

INHIBITION OF FLOWERING OF MEXICAN- AND GUATEMALAN-TYPE AVOCADOS UNDER TROPICAL CONDITIONS

M. SEDGLEY¹, P.B. SCHOLEFIELD² and D.McE. ALEXANDER³

¹ CSIRO Division of Horticultural Research, GPO Box 350, Adelaide, South Australia 5001 (Australia)

² CSIRO Division of Horticultural Research, Private Mail Bag 44, Winnellie, Northern Territory 5789 (Australia)

³ CSIRO Division of Horticultural Research, Private Mail Bag, Merbein, Victoria 3505 (Australia)

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ABSTRACT

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Avocado trees of a range of cultivars growing in Darwin, northern Australia (average yearly maximum 33°C, minimum 23°C), were observed for flower and shoot development. Terminal buds of the cultivars 'Fuerte', 'Rincon' and 'Edranol' sampled in July were not floral. Buds which did not burst were sampled in September and they contained developing flowers with perianth primordia. Vegetative extension growth resulted from laterals proximal to the inhibited terminal buds.

Avocado trees of the cultivars 'Fuerte' and 'Hass' which had initiated floral buds were transferred to controlled environment chambers with 33°C day, 23°C night (33/23) or 25°C day, 15°C night (25/15) with a 12-h photoperiod and photon flux density of 400 $\mu\text{mol m}^{-2} \text{s}^{-1}$ (400–700 nm). At 33/23 the trees had fewer flowers and a shorter flowering period than at 25/15. Inhibited floral buds and lateral vegetative extension resulted at 33/23, as observed in northern Australia. The unburst buds had developing flowers with perianth and stamen primordia.

The controlled environment experiments showed that the abnormal flushing behaviour of Mexican- and Guatemalan-type avocados growing in northern Australia was due to high temperature. Floral development was inhibited at the stage of stamen differentiation.

Keywords: avocado; flowering; flowering inhibition; *Persea americana* Mill; temperature.

INTRODUCTION

The avocado (*Persea americana* Mill.) is grown commercially in a number of countries, generally from 40° S. Lat. to 40° N. Lat., where the climates vary from temperate through subtropical to tropical (Ahmed and Barmore,

1980). This range of climate tolerance within the species is due to the existence of three ecological races. The West Indian race is thought to have evolved in the tropical lowlands of Central or northern South America, the Guatemalan race in the Central American highlands and the Mexican race in the drier cooler areas of Central America and Mexico (Knight, 1980). In general, the Mexican- and Guatemalan-race avocados or their hybrids are grown in temperate and subtropical areas and West Indian types in the tropics (Bergh, 1975). Limitations to cultivation of the different races depend largely on the tolerated temperature range. West Indian-race avocados are severely injured by temperatures below freezing, and Mexican and Guatemalan types do not thrive under conditions of continuous high temperatures. In the latter case, the reluctance of these races to flower and fruit contributes to the problem.

In the commercial avocado growing area of the River Murray Valley in southern Australia (S. Lat. 34°), floral initiation in the 'Fuerte' cultivar occurs during April and May and anthesis during September and October (Alexander, 1975; Scholefield et al., 1985). Floral primordia arise in the axils of the bud bracts and the apex of the avocado bud generally remains vegetative (Reece, 1942; Schroeder, 1945, 1951; Jackson and Sweet, 1972; Scholefield et al., 1985). The floral axillaries develop ahead of the vegetative apex and following anthesis, continued vegetative growth occurs as the apex develops. The terminal buds and the lateral buds down the shoot all have the potentiality to become floral.

In this paper we report abnormal budburst and poor flowering behaviour of Mexican- and Guatemalan-type avocados under tropical conditions in northern Australia. The climate in this area is dry monsoonal tropics, with a dry season from April to September and a wet season from October to March. The average maximum and minimum temperatures are 33 and 23°C, respectively, with little variation throughout the year (Australia, Bureau of Meteorology, 1975). In addition, we report controlled-environment experiments which have confirmed that floral budburst is inhibited by the continuous high temperatures experienced under these conditions. This abnormality has not been observed in the temperate and subtropical avocado growing areas.

