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Research article

CROSSABILITY STUDIES IN *TERMINALIA ARJUNA* AND *T.TOMEMTOSA*

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ABSTRACT: *T.arjuna and T.tomentosa* come under multipurpose tree category and are of immense economic importance besides being the primary food plants of Tasar silkworm Antheraea mylitta D. Blooming occurs from second week of May in T.arjuna and last week of May in T.tomentosa. Number of flowers per raceme range between 41 in accession 235 to 58 in accession 702 of T.arjuna and 53 (acc.531) to 73 (acc.501) of T. tomentosa. Fruit set per cent ranged between 2.0 in accessions 235 and 236 to 4.00 in accession 533 of T.arjuna. Per cent fruit set was 3.0 to 3.2 in accessions 501 and 531, respectively of T.tomentosa under open pollination condition. There was no fruit set in un - pollinated and covered racemes. Days required for fruit initiation in T.arjuna x T.arjuna combination varied between 12 to 14 days and fruit set was 1.8 to 2.5 percent. In T.arjuna x T.tomentosa combinations initiation of fruit set took 10 (acc.701 x acc.501) to 14 (acc.533 x acc.531) days and fruit set was 1.5 to 2.4 per cent. Present studies indicate that inter-specific hybridization is possible in T.arjuna and T.tomentosa. New hybrid varieties can be developed through inter-specific hybridization having higher yield in comparison to the existing genotypes.

Key Words: *T.arjuna*, *T.tomentosa*, pollen viability, Inter-specific hybridization, fruit set percent, fruit maturity, seed germination,

INTRODUCTION

Terminalia is a large genus comprising many deciduous trees or rarely woody climbers. It is distributed throughout the humid and semi humid tropics in world. About 18 species are most commonly found in India. The genus come under multipurpose tree category and is of immense economic importance in various industries like pharmaceutical, paper, soap, match industries, food, fodder, fuel and sericulture, as *T.arjuna* and *T.tomentosa* are the primary food plants of Tasar silkworm *Antheraea mylitta* D. It is estimated that about 11.6 million hectares of forest land is occupied by these species in India (Suryanarayana *et al*., 2005). Both the species have a wide range of adaptability and grows well even on the marginal land, enduring drought, alkalinity /salinity. Presently both the species are being promoted for mass plantation under various government schemes to promote sericulture for livelihood of poor and tribal families.

The objective of forest tree breeding is to develop fast growing high yielding genetically improved superior strains in order to bring new area under such varieties/strains to obtain higher productivity per unit are and time. A breeding programme, in fact involves judicious management of genetic diversity present in the species. Recognizing the importance of the diverse genetic resources of *Terminalia* sp. available in India, Central Tasar Research and Training Institute, Ranchi has established a field gene bank under *ex- situ* condition where more than 284 accessions collected from almost all geographical regions of the country are available.

For evolving a new variety, all the desirable characters are to be brought into a single phenotype. The variability studies in *T.arjuna* and *T.tomentosa* have been extensively studied by Kumar *et al*., 2009, 2010, 2013, Gargi *et al.*, 2010, 2015 and Sharma *et al.*,2011 which indicate the distribution of desirable traits into various genotype of different geographical origin and also in same geographical region . Tree breeding work has been done in many forest tree species but no information is available on this aspect either in *T. arjuna* or in *T.tomentosa*.

The paucity of the information on this aspect induced the authors to take up these studies for the first time in *T.arjuna* and *T.tomentosa* and the present report is the part of the work initiated in this line at this institute.

