



Flowering behaviour of avocado (*Persea americana*) genotypes in humid tropical region of India

P C TRIPATHI¹, G KARUNAKARAN², V SANKAR³, B R JAYANTHIMALA⁴ and S SUNANDA⁵

Central Horticultural Experiment Station, Chettalli, Kodagu, Karnataka 571 248

Received: 23 June 2016; Accepted: 27 September 2016

ABSTRACT

A study on flowering and fruiting behaviour of 35 accessions of avocado (*Persea americana* Mill.) was carried out at CHES, Chettalli during 2013-14. The results revealed that number of panicles/shoot ranged from 2.6 in accession CHESPA-I-4 to 13.8 in accession CHESPA-XII-4. The panicle length ranged from 5.16 cm in CHESPA-IX-3 to 18.4 cm in CHESPA-VIII-3. The number of flowers/shoot ranged from 22.68 to 218.96. The panicles were produced on terminal bud and most of them were determinate type. The flowering period ranged from 27 to 53 days. The double opening of flowering was noticed in all the accessions. The accessions were classified in 'A' type and 'B' type on the basis of their flowering pattern. In 'A' type accessions, flowers open in the morning as female stage and reopen in the afternoon of the next day at the male stage. In the type 'B' accessions, the flowers open in the afternoon as female stage, close in the evening and reopen the following morning at the male stage. Out of 35 genotypes evaluated, 20 were 'A' type while 15 were 'B' type. The average initial fruit set was 3.62% and it was highest (8.74%) in CHESPA-VIII-3 and lowest (0.50%) in CHESPA-VI-1. Average final fruit set was 0.32%. Among the 35 accessions evaluated, all the fruits dropped in 24 accessions before attaining harvest maturity. The highest final fruit set (1.32%) was recorded in accession CHESPA-II-1. Heavy fruit drop was observed during various stages of fruit growth and development in majority of the accessions. This may be attributed to improper pollination and environmental conditions during growth and development of fruits. The results will be useful in identifying suitable combinations of elite lines.

Key words: Avocado, Flowering, Flowering period, Fruit set s, Genotype

Avocado (*Persea americana* Mill.) is an evergreen tropical fruit tree native to Central America and Mexico. It originated possibly from more than one wild species. Spanish explorers recorded its cultivation from Mexico to Peru. Avocado is the most nutritive among fruits. The pulp is rich in proteins (up to 4%) and fat (up to 30%). The avocado is rich in copper and iron. In India, Avocado was introduced by American missionaries during 1912 to 1940. The avocado plants were brought by several visitors from different sources during last one century. Most of them were only seedlings and only few known varieties were brought for planting. Later on, seedling progenies of these varieties and seedlings were planted and spread by the growers in different parts of country particularly in Tamilnadu, Kerala and Karnataka (Ghosh 2000, Tripathi *et al.* 2015a). The cultivation of avocado is gaining popularity in coffee based cropping system of these states. An adult avocado tree produces thousands of flowers however very few flowers set fruits

and produces mature fruits (Lahav and Gazit 1994). There are several factors which contributes to low productivity. Among them, flowering pattern, poor pollination, degeneration of young fruits and fruit drop are major ones (Lesley and Bringham 1951, Sedgley 1977, Lahav and Gazit 1994). Avocado has a synchronous protogynous dichogamous breeding system that promotes outcrossing. Each perfect flower opens twice, the first functionally as a female flower with a receptive stigma; then the flower closes and following day the flower reopens functionally as a male flower with the stigmas no longer receptive and dehiscent anthers (Davenport 1986). On the basis of this pattern of flowering, the avocado varieties/clones are classified in 'A' type and 'B' type cultivars (Bergh 1974). In type 'A' cultivars, the flowers open in the morning in the female stage, close at mid-day and reopen the afternoon of the following day at the male stage. In the type 'B' cultivars, the flowers open in the afternoon at the female stage, close in the evening and reopen the following morning at the male stage. The combination of protogynous dichogamy and flowering behaviour of the avocado prevents self-pollination and promotes outcrossing. However, self-pollination occurs in orchards composed of a single genotype probably due to some overlapping between the male and female stages in the same flower, among flowers of the same tree or among

¹Principal Scientist (e mail: prakaashtripathii2000@yahoo.co.in), ⁴Scientist, (e mail: jayanthibr@iihr.res.in), ICAR-IIHR, Bengaluru, ²Senior Scientist and Head (e mail: karanstg@gmail.com), CHES, ICAR-IIHR, Hirehalli. ³Senior Scientist (e mail: skar@yahoo.com), ⁵ Research Associate (e mail: sunandas @yahoo.com), CHES, ICAR-IIHR Chettalli.

flowers of different trees of the same genotype (Davenport 1986). It is recommended to plants 'A' and 'B' type varieties in definite ratio for proper pollination and fruit set.

