Reproductive Biology of Tamarind (*Tamarindus indica* L.) under Semi-Arid Tropics of Western India

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Reproductive biology of fifteen elite genotypes of tamarind was studied during the year 2004 and 2005. Peak period of panicle emergence and flowering was recorded in the month of July and August, respectively in majority of genotypes. It was found to be earliest in CPT 1 closely followed by CPT 2, CPT 3, CPT 11 and CPT 13. Variable percentage of anthesis/ dehiscence was registered in different genotypes. Peak period of anthesis was recorded between 7-9 AM in all the genotypes during both the years. None of the genotypes showed anthesis before 5 A M and after 11AM. Anther dehiscence commenced after opening of flowers, *i.e*., at 8AM and continued till 12 noon. Peak period of dehiscence was recorded between 9-11 AM in all genotypes. None of the genotypes showed anther dehiscence before 8 AM and after12 noon. Time taken for complete development of flower ranged from 18-26 days, pollen viability ranged from 80.10-94.13 per cent being highest in CPT 3. Pollen germination ranged from 10.11–18.13 per cent being at the top in CPT 3 (18.13 per cent). Pollen diameter ranged from 34.12- 42.14 micron. Pollen grain was spherical in shape having light yellow colour in all genotypes. CPT 13 recorded maximum panicle length (15.20 cm) and fruit set per panicle (16.80). The peak period of fruit set was recorded in the month of September in majority of genotypes. These genotypes are being further evaluated.

Key Words: Anthesis, Dehiscence, Pollen germination, Pollen viability, Tamarind

Introduction

Tamarind (*Tamarindus indica* L.), a member of sub-family Caesalpiniaceae of family Fabaceae, is highly drought hardy and can be grown in dry land areas and on degraded wasteland. It is considered to be one of the most exquisite and valuable fruits of the tropics and sub tropics. It is the source of timber, fruits, seeds, fodder, medicinal extracts and has potential of industrial use (Karale *et al.*, 1999; Awasthi and Sharma, 1998; Pareek and Awasthi, 2002). It is highly heterozygous, cross-pollinated fruit crop and as such seedlings exhibit a wide range of variations, which aids in the selection of the superior desirable genotypes. Due to cross pollination and predomination of seed propagation over a large period of time, it gives immense opportunity to locate elite trees having horticultural traits. Tamarind flowers are always borne on newly emerging vegetative shoots irrespective of the time of year. In tamarind, anthesis starts in the morning as early as 4.30 AM and continues up to 8.30 AM with peak period at 6.30 AM (Karale, 2002). Thimaraju *et al*. (1977), Usha and Singh (1994), Sharma *et al.* (1994), Kumar *et al.* (2004) Singh and Singh (2004) and Singh *et al.* (2004) have also studied floral biology of tamarind, Jalphai (*Elaeocarpus floribundus* Bl), guava, peach and pear genotypes under various climatic conditions. Peak period of anthesis and dehiscence from 6.30-8.30 AM was observed in different guava genotypes (Dhaliwal and Singla, 2002; Singh, 2004). Fruit set was only 36 per cent with open pollination and increased to 56 per cent with cross-pollination in tamarind (Usha and Singh, 1996). In spite of the fact that tamarind can withstand adverse climate and grow in various types of soil, only a few attempts to improve its varietal wealth have been made under semi-arid regions. To begin with development of new elite genotypes, the information on detailed reproductive biology of the crop is essential. Therefore, studies were undertaken to gather this type of information under semi-arid conditions of western India.

Materials and Methods

The tamarind trees are found scattered through out Gujarat from cultivable land to waste lands. An extensive survey was carried out in district Panchamahals and fifteen promising genotypes were selected during the year 2004 and 2005 that had fairly wide spectrum of variability of various characters and they were considered as experimental materials. Thirty healthy panicles in each genotype were randomly selected to record panicle length and fruit set per panicle. To observe the time for anthesis and dehiscence, 50 flower buds expected to open the next days were tagged on the previous evening. The number of fully opened flowers was noted at one-

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hour interval (starting from 5.00 AM in the next morning). Fully opened flowers were marked with delible ink to avoid recounting. Like wise for dehiscence, fully dehisced anthers were removed to avoid confusion. These observations continued till all the 50 flower buds in each genotype anthesised/dehisced completely during the years of experimentation. The pollen viability in different genotypes was tested with two per cent acetocarmene solution. The pollen from freshly dehisced anthers was put on the slides. About 2 drops of freshly prepared 2 per cent acetocarmine solution was added to the slides and was covered gently with a cover slip. The mounted pollens were examined under the microscope after about 15 minutes, when they had attained proper staining. Pollen which stained deeply, looked normal and symmetrical were considered to be viable and the remaining ones as non-viable. Observations on pollen germinability was recorded by using hanging drop method in 15 per cent sucrose solution after 24 h.

