Scientia Horticulturae, 18 (1982/83) 207—213
Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

EFFECT OF LOW TEMPERATURES DURING FLOWERING ON FLORAL CYCLE AND POLLEN TUBE GROWTH IN NINE AVOCADO CULTIVARS

M. SEDGLEY and W.J.R. GRANT
Division of Horticultural Research, CSIRO, Adelaide, South Australia 5001 (Australia)
(Accepted for publication 15 February 1982)

ABSTRACT

Sedgley, M. and Grant, W.J.R., 1983. Effect of low temperatures during flowering on floral cycle and pollen tube growth in nine avocado cultivars. *Scientia Hortic.*, 18: 207—213.

The floral response of the type A avocado cultivars 'Reed', 'Wurtz', 'Rincon' and 'Jalna', and the type B cultivars 'Bacon', 'Ryan', 'Edranol', 'Sharwil' and 'Hazzard' was tested under growth-cabinet conditions of 17° C day, 12° C night, with a 12-h photoperiod and photon flux density of 400 μE m^{-2} s^{-1} (400—700 nm). Most of the flowers of all type A cultivars and the type B cultivar 'Bacon' had both a female and a male stage. None of the flowers of the other type B cultivars had a female stage but opened in the male stage only. Hand pollination resulted in some ovule penetration in the cultivars with female stage flowers. In those with only male-stage flowers, the pollen tubes grew no further than the style. Maintenance of fertility under low-temperature conditions during flowering appeared to be partly, but not entirely, linked to the type A flowering cycle.

INTRODUCTION

The avocado (*Persea americana* Mill.) is an established crop in many parts of the world (Knight, 1980) but yields are often unreliable. Low temperatures during flowering have been observed to result in low yields (Bringhurst, 1952; Peterson, 1956; Bergh and Whitsell, 1974) which may result in a heavy crop the following year, thus triggering an alternate-bearing cycle (Hodgson and Cameron, 1936). Avocados show protogynous dichogamy (Robinson and Savage, 1926) and there are 2 flowering types, A and B, which allow for cross-pollination. Under favourable temperature conditions, flowers of type A cultivars open in the female stage in the morning. They then close completely and re-open in the male stage in the afternoon of the following day. In type B cultivars, the female stage flowers open in the afternoon, close overnight and re-open in the male stage the following morning. In both flowering types, the flowers close permanently after the male stage. Field observations indicate that type B cultivars are generally less productive under

0304-4238/83/0000—0000/$03.00

cool flowering conditions than type A cultivars (Peterson, 1956), and this has resulted in a changeover from the cultivar 'Fuerte' (type B) to 'Hass' (type A) in California (Toumey, 1981). Controlled-environment growth-cabinet experiments have confirmed that this difference in performance is due to greater disruption of the floral cycle of 'Fuerte' than of 'Hass' under low temperatures during flowering (Sedgley, 1977a; Sedgley and Annells, 1981), resulting in poorer pollen tube growth and fruit set. The temperature regime in these experiments was a 17°C day and a12°C night.

In the present study, we investigated the effect of the 17°C day and 12°C night temperature conditions on floral cycle and pollen tube growth of a further 9 avocado cultivars, 4 A-types and 5 B-types. This was to investigate whether there was a physiological difference between A and B-type avocado cultivars in their floral response to low temperature.

MATERIALS AND METHODS

Cultivars and environmental conditions. — The 4 type-A cultivars were 'Reed', 'Wurtz', 'Rincon' and 'Jalna', and the 5 type-B cultivars were 'Bacon', 'Ryan', 'Edranol', 'Sharwil' and 'Hazzard'. Prior to the experiment, the trees were kept in a temperature-controlled glasshouse with a daytime maximum of approximately 25°C and an overnight minimum of 15°C. When the first floral bud had burst, 2 trees of each cultivar were placed in a growth cabinet with a 17°C day, 12°C night, a 12-h photoperiod (06.00 h—18.00 h) and a photon flux density of 400 μE m^{-2} s^{-1} (400—700 nm).

Floral behaviour. — Each plant was observed for floral cycle. Observations were made every 2 h during the light period and occasionally during the dark period. Each new flower was labelled with coloured cotton, its sex noted and subsequent cycling observed. Approximately 100 flowers were observed per plant over a 3-week period.

Pollen tube growth. — Twenty flowers on each plant were pollinated with pollen from the same tree by gently brushing the recurved pollen-bearing valve of an anther against the stigma surface. No self-incompatibility mechanism has been detected in the avocado (Sedgley, 1979). Female-stage flowers were pollinated shortly after opening. If no female-stage flowers were produced, then male-stage flowers were pollinated. Pistils were collected at 24 h following pollination. The single ovule was dissected from each pistil and both ovule and pistil were processed for fluorescence microscopy using the aniline blue fluorochrome (Martin, 1959). Most pollinations were carried out during the third week of flowering. Some pollinations were carried out during the first week of flowering and some were fixed after 48 rather than 24 h.