A large number of collections of avocado germplasm were collected for evaluation to identify high yielding genotype. These genotypes have lot of variability with respect to growth, yield and fruit characters (Tripathi *et al.* 2015b). Thus an attempt was made to classify the existing germplasm of avocado according to their flowering behavior, flowering phenology and daily flowering cycle under the environmental conditions of Coorg. Furthermore, those genotypes that exhibit sufficient overlapping in the blooming period with each other may be identified.

MATERIALS AND METHODS

In South India, avocado is grown in the humid tropical regions of Western Ghats of Karnataka, Kerala and Tamilnadu. The location of present study is situated at 1 050 m above mean sea level (75.83° E, 12.37°N). The climatic data of location for last 50 years showed that mean temperature range between 32° and 19°C. April is the hottest month and January is the coolest month. The average annual rainfall is 150 cm with major precipitation during July and August.

The present study on flowering and fruiting behaviour was carried out on 35 avocado genotypes conserved at avocado germplasm block of CHES Chettalli (Coorg, Karnataka) during 2013-14. These accessions were collected from the various sources in Western Ghats.

The trees were planted to field in 2000 at Central Horticultural Experiment Station, Chettalli, Karnataka. Tree spacing was 6 × 6 m. The soil was lateritic with 28.5 % clay content having 652 µg Ca/g soil and a pH of 5.70. The trees were managed according to standard local commercial practices, pruned annually, and watered as needed using a basin irrigation system. Fertilization was managed based on soil and leaf analysis. These plants were fertilized with 50g N, 30g P₂O₅ and 50 g K₂O/tree/year of tree age. These doses were divided in two halves and applied in the month of June and October. Pest populations were kept under control recommended pest management measurements.

The avocado trees flowers twice, in the months of March-April and September-October in Coorg conditions. The observations were recorded in autumn season on selected trees of these accessions. Ten shoots were selected in the month of September. The observations on number of panicles /shoot, panicle length, number of flowers/panicle, type of flower, flower opening time and period, initial fruit set and final fruit set were recorded from October to March. The flowering behaviour of each genotype was observed by counting the flowers in male and female stage in 10 inflorescences located in different positions in the trees. These flowers were labeled during the blooming period and the day of the first opening was noted. These flowers were monitored until the second flower opening. The accessions were categorized on the basis of their flowering pattern. The number of developing fruits retained on the selected shoots

was monitored weekly, the abscission date was noted and the final fruit set was calculated.

The F-Test procedure as described by Panse and Sukhatme (1995) was used for all statistical analyses.

RESULTS AND DISCUSSION

Panicle length and number of flowers

The panicle length ranged from 5.16 cm in CHESPA-IX-3 to 18.4 cm in CHESPA-VIII-3. Higher panicle length (>15 cm) was recorded in accessions CHESPA- II-3(17.9 cm), CHESPA-VII-2(17.6 cm), CHESPA-II-2 (16.9 cm), CHESPA-XII-1(16.8 cm), CHESPA-V-2(16.1 cm), CHESPA-IX-2 (15.6 cm), CHESPA-I-2 (15.3 cm) and CHESPA-II-4 (15.1 cm). Lower panicle (<10 cm) length was recorded in accessions CHESPA-IX-3, CHESPA-XVII-1 and CHESPA-I-4. The number of panicles/ shoot ranged from 2.6 in CHESPA-I-4 to 13.8 in CHESPA-XII-4. Higher numbers of panicles per shoot were recorded in CHESPA-XVII-2(13.6), CHESPA-XVII-1 (10.6), CHESPA-XII-2(10.2) and CHESPA-XVI-1 (10.2). The lower numbers of panicles/shoot was recorded in CHESPA- I-4 (2.60), CHESPA-XVI-4 (2.80) and CHESPA-I-3(3.40). The number of flowers/shoot ranged from 22.68 to 218.96. The higher numbers of flowers/shoot were recorded in CHESPA-XVII-2 (218.96) and CHESPA-XII-4 (163.29). Lower numbers of flowers/shoot were recorded in CHESPA-III-3 (22.68), CHESPA-IX-3 (25.80) and CHESPA-V-1(30.32) (Table 1). The panicles were produced on terminal bud and most of them were determinate type. Avocado flowers twice in a year under Coorg conditions and some time abrupt flowering has been observed. The off-season panicles are usually smaller than normal. The panicle length and number of flowers/ panicle are greatly influenced by maturity of shoot, bearing habit of tree, climatic conditions, exposures to low temperature and soil moisture stress in several fruit trees species (Lesley and Bringhurst 1951).