Results and Discussion

The observations on flowering studies, presented in Table 1, showed that peak period of panicle emergence was recorded in the month of July in majority of genotypes. It was noted in the month of August in CPT 9, CPT 10, CPT 14 and CPT 15. There was only one genotype, *i.e.*, CPT 1 which recorded peak period of panicle emergence in the month of June. The peak period of flowering was found to be earliest in CPT 1 (1st July) closely followed by CPT 2, CPT 3, CPT 4 and CPT 8 (Table 1). Similar trend with respect of panicle emergence and flowering was found in another successive year (2005) in different genotypes. Wide variability in respect of panicle emergence and period of flowering was recorded in mango and litchi under humid sub tropics of eastern India (Singh, 2002; Hoda *et al.*, 2003; Ray *et al.*, 2002; Das *et al.*, 2004).

The data indicated that anthesis started at 5 AM and continued up to 11 AM. The optimum time for anthesis was found from 6 to 9 AM, with the peak period of anthesis from 7 to 9 AM in all the genotypes (Table 2). However, least anthesis was recorded between 10 and 11AM, which was accounted to the tune of 1-3% in all the genotypes. It may be considered as negligible. None of the genotypes showed anthesis before 5 AM and after 11 AM. The anthesis was recorded 43, 42 and 41% in CPT 6, CPT 3 and CPT 5, respectively between 7 to 8 AM while CPT 1 recorded 35 per cent anthesis between 7 to 8 AM (Table 2). CPT 1 was the first to show higher rate of anthesis (6 per cent) followed by CPT 4, CPT 7 and CPT 9 between 5 to 6 AM. However, delayed anthesis was registered in CPT 3, CPT 13 and CPT 6, *i.e.*, 3 per cent between 5-6 AM. Anthesis between 10-11 AM ranged from 1 to 3 per cent in all the genotypes.

Data pertaining to anther dehiscence (Table 2) indicated that anther dehiscence commenced after opening of the flower, *i.e.*, at 8 AM and continued up to 12 AM. The peak period for anther dehiscence was registered from 9 to 11 AM in all the genotypes and it was considered as the most effective period for anther dehiscence, possibly due to the fact that temperature during these hours are usually higher than that in the morning and evening hours and fall in humidity during this period may also have accelerated the dehiscing process. None

Table 1. Time of panicle emergence and flowering in tamarind genotypes

Genotypes	Time of panicle emergence						Time of flowering					
	2004			2005			2004			2005		
	Start	Peak	Completion	Start	Peak	Completion	Start	Peak	Completion	Start	Peak	Completion
CPT1	22 May	6 June	27 June	18 May	8 June	28 June	15 June	1 July	20 July	17 June	2 July	22 July
CPT2	17 June	2 July	23 July	14 June	4 July	25 July	12 July	29 July	12 Aug.	13 July	28 July	14 Aug.
CPT3	18 June	3 July	24 July	17 June	6 July	25 July	13 July	30 July	18 Aug.	10 July	27 July	20 Aug.
CPT4	20 June	12 July	3 Aug.	21 June	14 July	4 Aug.	28 July	14 Aug.	28 Aug.	29 July	17 Aug.	29 Aug.
CPT5	23 June	15 July	5 Aug.	18 June	18 July	7 Aug.	1 July	15 Aug.	29 Aug.	3 July	18 Aug.	28 Aug.
CPT6	1 July	14 July	3 Aug.	2 July	13 July	2 Aug.	2 Aug.	17 Aug.	28 Aug.	1 Aug.	15 Aug.	27 Aug.
CPT7	2 July	20 July	7 Aug.	5 July	22 July	9 Aug.	11 Aug.	28 Aug.	12 Sept.	13 Aug.	29 Aug.	15 Sept.
CPT8	25 June	12 July	28 July	28 June	10 July	27 July	28 July	15 Aug.	26 Aug.	26 July	14 Aug.	28 Aug.
CPT9	13 July	1 Aug.	24 Aug.	12 July	3 Aug.	22 Aug.	6 Aug.	28 Aug.	10 Sept.	8 Aug.	25 Aug.	13 Sept.
CPTI0	12 July	2 Aug.	26 Aug.	15 July	4 Aug.	24 Aug.	12 Aug.	29 Aug.	13 Sept.	10 Aug.	28 Aug.	15 Sept.
CPT11	16 July	3 July	25 July	17 June	5 July	27 July	14 July	30 July	19 Aug.	12 July	28 July	20 Aug.
CPTI2	22 June	10 July	28 July	18 June	12 July	25 July	1 Aug.	14 Aug.	28 Aug.	2 Aug.	12 Aug.	25 Aug.
CPTI3	28 June	10 July	2 Aug.	24 June	13 July	4 Aug.	2 Aug.	16 Aug.	28 Aug.	3 Aug.	18 Aug.	27 Aug.
CPTI4	14 July	2 Aug.	22 Aug.	17 July	3 Aug.	20 Aug.	13 Aug.	27 Aug.	13 Sept.	10 Aug.	25 Aug.	15 Sept.
CPTI5	16 July	8 Aug.	24 Aug.	15 July	6 Aug.	22 Aug.	16 Aug.	28 Aug.	14 Sept.	17 Aug.	27 Aug.	17 Sept.

