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STUDIES ON FLORAL BIOLOGY AND BREEDING BEHAVIOUR OF SWEET ORANGE [*CITRUS SINENSIS* (L.) OSBECK.]

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ABSTRACT
In sweet orange flowering takes place only once in year *i.e.* February–March under North Indian conditions. The duration of floral bud development was 19-23 days in different cultivars and Jaffa was earliest to start flowering. The duration of flowering was 20-23 days in the cultivars. These cultivars came to full bloom in first week of March. Two type of inflorescence were observed *i.e.* leafy and leafless. The flowers were born on current season's growth in the axils of leaves either solitary or in cymes. Flower structure observed in sweet orange with five sepals, five petals and twenty stamens with superior ovary. The maximum opening of flowers and dehiscence of anthers took place in morning hours (10.00 A.M. to 12.00 noon) in all the cultivars. Stigma became receptive just after anthesis and remained receptive till 72 hours for pollination in all the cultivars. The maximum receptivity was recorded on the day of anthesis. The highest fruit set was recorded in cultivar Jaffa under open pollination (32.84%) followed by self-pollination (29.81%). From the results obtained, it showed that sweet orange cv. Jaffa followed by Pineapple proved to be best with respect to flowering and fruit set.

INTRODUCTION

Citrus is a commercially important fruit crop of India and grown across country with a production of 7.46 million tons from an area of 0.84 million hectares (Mistry *et al.,* 2012). Sweet orange has been reported to be originated in Southern China and, it was introduced to India during thirteenth century (Swingle, 1943; Webber, 1948). It is the second largest citrus fruit, cultivated in tropical and subtropical regions of the country. In India sweet orange is mainly cultivated in Andhra Pradesh, Maharashtra, Karnataka, Punjab, Rajasthan and Haryana on 0.15 million ha with a production of 1.31 million tonnes. Andhra Pradesh is the leading sweet orange producing state sharing 49 per cent of total production (Mistry *et al.,* 2012).

The intensity of flowering is influenced greatly by the period of growth cessation, and the amount of preceding bloom or crop. In North Indian conditions, where the temperature goes down substantially during winter months, major bloom of almost all citrus species occurs during early spring (February-March) when the atmospheric temperature starts rising after the cold winter and soil moisture conditions are suitable (Hayes, 1970). In South India, where there is no well-defined winter, the flowering season is longer and not very distinct. It is very common to get two crops, occasionally three also, in many citrus types grown in South India. The flowering can however, be regulated by withholding soil moisture or through fruit thinning by chemicals and adjustment of fruit harvesting (Naik,1963).

In addition, the knowledge of floral morphology, biology and fruit set are essential pre-requisite for initiating any breeding programme. Besides, such information would also be useful in taxonomical studies (Randhawa *et al.,* 1961). The floral biology in plants is also useful for understanding the mechanism of self-incompatibility and pollen sterility, which have major role in fruit breeding and fruit productivity. Flowering is a key process in citriculture and its evaluation is often difficult due to the canopy structure and field sampling. It also helps to fruit grower in selecting suitable cultivars which have higher yield potential and to adjust cultural operation in relation to flowering and fruiting (Ribeiro *et al.,* 2008).Although some data are available regards the floral biology of sweet orange but there is need of these studies in present changing climatic condition and to know the impact and response of fruit trees to these. Thus, with a view to provide up to date information regarding the floral biology of the sweet orange, the present investigations were undertaken to study the floral biology and breeding behavior of sweet orange (*citrus sinensis* (L.) Osbeck.) under Hisar condition.

MATERIALS AND METHODS

The experiment was carried out at the Orchard of Department of Horticulture, CCS Haryana Agricultural University, Hisar during 2013-14 growing season. Observations were recorded on floral bud development, time of flowering, duration of flowering, floral morphology, time of anthesis, dehiscence of anthers, stigma receptivity, and fruit set on four sweet orange cvs. Pineapple, Blood Red, Jaffa and Mosambi and analysis was worked out by Randomized Block Design with four treatment and five replications.