Categorization of accessions

The flowers of the accessions were hermaphrodite. The double opening of flowering was noticed in all the accessions. In first opening only stigma was receptive. The second opening was next day when only anther dehiscence took place. Most of the flowers opened in the morning time between 8.00 AM to 10.00 AM but some of the flowers opened in the afternoon between 2.00 PM to 5.00 PM An individual flower opened for 2 days, however the timing of the male and female phases were different. When the flower first opens it was in the female phase and the stigma was receptive to pollen. At the end of the female phase, which lasted 2 to 4 h, the flower closed. On the second day the same flower re-opened in the male phase and shed its pollen. The timing of the male and female phases was different among different accessions. Based on this unique flower behaviour, avocado accessions were classified in 'A' and 'B' types (Table 2). The accessions CHESPA-III-2, CHESPA-III 3, CHESPA-IV-1, CHESPA-IV- 3,

Table 1 Panicle length, number of panicles/shoot of avocado accessions

Accession No.	Length of panicle(cm)	No. of panicles/shoot	No. of flowers/shoot
CHES PA-I-2	15.3	3.80	67.25
CHES PA-I-3	12.9	3.40	61.20
CHES PA-I-4	9.6	2.60	35.32
CHES PA-II-1	13.2	8.80	75.68
CHES PA-II-2	16.9	6.80	81.60
CHES PA-II-3	17.9	7.80	66.30
CHES PA-II-4	15.1	5.20	53.80
CHES PA-III-2	14.8	3.80	36.72
CHES PA-III-3	11.0	3.60	22.68
CHES PA-IV-1	12.1	7.60	92.26
CHES PA-IV-2	11.4	7.00	60.20
CHES PA-IV-3	12.0	8.20	83.64
CHES PA-V-1	14.1	3.80	30.32
CHES PA-V-2	16.1	6.40	78.72
CHES PA-V-3	11.4	8.20	123.82
CHES PA-VI-1	13.3	8.00	80.00
CHES PA-VI-2	14.7	7.60	110.96
CHES PA-VI-3	11.4	6.40	72.50
CHES PA-VI-4	11.1	6.20	74.52
CHES PA-VII-1	13.3	6.40	86.15
CHES PA-VII-2	17.6	6.90	78.44
CHES PA-VIII-2	11.3	8.80	117.04
CHES PA-VIII-3	18.4	4.40	40.59
CHES PA-IX-2	15.6	8.20	82.16
CHES PA-IX-3	5.16	5.00	25.80
CHES PA-X-2	10.4	7.00	51.94
CHES PA-X-4	10.5	9.20	96.97
CHES PA-XII-1	16.8	7.80	81.25
CHES PA-XII-2	10.6	10.20	107.71
CHES PA-XII-4	11.6	13.80	163.39
CHES PA-XVI-1	12.94	10.20	131.99
CHES PA-XVI-2	14.0	8.60	84.28
CHES PA-XVI-4	11.0	2.80	34.34
CHES PA-XVII-1	9.2	10.60	134.41
CHES PA-XVII-2	13.4	13.60	218.96
CD (P=0.05)	1.61	1.38	21.89