RESULTS

The 2 trees of each cultivar behaved similarly and results were pooled.

Floral behaviour. — Most of the flowers of all the type A cultivars tested had a female stage followed by a closed stage followed by a male stage (Fig. 1). In all cases there were some flowers which omitted the female stage and opened once only in the male stage. The proportion varied from 15% in 'Reed' up to 46% in 'Jalna', and in the cultivars 'Rincon' and 'Jalna' there was an increase in the proportion of male-stage flowers over the period of observation. In all cultivars there were both female- and male-stage flowers open for most of the light period and anthers of the male-stage flowers

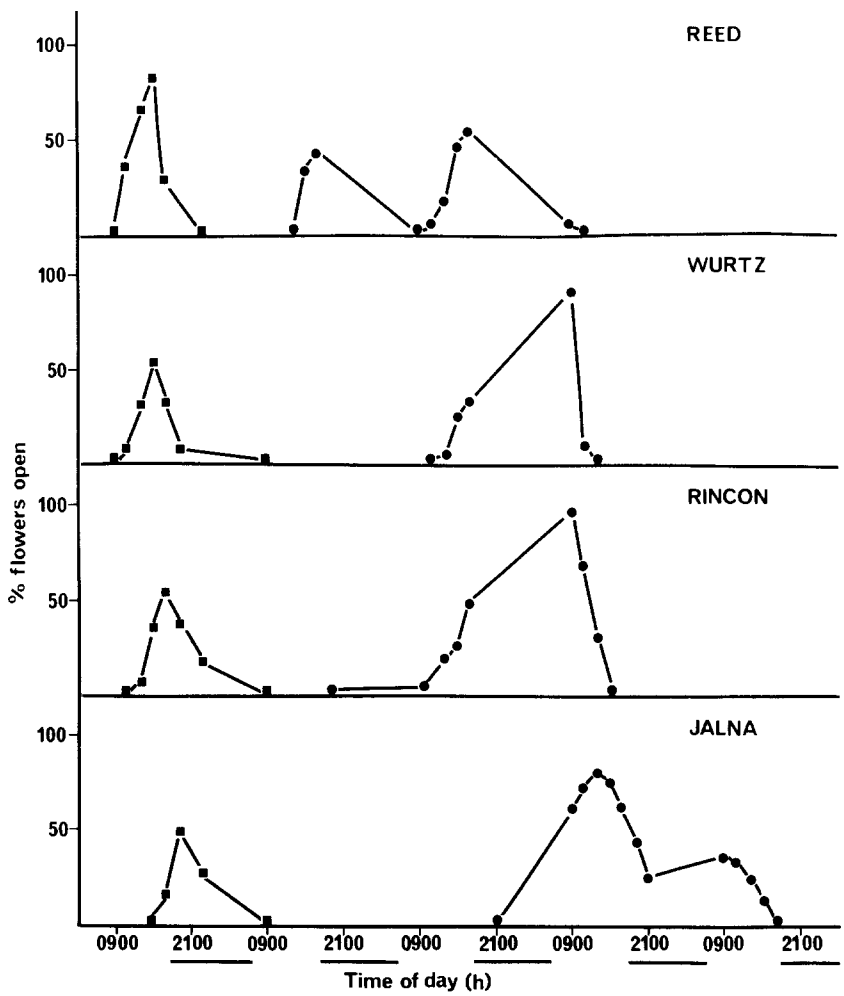

Fig. 1. Floral cycle of 4 type-A avocado cultivars at 17°C day and 12°C night. — ▪ —, female stage; — • —, male stage; ——, night period.