The aspects of floral biology like stages of flower bud development, season and duration of flowering, fruiting habit, floral morphology, sex ratio, anthesis, anther dehiscence, receptivity of stigma and fruit set were studied. For these studies, sufficient number fruiting shoots/inflorescence was selected at random. The observations were recorded from January to May 2013. The flower bud development was studied in seven different stages and average number of days required for completion of each stage was recorded. The dates of opening of first flower bud, till last date of blooming were recorded as season and duration of flowering. The emergence of flower buds/ inflorescence was noted as terminal, axillary or both (mixed) and with or without leaves and type of inflorescence as cymose, pair or solitary. The number of staminate and hermaphrodite flowers was recorded to work out sex ratio. The time of anthesis and anther dehiscence were studied at two-hour intervals commencing from 08.00 AM to 06.00 PM. The receptivity of stigma was studied by visual observation and by artificial pollination of flower at one day before anthesis, on the day of anthesis, one and two days after anthesis respectively and judged by the setting of fruits. To find out mode of pollination studies like fruit set observed by open (natural) pollination and selfing through bagging and percent of fruit setting recorded in both the mode of pollination.The overall significance of difference among the treatments was tested, using critical differences (C.D.) at 5% level of significance. The results were statistically analyzed with the help of a windows based computer package OPSTAT (Sheoran, 2004).

RESULTS AND DISCUSSION

Flower Bud Development

The flower bud development from emergence to bud burst, grouped in to seven different stages, had been described morphologically in Fig. 1.which required 19.8 (Jaffa) to 23.2 (Mosambi) days for its completion (Table 1). The days required for full bud development from the initiation of buds was between 19.8 days in Jaffa which is significantly lower than other cultivars 'Pineapple' and 'Blood Red' are at par with each other (20.8 days) and Mosambi took 23.2 days which is significantly higher than other cultivars. Rajput and Haribabu(1985) reported similar results under north Indian condition in sweet orange.

Stage- I to II

In the first stage buds just emerged, they are in the leaf axil or terminal end and fully covered with calyx. These were roundish, tiny and completely covered by calyx lobes and green in color. The buds at stage-I took 3.4 days in Jaffa to 4.4 days in Pineapple for reaching stage- II

Stage- II to III

The second stage commenced when the calyx lobes were observed to have just separated at the apex and the corolla tube was discernible. These were also roundish. The bud at stage-II took 3.6 days in Jaffa to 5.4 days in Mosambi for reaching stage- III.

Stage- III to IV

In stage-III, buds are conical to roundish in shape and length of corolla tube and calyx cup are almost equal. The bud at stage-III took 4.4 days in Pineapple to 5.2 days in Mosambi for reaching stage- IV.

Stage- IV to V

When the buds were almost half developed, they were considered to be in the fourth stage of development. The length of corolla is almost double the length of calyx. The buds remained in this stage for 3.4 days in Pineapple to 4.4 days in Mosambi.

Stage- V to VI

In stage-V, buds are usually elliptic ovate in shape, length of corolla tube being approximately three time the calyx cup. The buds remained in this stage for 3 days and this was same

Table 1: Flower bud development stages, time and duration of flowering

Cultivars	Number of days required for passing from one stage to the other						Total number of days	Time of flowering		Duration of flowering (days)
	I to II	II to III	III to IV	IV to V	V to VI	VI to VII		Initiation of flowering	End of flowering	
Pineapple	4.4	4.6	4.4	3.4	3	1	20.8	2nd March	22nd March	20.2
Blood Red	4.2	4.2	4.6	3.8	3	1	20.8	7th March	29th March	21.4
Jaffa	3.4	3.6	4.6	4.2	3	1	19.8	28th Feb.	23rd March	23.5
Mosambi	4.2	5.4	5.2	4.4	3	1	23.2	9th March	31st March	21.4
Average	4.0	4.4	4.7	3.9	3	1	21.1	-	-	21.6
SE(m) ±	-	-	-	-	-	-	0.30	-	-	0.38
CD at 5%	-	-	-	-	-	-	0.94			1.21

Table 2: Time of anthesis and dehiscence of anther in sweet orange cultivars (Flowers opened at two hours interval in percentage)

Cultivar	8 AM – 10 AM		10 AM – 12 PM		12 PM– 2 PM		2 PM – 4 PM		4 PM – 6 PM	
	A	D	A	D	A	D	A	D	A	D
Pineapple	11.04	11.91	42.75	43.13	22.09	24.01	12.20	12.43	09.32	6.48
Blood Red	12.73	11.23	41.25	42.76	21.77	25.25	11.91	13.01	09.34	5.64
Jaffa	10.50	13.63	42.97	44.55	21.59	22.76	12.54	12.69	09.98	4.63
Mosambi	11.47	11.95	42.36	42.44	22.51	24.15	12.59	13.69	07.83	5.52