Table 2. Time of anthesis and dehiscence in different genotypes of tamarind

Genotypes		Flowers opened and anthers dehisced at hourly interval (%)							Flowers opened and anthers dehisced at hourly interval (%)						
		2004							2005						
		5-6	6-7	7-8	8-9	9-10	10-11	11-12	5-6	6-7	7-8	8-9	9-10	10-11	11-12
CPT1	A	6	20	35	32	4	3	0	5	21	36	31	5	2	0
	0	0	0	0	9	40	45	6	0	0	0	7	42	47	4
CPT2	A	4	22	40	31	2	1	0	3	21	42	30	3	1	0
	0	0	0	0	8	38	47	7	0	0	0	9	38	47	6
CPT3	A	3	22	42	30	2	1	0	1	24	40	32	2	1	0
	0	0	0	0	8	41	48	3	0	0	0	7	41	48	4
CPT4	A	5	19	38	32	4	2	0	4	20	37	32	5	2	0
	0	0	0	0	8	40	46	6	0	0	0	8	42	44	6
CPT5	A	3	21	41	32	2	1	0	2	19	42	34	2	1	0
	0	0	0	0	9	39	45	7	0	0	0	8	40	44	8
CPT6	A	4	20	43	30	2	1	0	3	18	45	31	2	1	0
	0	0	0	0	8	40	44	8	0	0	0	9	40	45	6
CPT7	A	5	19	38	**33**	3	2	0	4	20	40	32	2	2	0
	0	0	0	0	9	40	43	8	0	0	0	8	40	44	8
CPT 8	A	4	21	37	34	3	1	0	5	20	38	**33**	3	1	0
	0	0	0	0	9	40	45	6	0	0	0	10	39	46	5
CPT9	A	4	19	37	33	4	2	0	5	21	38	32	3	1	0
	0	0	0	0	10	39	44	7	0	0	0	9	38	45	8
CPT10	A	5	20	40	30	4	1	0	5	21	42	28	2	2	0
	0	0	0	0	8	40	45	7	0	0	0	10	38	45	7
CPT11	A	4	22	39	31	2	2	0	5	23	40	30	1	1	0
	0	0	0	0	1I	36	43	10	0	0	0	12	35	42	11
CPT12	A	4	23	40	29	3	1	0	3	22	43	28	2	2	0
	0	0	0	0	7	40	45	8	0	0	0	8	39	45	8
CPT13	A	3	24	39	30	3	1	0	5	19	40	32	3	1	0
	0	0	0	0	10	42	44	8	0	0	0	10	40	45	5
CPT14	A	4	20	39	30	5	2	0	3	21	40	28	4	4	0
	0	0	0	0	8	40	45	8	0	0	0	8	40	43	9
CPT15	A	5	22	36	30	5	:2	0	4	21	36	30	6	3	0
	D	0	0	0	9	38	43	10	0	0	0	10	37	41	12

