenty 0.25 mm x 0.25 mm squares.

2.3 Porometry and Conditions of measurement

Photosynthesis or respiration, transpiration and stomatal conductance of inflorescences still attached to the tree were measured in the field using a portable porometer type LCA 3 from Bonn, Germany, or LCA 4 on loan from ADC, Hoddesdon, UK (Blanke and Whiley, 1995). The customized cuvette which consists of two glass hemispheres was shipped from Bonn by air courier. Inflorescences were enclosed in the cuvette. Flow rates into the fruit cuvette and into the LCAs were controlled by the two mass flowmeters and were typically 1 L min⁻¹. Temperature and PAR were recorded by internal temperature sensors, an external thermistor and PAR sensor on the cuvette. Photosynthesis and respiration were determined by the difference in CO₂ concentration of the air stream entering and leaving the cuvette, as measured by the infrared gas analyser in the LCAs. Transpiration and stomatal conductance were determined by the difference in humidity of air entering and leaving the customized cuvette, measured by two Corechi sensors of the LCA 3 or the infrared gas analyser of the LCA 4. Calculations were made by computer programs installed in the LCAs after modification for inflorescences.

Measurements were conducted between 8.00 am and 9.30 am with temperatures of 20 to 24°C, vapour pressure deficits (VPD) of 0.9 to 1.2 kPa and a saturating PAR of 1000 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Measurements were repeated on 14 typical mornings over the 4 week period of anthesis to fruit set from March to April 1995.

2.4 Leaf area determination

Leaf area was measured with a portable, non-destructive areameter type CI201 (CID Inc., Moscow, Idaho, USA).

3. Results and discussion

Inflorescences containing four panicles, and additionally for indeterminate inflorescences 7 to 9 leaves with a leaf area of 100 to 200 cm², and individual leaf areas up to 20 cm² were used in this study. This permitted comparison between determinate versus indeterminate inflorescences at the same phenological stage of development over the four week period. The following differences in physiology were observed

between determinate and indeterminate inflorescences at the same stage of development.

The observations in 1995 confirm our earlier findings (Blanke and Lovatt, 1993) that the tepals of the avocado flower, and hence the *determinate* inflorescence, exhibited only 3 stomata mm^{-2} . The absence of stomata on leaves of *indeterminate* inflorescences with less than 20 cm^2 leaf area indicates that cuticular transpiration is the predominant source of water loss at anthesis. When attaining 20 cm^2 , leaves in the *indeterminate* inflorescences were still red and were in the process of developing 80 to 110 stomata mm^{-2} (table 1). The stomata were open, appeared regulatory and were 12-17 x 14-21 μm in size, with guard cells starting to become covered by epicuticular wax. This indicates that only the developing stomata at fruit set on the older leaves of *indeterminate* inflorescences provide control over transpiration.

Per unit surface area, avocado flowers transpired more water than inflorescence leaves. Flowers transpired ca. 1.2 $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$, while young inflorescence leaves transpired ca. 1 $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$.

Per inflorescence, leaves of an indeterminate inflorescence transpired ca. 25 $\text{ml H}_2\text{O inflorescence}^{-1} \text{ day}^{-1}$ compared with the four panicles which transpired at the most only 5 $\text{ml H}_2\text{O inflorescence}^{-1} \text{ day}^{-1}$. An indeterminate inflorescence transpiring 30 $\text{ml H}_2\text{O day}^{-1}$ consumed 1 liter water $\text{inflorescence}^{-1}$ during four weeks of development. Leaf transpiration accounted for 80% of this water consumption.

The fact that *indeterminate* inflorescences transpired more water and exhibited greater mass flow through the inflorescence compared to determinate inflorescences suggests two possibilities:

- (i) greater movement of xylem transported nutrients and plant growth regulators into indeterminate inflorescences with the possibility of their increased availability to setting fruit of indeterminate inflorescences, or
- (ii) significant transpirational demand created by the leaves of the indeterminate inflorescences which may draw plant growth regulators away from the setting fruit.

During the day, neither flowers nor inflorescence leaves showed net photosynthesis. The flowers respired more than leaves in the indeterminate inflorescence, when expressed on a unit surface area (table 1). The oldest leaves of indeterminate inflorescences exceeded the CO_2 compensation point as their chlorophyll content increased steadily to 1 $\text{mg chlorophyll g}^{-1}$ fresh weight indicating de-novo chlorophyll synthesis (table 1).

4. Conclusion

These results indicate the competition for photo-assimilates as respiratory substrates between flowers and developing leaves of indeterminate inflorescences of the 'Hass' avocado under California conditions. Both flowers and leaves were identified as sinks rather than sources of carbon with the two oldest leaves of indeterminate inflorescences becoming photo-autotrophic after fruit set. This study also provided evidence of a considerably larger water flux through the indeterminate inflorescences compared to determinate inflorescences, an effect largely due to transpiration of the leaves in the indeterminate inflorescences; its physiological significance is now under investigation.

Table 1 - Stomata, transpiration, respiration and chlorophyll of determinate versus indeterminate avocado inflorescences

| Parameter | Determinate inflorescence | | Indeterminate inflorescence | |
|----------------------------------|---------------------------|--|---|--|
| | flowers/tepals | | flowers/tepals | leaves |
| Total leaf area | n.a. | | n.a. | 150 cm ² (8 leaves) |
| Stomata density mm ⁻² | 3 | | 3 | 80-110 mm ⁻² |
| Chlorophyll | 0.3 | | 0.3 | 1 mg g frwt ⁻¹ |
| <i>Per unit surface area,</i> | | | | |
| transpiration | 1.2 | | 1.2 | 1mmol H ₂ O m ⁻² s ⁻¹ |
| respiration | 30 | | 30 | 3 μmol CO ₂ m ⁻² s ⁻¹ |
| <i>Per inflorescence,</i> | | | | |
| transpiration | 5 | | 5 | 25 ml H ₂ O day ⁻¹ |
| Transpiration | 5 | | 30 ml water day ⁻¹ inflorescence ⁻¹ | |

Measuring conditions: 20-24°C, 0.9-1.2 kPa VPD, 1000 μmol PAR m⁻² s⁻¹ in Riverside, April 1995; n.a. - not applicable.

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