A- Anthesis, D- Dehiscence of anthers

Table 3: Per cent stigma receptivity through visual and fruit set method

Cultivars	Per cent stigma receptivity based on							
	Visual obs. One day before anthesis	% fruit set	Visual obs. On the of day of anthesis	% fruit set	Visual obs. One day after the anthesis	% fruit set	Visual obs. Two days after anthesis	% fruit set
Pineapple	24.4	25.3	77.7	73.7	44.0	31.6	21.1	14.4
Blood Red	24.4	26.8	81.8	76.8	42.5	32.9	22.7	15.5
Jaffa	26.1	26.1	79.2	75.3	40.7	32.5	22.7	15.5
Mosambi	26.8	26.1	80.0	74.0	42.4	30.3	22.4	15.7
Average	25.4	26.1	79.7	74.9	42.4	31.8	22.2	15.3

Table 4: Fruit set under different modes of pollination (%).

Cultivars	Per cent fruit set under	
	Self pollination	Open pollination
Pineapple	26.38(32.58)	29.03(30.88)
Blood Red	25.94(31.11)	26.73(30.59)
Jaffa	29.81(34.94)	32.84(33.07)
Mosambi	26.39(32.34)	28.66(30.90)
SE(m) ±	0.47	0.33
CD at 5%	1.46	1.05

for all the cultivars.

Stage- VI to VII

In stage-VI, buds usually attain their full size and shape and were fully developed. No further elongation of bud took place. A faint suture appeared at the top of corolla tube and ready to open next day. The buds remained in this stage only for one day in all the cultivars.

Stage- VII

In this stage, flowers are fully open. It was interesting to note that number of days required increases from stage one to stage four and then reduced with the advancement of the season in all the cultivars. The development of a flower bud in citrus is greatly influenced by the prevailing temperature. A low temperature induces many buds to grow out and most of these are floral. As the temperature increases time taken by a bud to develop is reduced (Rajpoot and Haribabu, 1985).

Time and Duration of flowering

The initiation of flowering varied from 28th February in Jaffa to 9th March in Mosambi (Table 1) and same trend was observed in full bloom and end of flowering. The total duration of flowering in sweet orange cultivars varied from 20.2 days to 23.5 days. Sweet orange cultivar Jaffa took maximum number of days (23.5) to complete flowering and minimum days were in cv. Pineapple (20.2). The cultivar Pineapple and Blood Red took equal numbers of days *i.e.* 20.8 days for flowering. However, owing to the diversity in climate in India, citrus species are observed to flower in other season also. Under Hisar condition where there are distinct winter and summer seasons, the sweet orange bloom only once in year *i.e.* in spring (February- March) whereas, Sathgudi orange in South India, flowers during December-April and September-December. In Central and Western India, oranges flower three times *i.e.*June,October and February (Sharma and Hare Krishna, 2014). The flowering season is mainly influenced by climatic conditions especially thetemperature level also observed in mango by Singh *et al.* (2014).

Earlier studies of revealed that variations in flowering seasonality based upon environmental factors and genetic makeup of the cultivars (Nebauer *et al.,* 2006). Citrus flowering that it is a complex process and is influenced by number of interacting factors. Low winter temperature is recognized as an important factor, but the flowering response has not been quantified under variable natural conditions. Results shows that buds at apical positions produced more flowers than buds located far from the apex and crop load reduced flowering by an average of 41.5% compared to no crop load and varied cultivar (Valiente and Albrigo, 2004).

Floral biology

In all cultivars, flower buds were found to be mostly arising from the axils of the leaf and sometimes terminal. Two types of inflorescence were observed *viz*. leafy inflorescence and leafless inflorescence. The mean percentage of leafy inflorescence was higher (81.30%) than the leafless inflorescence (18.40%). Number of flowers per inflorescence varied according to the type of inflorescence *i.e*. leafy inflorescence (20.70) or leafless inflorescence (14.08), similarly two types of inflorescence were reported by Xuehu *et al*. (2009) in Tankan (*Citrus tankan* Hayata). Two types of flowers were observed in sweet orange, *viz*. hermaphrodite (complete) and staminate (incomplete). The former had fully developed pistil, stamens, while in the latter only stamens were developed and the pistils were either rudimentary or partially developed. The mean percentage of hermaphrodite flowers was recorded higher (76.98%) than the staminate flowers (22.93%). The calyx is a cup like structure surrounding the base of the petals. It is green in color. The number of sepals is usually five, which are, united (Gamosepalous). The corolla has usually five petals. They are usually white, they are not united (Polypetalous). The number of anthers in sweet orange found mostly 20. The filaments are more or less united at base into groups of four or five and are free at the apex (Polyadelphous). The superior type of ovary was found in all cultivars of sweet orange. Similar results were reported by Rajput and Haribabu (1985) under North Indian conditions.