MATERIALS AND METHODS

Five-year-old grafted avocado trees of the cultivars 'Fuerte', 'Rincon' and 'Edranol', growing near Darwin (S. Lat. 12° 27'), were observed for vegetative and floral growth. Terminal buds were sampled in July and September. They were bisected and fixed in 3% glutaraldehyde in 0.025 M phosphate buffer pH 7.0, dehydrated through alcohols and embedded in glycol methacrylate. Longitudinal sections were cut at 5 μ m and stained with periodic acid-Schiff's reagent and toluidine blue O for microscopic examination (Feder and O'Brien, 1968) for presence of floral development.

A range of cultivars growing in avocado collections at research stations and grower properties near Darwin was examined for the presence of the growth abnormality pictured in Fig. 1b. Trees were rated as: 0, none evident; L, low incidence; M, medium incidence; H, high incidence. Some branches on trees in experimental plantings were cinctured prior to anthesis, a practice reported to increase yields (Trochoulis and O'Neill, 1976), and observed following fruit harvest for the presence of the abnormality.

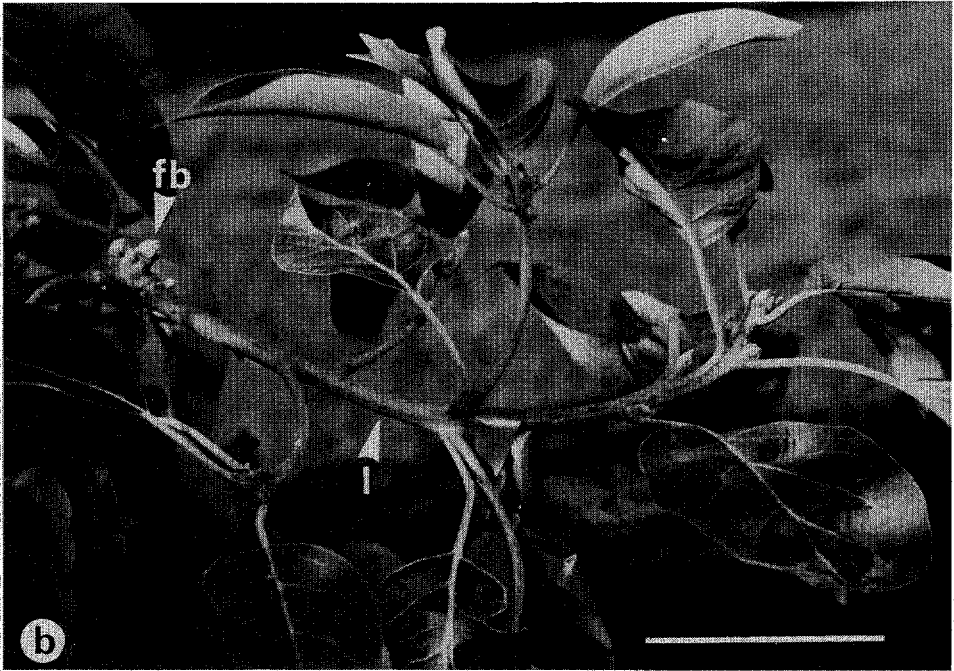
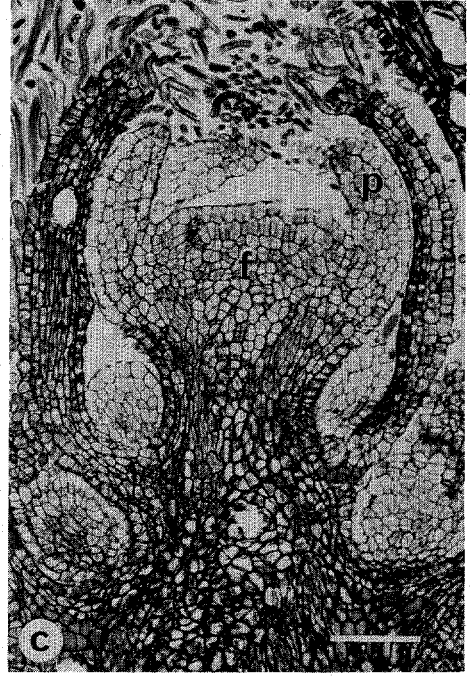
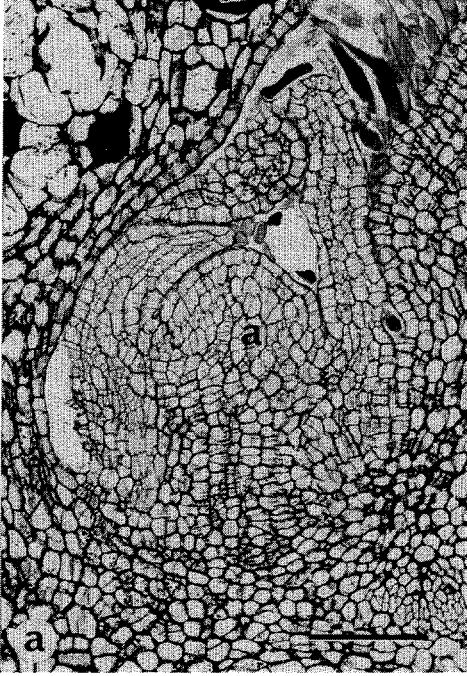
Two-year-old grafted avocado trees of the cultivars 'Fuerte' and 'Hass', which had been trained to 3 main shoots, were selected with a minimum of 5 floral buds as judged by their swollen external appearance. Prior to the experiment, the trees were maintained in a glasshouse with temperature conditions of approximately 20°C day and 10°C night, which was conducive to floral initiation (Buttrose and Alexander, 1978). Three trees of each cultivar were placed in growth cabinets with temperatures of 33°C day/23°C night (Darwin temperatures) or 25°C day/15°C night (temperatures under which normal floral behaviour occurs; Sedgley, 1977; Sedgley and Annells, 1981), both with a 12-h day (07.00–19.00) and a photon flux density of 400 $\mu\text{mol m}^{-2} \text{s}^{-1}$ (400–700 nm). The plants were kept well watered and were observed daily for number of flowers, number of floral buds bursting and total flowering period. At the end of the experiment, any unburst swollen buds were fixed and prepared for microscopy as described previously.