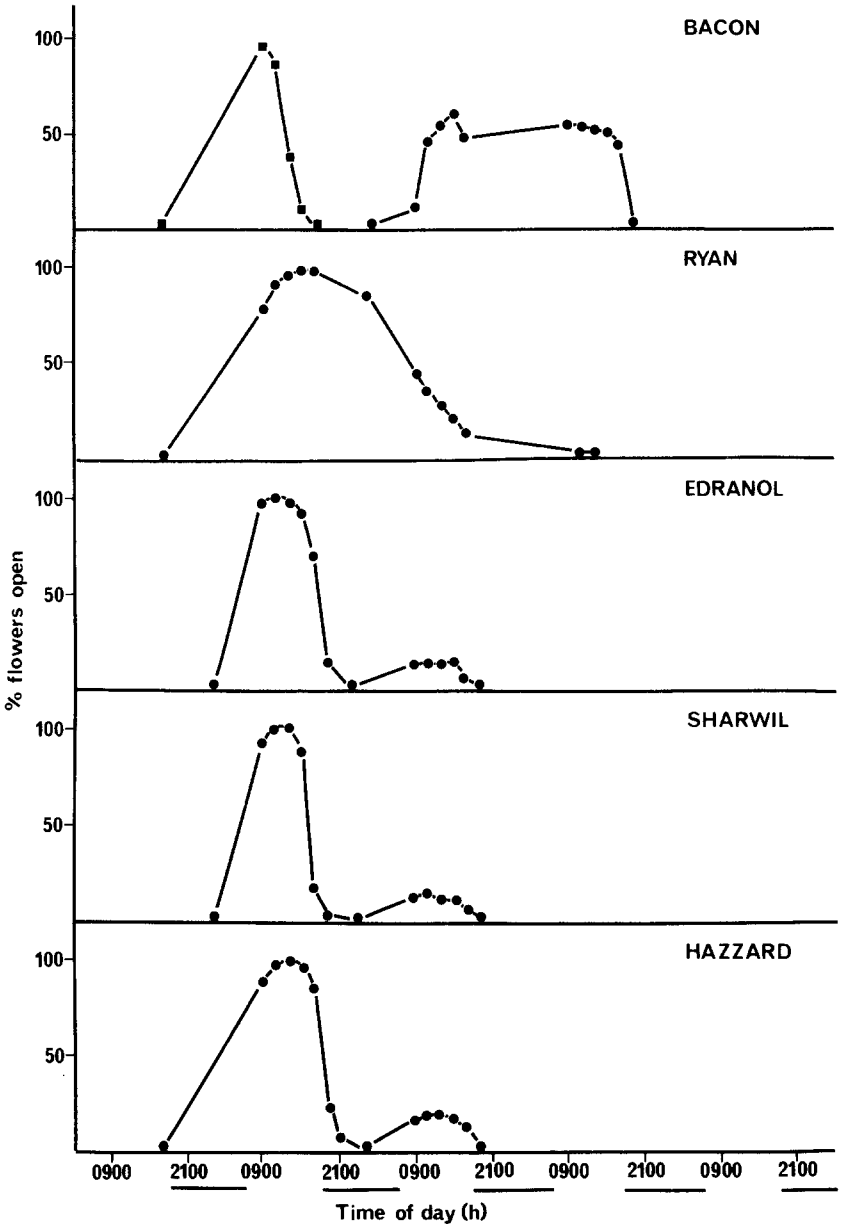

Fig. 2. Floral cycle of 5 type-B avocado cultivars at 17° C day and 12° C night. —■—, female stage; —●—, male stage; ——, night period.

dehisced in the late afternoon in all cultivars except 'Jalna', where the anthers dehisced in the morning. There was considerable spread in the opening-time of both female- and male-stage flowers, and all of a particular day's flowers were rarely open at the same time. In the cultivars 'Wurtz',

'Rincon' and 'Jalna', the male-stage flowers re-opened 48 h after the closure of the female-stage flowers. There was one period of male-stage opening in 'Wurtz' and 'Rincon', but in 'Jalna' about 10% of the flowers opened twice in the male stage and in 'Reed' half of the flowers opened in the male stage 24 h after the female stage and the other half after 48 h. The average floral cycle time was 72 h.

Of the 5 type B cultivars tested, only 'Bacon' flowers had a female stage (Fig. 2). 'Ryan' flowers opened once only in the male stage, and in the other cultivars between 10 and 20% of the flowers opened twice in the male stage. Anther dehiscence occurred mainly in the morning, but in 23% of the 'Hazzard' flowers there was no dehiscence at all. The average floral cycle time for 'Bacon' was 72 h, for 'Ryan' 36 h and for the other type B cultivars it was 24 h.

Pollen tube growth. — Pollen tube growth in the pistil was very variable, but only cultivars whose flowers opened in the female stage had pollen tubes in the ovary and ovule (Table I). Thus, in all the type B cultivars except 'Bacon', pollen tube growth was arrested in the style, whereas in all the type A cultivars and the type B cultivar 'Bacon', some of the ovules were penetrated by a pollen tube. The results of pollinations carried out during the first week of observation did not differ from those in the third, and there was no difference between 24 h and 48 h after pollination.