Time of anthesis and anther dehiscence

All the varieties were in peak period of flowering during March and five trees of each variety were selected for counting the number of flowers opened in day observations started at 8 AM when practically opening of flowers just started and continued till 6 PM, by which time the anthesis for the day was more or less over. Flower was considered to be anthesized when all the petals were fully opened. It is clear from data (Table 2) that the time of anthesis in all sweet orange cultivar is spread from 8 AM to 6 PM with peak anthesis at 10 AM to 12 noon closely followed by 12 noon to 2 PM, similar pattern of anthesis recorded in local malta of sweet orange (Manju and

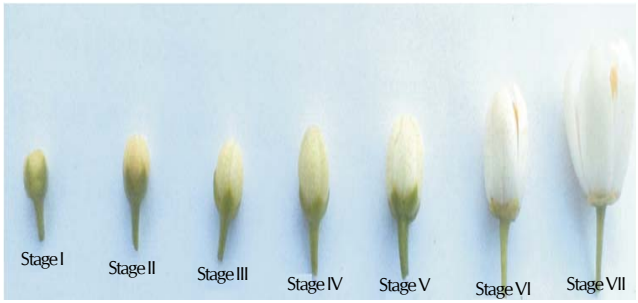

Figure 1: Floral bud development stages in sweet orange cultivars

Rawat, 2010).The rate ofanthesis was retarded during 4 to 6 PM. The dehiscence of anthers started simultaneously with the anthesis. The anthers became pale yellow with powdery mass and a longitudinal slit was formed between the lobes. Mostly in all the cultivars anther dehiscence took place just after anthesis started at 8 AM and continued up to 6 PM. Maximum anther dehiscence (42.44 to 44.55 %) took place between 10 AM to 12 AM. In some citrus varieties, reported the time of anthesis between 9 AM to 12 noon and dehiscence of anthers between 10 to 14hours, thus indicating species and varietal differences in respect of anthesis and anther dehiscence (Rajput and Haribabu, 1985). Similarly,the peak period of dehiscence was observed from 10.00 to 12.00 in *Aloe vera* (Rathod *et al.*, 2014).

Stigma receptivity

Stigma receptivity in Sweet orange cultivars was observed by two methods, which are illustrated in details as follows-

By visual method

on the basis of appearance and color of the stigma appeared to be receptive one day before anthesis and continued up to two day after anthesis. The peak period of anthesis was recorded on the day of anthesis in all the cultivars (Table 3).

By fruit set method

The observation based on actual pollination test showed the similar results like the visual observation (Table 3). All the sweet orange cultivars showed variation in stigma receptivity. The maximum fruit set was obtained when pollination was done on the day of anthesis. The maximum fruit set was obtained when pollination was done on the day of anthesis (73.7 to 76.8%). There after a sharp decline was noticed in the fruit set. Rajput and Haribabu (1985) reported that most receptivity period of stigma was found on the day of anthesis, followed by the day succeeding and preceding the anthesis (Rajput and Haribabu, 1985).

Fruit set (%)

Fruit set was determined by two modes of pollination *i.e.*selfing by bagging and open pollination. In all the sweet orange cultivars higher fruit set was obtained in open pollination than self-pollination. In open pollination, fruit set was recorded maximum (32.84%) in Jaffa and minimum in Blood Red (29.81%), similarly in self-pollination higher fruit set was recorded in Jaffa (26.73%) and low set was in Blood Red (25.94%) (Table 4). It is clear from results that, the percentage of fruit-set was more in open pollination than self-pollination. The observations on fruit set Malta lemon were recorded by RajputandHaribabu(1985) in Delhi condition. They found that fruit set was significantly higher in Malta lemon when the flowers were cross-pollinated. Greater fruit set was observed in the leafy than in the leafless inflorescence, although the variation was not significant (Iqbal and Karacali, 2004).

Values given in parentheses are angular transformed

This suggests a sort of self-incompatibility, which, however, needs further confirmation. Experiment conducted by Saleem *et al*. (2008) shows that Polyamines significantly increased initial fruit set, yield/tree, and production of grade-I fruit. Maximum fruit set (25.89%) was observed on trees sprayed with spermidine followed by spermine (22.73%) and putrescine (15%) compared with control (10.10%).In many commercial citrus species, high fruit load inhibits vegetative growth and floral induction. As a result, trees that had a high fruit load will bear few flowers and fruit the following year, along with abundant vegetative growth and high fruit load impacts the process of flowering (Samach and Smith, 2013).

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