CHESPA-VI-1, CHESPA-VI-2, CHESPA-VI-3, CHESPA-VI-4, CHESPA-VII-1, CHESPA-VII-2, CHESPA-XII-1, CHESPA-XII-2, CHESPA-XII-4, CHESPA-XVI-1, CHESPA-XVI-2, CHESPA-XVI-4, CHESPA-XVII-1 and CHESPA-XVII-2 were found Type 'A' type while accessions CHESPA-I-2, CHESPA-I-3, CHESPA-I-4, CHESPA-II-1, CHESPA-II-2, CHESPA-II-3, CHESPA-II-4, CHESPA-V-1, CHESPA-V-2, CHESPA-V-3, CHESPA-VIII-2, CHESPA-VIII-3, CHESPA-IX-2, CHESPA-IX-3, CHESPA-X-2 and CHESPA-X-4 were found 'B' Type (Table 2 and 3). The categorization base based on the earlier reports where the avocado varieties and accessions were found to have 'A' and 'B' types genotypes (Bergh 1974, Davenport 1986).

Table 2 Time of opening and closing of pistillate and staminate stages of Type 'A' avocado accessions

Accession No.	First day (Pistillate)		Second day (Staminate)	
	Opening	Closing	Opening	Closing
CHESPA-III-2	10.30 AM	2.30 PM	3.00 PM	6.00 PM
CHESPA-III-3	10.30 AM	2.30 PM	3.00 PM	6.00 PM
CHESPA-IV-1	10.00 AM	12.30 PM	1.00 PM	4.30 PM
CHESPA-IV-2	10.00 AM	12.30 PM	1.00 PM	4.30 PM
CHESPA-IV-3	10.00 AM	12.30 PM	1.00 PM	4.30 PM
CHESPA-VI-1	9.30 AM	12.30 PM	1.00 PM	4.00 PM
CHESPA-VI-2	9.30 AM	12.30 PM	1.00 PM	4.00 PM
CHESPA-VI-3	9.30 AM	12.30 PM	1.00 PM	4.00 PM
CHESPA-VI-4	9.30 AM	12.30 PM	1.00 PM	4.00 PM
CHESPA-VII-1	9.30 AM	12.30 PM	1.00 PM	4.00 PM
CHESPA-VII-2	9.30 AM	12.30 PM	1.00 PM	4.00 PM
CHESPA-XII-1	9.30 AM	12.30 PM	1.30 PM	5.30 PM
CHESPA-XII-2	9.30 AM	12.30 PM	1.30 PM	5.30 PM
CHESPA-XII-4	9.30 AM	12.30 PM	1.30 PM	5.30 PM
CHESPA-XVI-1	11.00 AM	2.30 PM	4.30 PM	7.00 PM
CHESPA-XVI-2	11.00 AM	2.30 PM	4.30 PM	7.00 PM
CHESPA-XVI-4	11.00 AM	2.30 PM	4.30 PM	7.00 PM
CHESPA-XVII-1	9.45 AM	2.00 PM	1.30 PM	4.30 PM
CHESPA-XVII-2	9.45 AM	2.00 PM	1.30 PM	4.30 PM

Flowering duration and flower opening

The flowering period of selected accessions ranged from 26 to 53 days. The flowering started in third week of September and ended in second week of November. The longest flowering period was recorded in CHESPA-XII-2 (53 days) from 20 September to 12 November. The accessions CHESPA-II-4, CHESPA-IV-1, CHESPA-V-3 ,

Table 3 Time of opening and closing of pistillate and staminate stages of Type 'B' avocado accessions

Accession No.	First day (Pistillate)		Second day (Staminate)	
	Opening	Closing	Opening	Closing
CHESPA-I-2	1.00 PM	3.30 PM	9.30 AM	6.30 PM
CHESPA-I-3	1.00 PM	3.30 PM	9.30 AM	6.30 PM
CHESPA-I-4	1.00 PM	3.30 PM	9.30 AM	6.30 PM
CHESPA-II-1	1.00 PM	3.30 PM	9.30 AM	6.30 PM
CHESPA-II-2	1.00 PM	3.30 PM	9.30 AM	6.30 PM
CHESPA-II-3	1.00 PM	3.30 PM	9.30 AM	6.30 PM
CHESPA-II-4	1.00 PM	3.30 PM	9.30 AM	6.30 PM
CHESPA-V-1	1.45 PM	4.30 PM	11.45 AM	6.30 PM
CHESPA-V-2	1.45 PM	4.30 PM	11.45 AM	6.30 PM
CHESPA-V-3	1.45 PM	4.30 PM	11.45 AM	6.30 PM
CHESPA-VIII-2	3.00 PM	6.30 PM	8.45 AM	3.15 PM
CHESPA-VIII-3	3.00 PM	6.30 PM	8.45 AM	3.15 PM
CHESPA-IX-2	4.15 PM	7.00 PM	7.30 AM	5.00 PM
CHESPA-IX-3	4.15 PM	7.00 PM	7.30 AM	5.00 PM
CHESPA-X-2	1.00 PM	5.30 PM	11.00 AM	7.00 PM
CHESPA-X-4	1.00 PM	5.30 PM	11.00 AM	7.00 PM