The 'Fuerte' cultivar is a predominantly Mexican type although it has some Guatemalan genes (Bergh, 1975). 'Hass' is a Guatemalan-type cultivar with up to a quarter Mexican genes (Bergh and Whitsell, 1974) and 'Rincon' and 'Edranol' are considered to be Mexican–Guatemalan hybrids (Bergh, 1975).

RESULTS

Darwin observations. — Swollen terminal buds were observed on the trees in July. Microscopic examination showed that the axillaries had commenced elongation but had not yet started to produce floral primordia (Fig. 1a). The buds continued to swell but very few flowered. In the majority of cases, the swollen terminal remained unburst and a lateral bud proximal to the terminal bud burst, usually as a vegetative shoot, and the branch continued to extend in this atypical manner (Fig. 1b). Microscopic examination of the unburst terminals sampled in September showed that they had floral axillaries with developing flowers with perianth primordia (Fig. 1c). The results were similar for the three cultivars, and none of the floral axillaries appeared abnormal in any way.

The results from the survey of the incidence of this budburst abnormality in avocado cultivars are presented in Table I. Those cultivars and seedlings of West Indian type exhibited less of the abnormality than the Mexican- and Guatemalan-type cultivars. Cinctured branches flowered and fruited better than the remainder of the trees but the budburst abnormality was still observed.



Controlled environment observations. — Under the warmer conditions of 33/23, the plants flowered for a much shorter period and produced fewer flowers than under 25/15 (Table II). The 'Fuerte' cultivar was more sensitive to higher temperatures than 'Hass', as the number of flowers was reduced by 92% as compared with 53% for 'Hass'. There were four reasons for the reduction in flower number. The first was observed in 'Fuerte' only and involved the abscission of floral branches of burst floral buds prior to anthesis. The second reason was the fewer flowers per bud at 33/23 than at 25/15 in both cultivars (Table II), indicating that some floral axillaries of the bud did not burst. Thirdly, some of the swollen apparently floral buds did not burst at all and, fourthly, more floral buds were produced during the experimental period in both cultivars at 25/15 than at 33/23.