TABLE I

Pollen tube growth of 9 avocado cultivars at 17° C day and 12° C night

Flowering type	Cultivar	Average no. of pollen grains on stigma	Average no. of pollen tubes in			Percentage of ovules penetrated by a pollen tube
			Upper style	Lower style	Ovary	
A	Reed	16.5	9.1	1.5	0.3	8
A	Wurtz	51.0	25.9	1.7	0.7	23
A	Rincon	39.0	19.7	2.4	0.6	3
A	Jalna	50.9	29.3	2.0	0.7	1
B	Bacon	38.5	20.6	2.0	0.7	1
B	Ryan	47.2	21.7	0	0	0
B	Edranol	11.8	9.5	0	0	0
B	Sharwil	20.0	11.4	0.1	0	0
B	Hazzard	16.7	8.5	0	0	0
LSD (p=0.05)		11.7	5.7	0.4	0.2	

DISCUSSION

All of the type A cultivars, but only one of the type B cultivars, tested maintained their fertility as measured by penetration of an ovule by a pollen tube under low temperatures during flowering. This supports previous controlled-environment experiments with the cultivars 'Fuerte' and 'Hass' (Sedgley, 1977a; Sedgley and Annells, 1981) and the observation by Peterson (1956) that type B cultivars are generally less productive than A-types under cool conditions. It has also been observed that the type B cultivar 'Sharwil' performs poorly in some of the cooler coastal areas of south-eastern Australia (T. Whiley, personal communication, 1981). There was variability in the results observed, as one type B cultivar ('Bacon') had female-stage flowers with ovule penetration and some of the type A cultivars ('Rincon' and 'Jalna') had increasing proportions of flowers which opened once only in the male stage. Nevertheless, in general, the type A cultivars could withstand periods of low temperatures during flowering with less adverse effects on pollen tube growth than the type B cultivars. Fertility was not measured by yield in this experiment as small potted trees were used which give variable fruit set responses even under more favourable temperature conditions (M. Sedgley, 1981, unpublished results).

In all cases, the length of the floral cycle was extended under the cool conditions, from the usual 36-h cycle for type A cultivars and 20-h for type B's (Robinson and Savage, 1926). This was also observed for the type B cultivar 'Fuerte' (Sedgley, 1977a) and the type A cultivar 'Hass' (Sedgley and Annells, 1981) under low temperature conditions.

Where both female- and male-stage flowers were produced, some flowers of each were open at the same time so that pollen could be transferred. The female-stage flowers also overlapped with the male stages of the type B cultivars so that cross pollination could occur. It has been reported previously that pollen tube growth is poorer in male-stage than female-stage avocado flowers (Sedgley, 1977b). The flowers are hermaphrodite, so female and male organs are present in both sex stages, but the female organs have reduced fertility by the time the flower opens in the male stage.

Thus, there appears to be a physiological difference within the species in floral response to low temperatures. This difference may be linked to the flowering-type character, but there is at least one exception to this and variability in response generally. Of the type B cultivars tested, 'Bacon' would be the most likely to yield well in areas where low temperatures of around 17°C can be expected during flowering. Any of the type A cultivars would probably be suitable, although the higher proportions of male-stage-only flowers in 'Rincon' and 'Jalna' may mean that 'Reed' or 'Wurtz' would be more productive in cooler areas.

ACKNOWLEDGEMENTS

We thank Don McE. Alexander for providing the avocado trees and Tony Whiley of the Department of Primary Industry, Queensland, for discussion.

REFERENCES

Bergh, B.O. and Whitsell, R.H., 1974. Self-pollinated Hass seedlings. Calif. Avocado Soc. Yearb., 1973—74: 118—126.

Bringhurst, R.S., 1952. Sexual reproduction in the avocado. Calif. Avocado Soc. Yearb., 1952: 210—214.

Hodgson, R.W. and Cameron, S.H., 1936. Temperature in relation to the alternate bearing behavior of the Fuerte avocado variety. Proc. Am. Soc. Hortic. Sci., 33: 55—60.

Knight, R., Jr., 1980. Origin and importance of tropical and subtropical fruit crops. In: S. Nagy and P.E. Shaw (Editors), Tropical and Subtropical Fruits. AVI Publishing, Westport, CT, pp. 1—120.

Martin, F.W., 1959. Staining and observing pollen tubes in the style by means of fluorescence. Stain Technol., 34: 125—128.

Peterson, P.A., 1956. Flowering types in the avocado with relation to fruit production. Calif. Avocado Soc. Yearb., 1956: 174—179.

Robinson, T.R. and Savage, E.M., 1926. Pollination of the avocado. U.S.D.A. Circ., 387: 1—16.

Sedgley, M., 1977a. The effect of temperature on floral behaviour, pollen tube growth and fruit set in the avocado. J. Hortic. Sci., 52: 135—141.

Sedgley, M., 1977b. Reduced pollen tube growth and the presence of callose in the pistil of the male floral stage of the avocado. Scientia Hortic., 7: 27—36.

Sedgley, M., 1979. Inter-varietal pollen tube growth and ovule penetration in the avocado. Euphytica, 28: 25—35.

Sedgley, M. and Annells, C.M., 1981. Flowering and fruit-set response to temperature in the avocado cultivar 'Hass'. Scientia Hortic., 14: 27—33.

Toumey, J., 1981. Once popular Fuerte hits bottom. Avocado Grower, 5(6): 11—12.