A= Anthesis, D= Dehiscence

of the genotypes showed anther dehiscence before 8 AM and after 12 AM. It was recorded that CPT 3, CPT 2 and CPT 4 showed maximum anther dehiscence (48, 47 and 46 %, respectively) between 10 to 11 AM. Dehiscence of anthers ranged from 3-12 per cent in different genotypes between 11-12 AM. The similar pattern was followed during the successive year 2005. These observations are found in conformity with the findings of Singh *et al.* (2004a). In tamarind, anthesis starts in the morning as early as 4.30 AM and continues up to 8.30 AM with peak of anthesis at 6.30 AM and after 8.30 AM there was no anthesis (Karale, 2002). Thimmaraju *et al*. (1977) reported that peak anthesis and dehiscence took place at 6.00 AM and 10.30 AM, respectively in tamarind. Peak period of anthesis and dehiscence was recorded between 6-8 AM in guava during both the seasons (winter and rainy), none of the genotypes showed anthesis before 4 AM and after 11 AM, anther dehiscence commenced just after opening of flowers, *i.e.*, at 5 AM and continued till 11 AM (Singh and Singh, 2004). Sandhu *et al.* (1987) reported that dehiscence in guava varieties took place15-30 minutes prior to the opening of flowers and the peak period of dehiscence was found between 6-9 AM. The variability in flower biology of tamarind genotypes under various climatic conditions might be due to location and varietal characteristics.

In tamarind, flower bud initiation began with resumption of the vegetative growth, just after leaf fall. The flower buds were borne on the current season's growth in different genotypes. The observations on flowering studies presented in Table 3 showed that tamarind genotypes differed in their time requirement to complete the bud development and it ranged from 18-26 days being highest in CPT 7, closely followed by CPT 5, CPT 6, CPT 8 and CPT 14, however it was noted to be least in CPT 1 and CPT 4. Thimmaraju *et al.* (1977) reported that flower bud development took about 20 days from first visible initiation in tamarind. The Varietal variability in respect of flowering period has also been reported by Sharma *et al.* (1994) Singh *et al*. (2004) and Kumar *et al*. (2004) in Jalphai (*Elaeocarpus floribundus* Bl), pear and peach genotypes,

Table 3. Pollen characteristics of tamarind genotypes

Genotypes	Time taken for flower development (Days)		Pollen viability (%)		Pollen germination (%)		Pollen diameter (Micron)	
	2004	2005	2004	2005	2004	2005	2004	2005
CPTI	18	19	83.69	84.63	14.19	14.54	34.12	35.17
CPT2	20	21	84.50	85.39	15.08	15.12	36.50	37.19
CPT3	22	23	93.50	94.13	18.13	18.34	35.63	35.93
CPT4	18	19	92.13	93.10	17.15	17.60	40.12	41.12
CPT5	23	22	90.50	91.12	16.70	16.80	39.13	40.14
CPT6	24	24	91.20	92.14	16.14	16.90	41.12	42.14
CPT7	25	26	88.34	89.13	15.03	15.17	37.13	38.39
CPT8	23	24	86.39	87.16	14.10	14.14	38.20	39.40
CPT9	20	22	84.12	85.39	12.60	13.00	36.13	37.89
CPTI0	23	22	86.39	88.10	15.10	15.30	37.12	38.14
CPT11	18	21	80.10	81.23	10.11	10.23	36.14	37.10
CPTl2	20	23	84.40	83.10	15.50	15.80	39.34	39.20
CPT13	19	24	83.60	85.60	13.60	13.90	40.40	41.10
CPTl4	19	26	88.30	86.20	16.80	16.95	41.00	41.45
CPTI5	18	23	84.20	86.12	14.00	13.50	38.00	37.21
CD (P=0.05)	—	—	1.12	0.68	1.14	1.02	1.36	1.12

respectively under various climatic conditions.

Stainability test was employed as an index of pollen viability. In acetocarmine solution (2.0%), maximum pollen viability (93.50%) was observed in CPT 3, which was closely followed by CPT 4, CPT 6 and CPT 5, however minimum pollen viability was observed in CPT 11 (80.10%). Similar trends were observed in the year 2005. Kumar *et al.* (2004) reported that pollen viability ranged from 74.90-94.22 per cent in different peach cultivars under Uttaranchal conditions. Singh *et al.* (2004b), obtained 75.60-88.00 per cent pollen viability in different pear cultivars.