At 33/23, the flowering period was reduced by 77% in 'Fuerte' and by 52% in 'Hass' and the trees, particularly of the 'Fuerte' cultivar, underwent a vegetative flush from lateral buds along the shoots (Fig. 2a). Microscopic examination of the unburst swollen buds showed that they were floral. Stages of development observed ranged from axillaries which had just started to produce floral primordia (Fig. 2b) to developing flowers with stamen primordia (Fig. 2c).

DISCUSSION

Avocados grown in controlled-environment conditions simulating the temperatures experienced in northern Australia produced the same inhibition of floral development and abnormal vegetative extension growth as observed on trees in Darwin. Floral initiation and early development appeared normal, but further development was generally halted at the stage just prior to stamen development in the flowers. It is possible that the differentiation of the sex organs may be particularly sensitive to high temperature, as is the case during later stages of floral development in many other species (Randolf, 1932; Sax, 1937; Langer and Olugbemi, 1970; Saini and Aspinall, 1982; Saini et al., 1983). It was interesting to note that the vegetative apex of the inhibited terminal buds did not burst. The inhibited development of the floral axillaries appeared to limit development of the vegetative apex in the same bud. This led to a tree of abnormal appearance, with numerous wispy lateral shoots rather than strong leaders.

The plants used in the controlled-environment experiments had initiated floral buds under conducive conditions. The most advanced of the floral buds

Fig. 1. Avocado trees in Darwin. (a) 'Fuerte' bud harvested on 5 July 1980 showing elongated axillary meristem (a). Bar represents 100 μm . (b) 'Fuerte' shoot showing the terminal floral bud (fb) which has failed to burst and the proximal vegetative lateral (l) which has burst to continue the extension of the shoot. Bar represents 10 cm. (c) 'Edranol' bud harvested on 15 September 1980 showing axillary meristem with developing flower (f) with perianth primordia (p). Bar represents 100 μm .

TABLE I

Rating for incidence of abnormal budburst on a range of unnamed seedlings and named avocado cultivars growing near Darwin, Northern Territory

Unnamed seedlings	Number of trees observed	Average rating ¹	Origin of seedling ²	Named cultivars	Number of trees observed	Average rating ¹	Origin of cultivar ²
AV 64	2	0	WI hybrid	Edranol	2	M	M/G hybrid
AV 83	2	0	WI hybrid	Fuerte	20	L-M	M/G hybrid
AV 88-1A	2	0	WI hybrid	Hall	10	0-L	WI hybrid
AV 88-1B	1	0	WI hybrid	Hass	23	L-M	G
AV 88-2	2	0	WI hybrid	Hazzard	2	L-M	G
AV 88-3	1	0	WI hybrid	Nabal	9	L	G
AV 88-4	2	0	WI hybrid	Reed	10	M	G
AV 88-5	2	0-L	WI hybrid	Rincon	6	M	M/G hybrid
AV 88-6	1	0	WI hybrid	Sharwil	10	L	G
AV 88-7	1	0	WI hybrid	Wurtz	10	L	M/G hybrid
AV 88-8	2	L-M	WI hybrid	Zutano	4	0-L	M/G hybrid
AV 88-9	1	0	WI hybrid				
AV 107	2	0	WI hybrid				
AV 123A	2	0	WI hybrid				
AV 123B	1	0	WI hybrid				
AV 158	1	0	WI hybrid				
AV 181B	1	0	WI hybrid				

¹ Rating for incidence of abnormal budburst; 0 = none; L = some; M = medium.

² WI = West Indian; M = Mexican; G = Guatemalan. The exact composition of the seedlings and cultivars is not known.