Table 4 Comparison of flowering and fruiting behaviour of A and B type accessions of avocado

Accession	Length of panicle (cm)	No. of branch	No. of flowers/ branch	Initial fruit set (%)	Final fruit set (%)	Fruit weight (g)
A Type	12.76	7.86	89.18	3.32	0.27	308.93
B Type	13.37	6.43	71.30	4.27	0.37	421.99
CD (P=0.05)	NS	NS	NS	NS	NS	NS

CHESPA-XII-2, CHESPA-XVI-1 started early flowering. Among these accessions CHESPA-IV-1 and CHESPA-XII-2 are 'A' type while CHESPA-II-4 and CHESPA-V-3 are 'B' type. The accessions CHESPA-XII-2, CHESPA-XII-4, CHESPA-XV-2, CHESPA-XVI-4 flowered late in the season and all of them are 'A' type. The peak flowering period of most the accessions was second and third week of October and in majority of the accessions, it was coinciding with each others. The flowering duration and initiation of flowering was different in different accessions.

The flowering in 'A' type accessions the pistillate flower opened on first day between 9.30 AM and 2.30 PM. The duration of flower opening was two and half hours to four hours. Some of the accessions CHESPA-VI-1, CHESPA-VI-2, CHESPA-VI-3, CHESPA-VII-2, CHESPA-XII-2, CHESPA-XII-2 and CHESPA-XII-4 flower started opening at 9.30 AM and closed by 12.30 PM. In CHESPA-XVII-1, CHESPA-XVII-2, the flower open at 9.45 AM and closed at 2.00 PM. In other accessions, the flower opened at 10.30 AM and closed at 2.30 PM. The staminate flowers opened on next day 1.00 PM to 3.00 PM and closed between 4.00 PM to 7.00 PM. The duration of flower opening was two and half hours to four hours (Table 2).

In 'B' type accessions, pistillate flower opened in the afternoon of first day between 1.00 PM and 7.00 PM. The duration of flower opening was two and half hours to four hours. In some accessions namely CHESPA-I-2, CHESPA-I-3, CHESPA-I-4, CHESPA-II-1, CHESPA-II-2, CHESPA-II-4, flowers opened at 1.00 PM and closed by 3.30 PM. In other accessions flower opened at 4.15 PM and closed at 7.00 PM. The staminate flowers opened on next day 7.30 AM to 11.45 AM and closed between 3.15 PM to 7.00 PM. The flower opening duration in these accessions was between 7.0 to 9.0 hours (Table 3). The similar flowering behaviour of avocado was reported by several workers in the past (Lesley and Bringham 1951, Sedgley 1977, Sedgley and Annels 1981, Ish-Am and Eisikowitch 1991). Generally under optimum conditions, the floral behaviour is predictable. However, the flower opening cycle is sensitive to environmental conditions, mainly temperature. The sensitivity of the flowering behaviour to environmental factors depends on the cultivars, and, in general, type 'B' cultivars are more sensitive than type 'A' cultivars to low temperatures (Sedgley and Grant 1983).