Pollen germination was very poor irrespective of the genotypes (Table 3). The maximum pollen grain germination was recorded in CPT 3 (18.13 per cent) closely followed by CPT 4, CPT 5 and CPT 6, while it was found to be least in CPT 11 (10.11 per cent). Differences in pollen germination may be due to varying percentage of pollen viability in different genotypes. Pollen diameter varied from 34.12- 41.38 microns. Pollen grain was spherical in shape having light yellow colour in all genotypes. Almost similar trend was recorded during the year 2005. There was marked variation in average panicle length in most of the genotypes and CPT 13 recorded the maximum panicle length (15.00 cm), closely followed by CPT 8 (14.60 cm), CPT 15 (14.00 cm) and CPT 10 (13.40 cm). Least panicle length was found in CPT 1 (9.20 cm). CPT 4, CPT 5, CPT 9, and CPT 11 were statistically at par with each other in respect of average panicle length. Similar pattern was followed by different genotypes pertaining to panicle length during the year 2005.

Table 4. Panicle length, fruit set per panicle and time of fruit set in tamarind genotypes

Genotypes	Average panicle length (cm)		Fruit set per panicle		Date of fruit set					
					2004			2005		
	2004	2005	2004	2005	Start	Peak	Completion	Start	Peak	Completion
CPT1	9.20	9.30	8.60	8.80	18 July	2 Aug.	18 Aug.	17 July	] Aug.	20 Aug.
CPT2	9.40	9.70	8.00	9.80	10 Aug.	28 Aug.	10 Sept.	9 Aug.	27 Aug.	] I Sept.
CPT3	12.50	13.70	13.40	3.80	12 Aug.	29 Aug.	15 Sept.	10 Aug.	27 Aug.	16 Sept.
CPT4	11.60	12.80	1.10	9.20	27 Aug.	12 Sept.	22 Sept.	26 Aug.	10 Sept.	20 Sept.
CPT5	11.00	9.20	8.20	8.10	2 Aug.	10 Sept.	25 Sept.	I Aug.	12 Sept.	26 Sept.
CPT6	12.20	12.00	15.00	13.10	1 Sept.	13 Sept.	22 Sept.	3 Sept.	12 Sept.	23 Sept.
CPT7	13.96	13.82	9.10	9.50	10 Sept.	22 Sept.	28 Sept.	8 Sept.	20 Sept.	26 Sept.
CPT8	14.60	15.40	13.50	12.40	26 Aug.	12 Sept.	22 Sept.	25 Aug.	II Sept.	20 Sept.
CPT9	11.50	12.70	8.20	8.40	5 Sept.	24 Sept.	29 Sept.	4 Sept.	22 Sept.	28 Sept.
CPT10	13.40	12.80	9.50	9.10	10 Sept.	22 Sept.	30 Sept.	II Sept.	20 Sept.	28 Sept.
CPT11	11.20	11.00	6.80	8.10	14 Aug.	25 Aug.	12 Sept.	13 Aug.	26 Aug.	13 Sept.
CPT12	13.00	13.80	7.20	8.50	2 Sept.	10 Sept.	22 Sept.	I Sept.	I I Sept.	23 Sept.
CPT13	15.00	15.20	16.80	15.20	I Sept.	10 Sept.	23 Sept.	3 Sept.	9 Sept.	24 Sept.
CPT14	]3.04	]3.00	7.10	7.60	10 Sept.	20 Sept.	27 Sept.	12 Sept.	18 Sept.	28 Sept.
CPT15	14.00	14.20	5.80	6.60	15 Sept.	19 Sept.	30 Sept.	13 Sept.	17 Sept.	29 Sept.
CD (P=0.05)	0.80	0.78	1.13	1.19						

Variation in number of fruit set per panicle was recorded and it was found to be highest in CPT 13 (16.80), closely followed by CPT 6 (15.00), CPT 3(13.40) and CPT 8 (13.50) (Table 4). Date of fruit set varied from middle of July to middle of September in different genotypes. In majority of genotypes, peak period of fruit set was observed in the middle of September. Though, flowering is profuse in tamarind, the fruit set under natural conditions is low, ranging from 3-5 %, which can be increased to about 50-55 % under artificial cross pollination. Fruit set was only 36 per cent with open pollination and increased to 56 per cent with cross pollination (Usha and Singh, 1996). Kumar *et al.* (2004) reported that pollen germination ranged from 62.12-78.23 per cent in different peach cultivars under Uttaranchal conditions. Pollen grain viability ranged from 91.05-97.91 per cent among different genotypes of pomegranate (Sharma and Bist, 2003). Dhaliwal and Singla (2003), Hoda *et al.* (2003), Singh *et al.* (2004), Singh and Singh (2005b) and Singh and Singh (2005a) recorded wide variation in reproductive attributes of guava, mango, tamarind, *Jamun* and *Mahua* respectively under various climatic conditions. These promising genotypes are being further evaluated.

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