TABLE II

Flowering data for the avocado cultivars 'Fuerte' and 'Hass' under different temperature conditions

Temperature conditions (day/night) (°C)	Cultivar	Flowering period (days)	Total number of flowers	Total number of buds flowering	Number of flowers per bud	Number of unburst floral buds
33/23	Fuerte	12.0	66.9	3.4	21.5	3.8
33/23	Hass	14.8	679.2	8.8	77.5	2.6
25/15	Fuerte	52.0	857.5	16.0	53.6	0
25/15	Hass	30.9	1456.7	12.7	114.1	0
D (P = 0.05)		4.1	454.0	0.2	32.7	1.0

Data were transformed to square roots for analysis as treatments had widely different variances.

had already burst prior to the start of the experiment, so many buds would have passed the stage of stamen differentiation at which development appeared to be inhibited by high temperatures. Thus it appears that flowering can proceed once this stage has been passed. It is likely that under 25/15, extra floral buds were initiated during the course of the experiment. Schroeder (1951) reported floral initiation between 6 and 8 weeks prior to anthesis in the cultivars 'Fuerte', 'Mèxicola' and 'Dickinson' growing in California.

Under southern Australian conditions (S. Lat. 34°), floral initiation was observed in April and May and anthesis occurred during September and October following a cool winter (16.1°C max., 4.8°C min.; Scholefield et al., 1985). Under the warmer winter conditions of southern California (Schroeder, 1951), flowering can occur from November (early winter) through to June (early summer). Thus the relatively long floral development period in southern Australia is probably due to slow growth conditions. Under the high temperatures of northern Australia, flowers may be produced at any time, although most flowering occurs during July–September. The floral development period, in those cases where flowering occurs, appears to be very short, as buds harvested in July were not floral.

A comparison of the maximum and minimum temperatures in some avocado-growing areas in Australia (Table III) shows that high daytime temperatures can be experienced in most regions during the period of floral development. This is particularly true of the Mareeba (Atherton) area in north Queensland, where there is a flourishing industry based on Mexican- and Guatemalan-type cultivars. The major difference between Darwin and the avocado-producing regions is in the night temperature. It is possible that high night temperature or high average diurnal temperature is more important than the daily maximum. This is considered to be likely, as our glasshouse observations indicate that only a short period of a few days at continuous high temperature is sufficient to produce an irreversible inhibition of budburst.

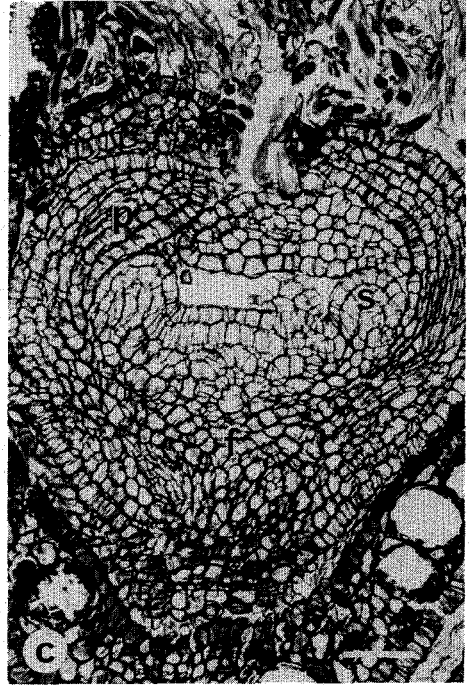
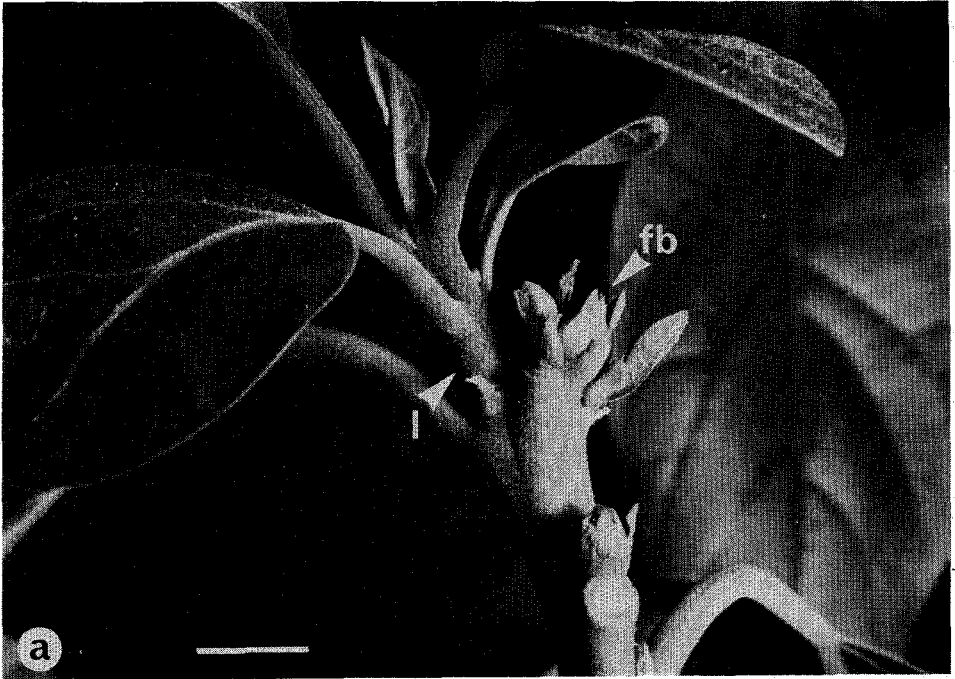