Initial fruit set and Final fruit set

The average initial fruit set was 3.62 percent. It was highest (8.74%) in accession CHESPA-VIII-3 and the lowest (0.50%) in CHESPA-VI-1. The accessions CHESPA-I-3,

CHESPA-II-3, CHESPA-IV-1, CHESPA-V-1, CHESPA-V-2, CHESPA-VII-2, CHESPA-VIII-2, CHESPA-IX-3, CHESPA-X-2, CHESPA-XII-2 recorded more than 5.0% initial fruit set. Some accessions, i.e. CHESPA-XVI-1, CHESPA-VI-1, CHESPA-II-4 and CHESPA-I-2 recorded low initial fruit set. There was heavy fruit drop during the growth and development of fruits and average final fruit set was only 0.31%. There was 100% fruit drop in selected shoots of 24 accessions and no fruit were recorded on selected panicles. However, there were few fruits on other shoots. The highest final fruit set (1.32%) was recorded in accession CHESPA-II-1. The fruit weight was highest in accession CHESPA-II-1 (563 g) while yield was highest in CHESPA-VII-1 (83 kg/tree). This may be correlated with improper pollination and environmental conditions during flowering period and growth and development of fruits. Excessive flower and fruit abscission a general problem in avocado fruit production and final fruit set range from 0.001 to 0.23% (Sedgley 1980, Davenport *et al.* 1994). The comparison of 'A' and 'B' types of accessions shows that there is no difference in the length of panicles, number of panicles/shoot, number of flowers/panicle, initial and final fruit set, yield and fruit weight of these accessions (Table 4). The results revealed that the different flowering pattern do not have any relationship with flowering and fruiting characters.

The study revealed that the avocado accessions belong to both 'A' and 'B' types. These accessions have different pattern of flower opening but there is no difference in the flowering and fruiting characters. Further the information may be useful while indentifying the elite accessions of 'A' and 'B' types so that they may serve as better pollen parents for each other in commercial plantations.

REFERENCES

- Bergh B O. 1974. The remarkable avocado flower. *California Avocado Society Year Book* 57:40-1.
- Davenport T L. 1986. Avocado flowering. *Hortic. Rev.* 8: 257-89.
- Davenport T L, Parnitzki P, Fricke B S and Hughes M S. 1994. Evidence and significance of self pollination of avocados in Florida. *Journal of American Society of Horticultural Science* 114: 1 200-7.
- Ish-Am I G and Eisikowitch D. 1991. New insight into avocado flowering in relation to its pollination. *California Avocado Society Year Book*. 75: 125-37.
- Ghosh S P. 2000. Avocado production in India. In avocado production in Asia and pacific. FAO publication 2000/09, FAO regional office, Bangkok, p 24-30.
- Lahav F and Gazit S. 1994. World of avocado cultivation according

- to flowering type. *Fruits* **49**: 299–313.
- Lesley J W and Bringhurst R S. 1951. Environmental conditions affecting pollination of avocados. *California Avocado Society Year Book*. **36**: 169–73.
- Panse V G and Sukhatme V G. 1995. *Statistical Methods for Agricultural Workers*, 2nd Edition. ICAR, New Delhi.
- Sedgley M. 1980. Anatomical investigation of abscised avocado flowers and fruitlets. *Annals of Botany* **46**: 771–7.
- Sedgley M. 1977. The effect of temperature on floral behaviour, pollen tube growth and fruit set in the avocado. *Journal of Horticultural Science* **52**: 135–41.
- Sedgley M. 1987 Flowering, pollination and fruit set of avocado. *S. Afr. Avocado Growers 'Association Year Book*. **10**: 42–3.
- Sedgley M and Annels C M. 198. Flowering and fruit-set response to temperatures during flowering on floral cycle and pollen tube growth in nine avocado cultivars. *Sci. Hortic.* **18**: 207–13.
- Sedgley M and Grant W J R. 1983. Effect of low temperatures during flowering on floral cycles and pollen tube growth in nine avocado cultivars. *Science Horticulture* **18**: 207–13.
- Tripathi P C, Sankar V, Senthil kumar R and Priti Sonavane. 2015a. Avocado –Introduction. (In) *Souvenir and Abstract of Brain Storming Session on Avocado*, CHES Chettalli, May 27, 1–6.
- Tripathi P C, Karunakaran G, Sakthivel T, Sankar V Senthil Kumar R, Jayanthi Mala B R, Priti Sonavane, Ravisankar H and Chithraichelvan R. 2015b. Avocado Research at CHES Chettalli. (In) *Souvenir and Abstract of Brain Storming Session on Avocado*, CHES Chettalli, May 27, 7–17.