TABLE III

Temperature data for some avocado growing areas in Australia during the period of floral development (Australia, Bureau of Meteorology, 1975)

		Merbein, Victoria	Alstonville, New South Wales	Mareeba (Atherton), Queensland	Darwin, Northern Territory
April	Mean max. (°C)	23.9	24.4	28.4	32.7
	Mean min. (°C)	10.5	15.0	17.1	23.9
May	Mean max. (°C)	18.8	21.2	26.6	31.9
	Mean min. (°C)	7.0	12.3	14.8	21.8
June	Mean max. (°C)	16.0	18.8	25.1	30.6
	Mean min. (°C)	4.9	9.7	12.9	19.9
July	Mean max. (°C)	15.5	18.4	25.3	30.3
	Mean min. (°C)	4.4	8.6	11.2	18.9
August	Mean max. (°C)	16.8	20.2	26.6	31.2
	Mean min. (°C)	5.2	9.8	11.7	20.3
September	Mean max. (°C)	19.9	21.5	28.1	32.5
	Mean min. (°C)	7.3	11.5	12.9	22.9
October	Mean max. (°C)	24.5	24.6	30.7	33.3
	Mean min. (°C)	10.0	14.2	15.6	24.9

The yields of fruit on most of the cultivars growing near Darwin have been low, and this has been attributed to poor flowering. Cincturing caused more flowering, but not by preventing the budburst abnormality from occurring. The cincturing or girdling treatment increases carbohydrate levels which stimulates floral initiation in some species (see Jackson and Sweet, 1972). Our observations suggest a lack of carbohydrate build-up in the trees, possibly due to high respiration rate within the canopy under the high-temperature conditions. This may be the cause of the abnormal budburst.

Cultivars of the West Indian type of avocado exhibited less abnormality during burst of floral buds than Mexican/Guatemalan types. However, their productivity was still unacceptable. The West Indian type of avocados are more tropical in their requirements, and we believe that some cultivars of this group will eventually prove suitable for the development of a small avocado industry in north-west Australia. Some of these cultivars are presently under test.

Fig. 2. Avocado trees at 33/23. (a) 'Fuerte' shoot showing terminal floral bud (fb) which has failed to burst and proximal vegetative lateral (l) which is bursting to continue the extension of the shoot. Bar represents 1 cm. (b) 'Hass' bud showing elongated axillary meristem which has started producing floral meristems (m). Bar represents 50 μ m. (c) 'Fuerte' bud showing developing flower (f) with perianth (p) and stamen (s) primordia. Bar represents 50 μ m.

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