MATERIAL AND METHODS

Of the ten accessions used in the present study, accessions 123,143, 235,236,533,615,701 and 702 were of *T.arjuna* and accessions 501 and 531 were of *T.tomentosa.* All the accessions are maintained in the germplasm bank of the Institute and were 8-10 years old. Crossing studies were started in the month of May 2012 at the time of initiation of flowering. Daily visual observations were made from bud primordial initiation to fruit setting in two clones of each accession on four branches at different position. The observations were also recorded on inflorescences and floral bud development and stigma receptivity period. Pollen viability was studied by Alexander staining method (1969, 1987). Breeding behavior was examined through selfing by covering the inflorescence with muslin cloth bags before opening of buds. Ten racemes in each accession were covered with muslin cloth 3 days after emergence of the inflorescence. An equal number of racemes were kept open in close vicinity of the so covered inflorescences. Pollen grains from desired parents were collected at the time of anthesis and dusted over the receptive stigmas of the flowers in the covered spikes with the help of camel hair brush. Pollination was repeated for 4 consecutive days to pollinate the flowers of all the ages in the individual spike. Soon after the pollination, the inflorescences were covered to avoid further pollen contamination. The bags covered over the inflorescences were removed after complete withering of the stigma to allow further growth of the shoots as well fruits. Observations on days taken for initiation of fruit setting in pollinated, covered but un-pollinated and inflorescences kept open and tagged near the covered inflorescences were recorded till the time of fruit harvest. Observations pertaining to fruit weight, length and diameter and seed germination were also recorded.

RESULTS AND DISCUSSION

Blooming occurs from second week of May in *T.arjuna* and last week of May in *T.tomentosa.* The inflorescences arise from the axil of spur shoot leaves as small protruding structure. They are racemes bearing numerous flowers whose rachis varies in length. Floral buds starts opening after 12 to 18 days (acc.143) in *T.arjuna* and 14 days in *T. tomentosa* (Table1). Number of flowers per raceme ranges between 41 in accession 235 to 58 in accession 702 of *T.arjuna* and 53 (acc.531) to 73 (acc.501) of *T. tomentosa.* Flower development is acropetal with protandry condition. Anthesis occurred between 9 to 10 am. Pollen size is 12.42 (acc.701) to 16.91 µm (acc.235) in *T. arjuna* and 14.80 (acc.501) to 16.1 µm (acc.531) of *T. tomentosa.* Pollen grains are medium spherical, tricolpate with smooth exine and yellow in colour. Pollen fertility ranges between 66.0 (acc.235) to 87.10 per cent (acc.702) in *T.arjuna.*In *T.tomentosa* it was 87.30 to 87.69 % in accessions 531 and 501 respectively. The pollen tube behavior in covered and un- pollinated, covered and pollinated and open pollinated flowers showed that in covered and un-pollinated flowers pollen tubes were inhibited on the stigma itself and never traverse through style. Pollens remain viable for two days at room temperature. Similar observations on pollen viability has been reported by Kumar *et al*., 2002 and David *et al*., 2012 in *T.arjuna* and Thangaraja and Ganesan (2008) in *Terminalia paniculata* Roth. Pollen starts germinating within 15 minutes after dusting over the stigma. Stigma receptivity lasts for one day and was most receptive between 8.30 to 10 am. It was observed that time taken for initiation of fruit setting ranges between 10-14 days in all the accessions of *T.arjuna* and *T.tomentosa* under open pollination condition Fruit set percent ranged between 2.0 in accessions 235 and 236 to 4.00 in accession 533 of *T.arjuna*. However, it was 3.0 to 3.2 percent in accessions 501 and 531, respectively of *T.tomentosa* under open pollination condition. There was no fruit set in un-pollinated covered spikes. Fruit ripening occurs between February through May. Fruit size stabilizes in 70 days in *T.arjuna* and 90 days in *T.tomentosa* (Figs. 1&2). The fruit completely matures in 340 days in *T.tomentosa* and 350 days in *T.arjuna.* It is a short pedicellate five winged indehiscent drupe. Seed is enclosed by the fibrous endocarp. It is cylindrical-elliptic. The seed coat is dull and yellow.

Days taken for fruit initiation and percent fruit set in various cross combinations involving *T.arjuna x T.arjuna, T.arjuna x T.tomentosa* and *T.tomentosa x T.arjuna* are presented in Table 2. Days required for fruit initiation in *T.arjuna x T.arjuna* combination varies between 12 to 14 days and fruit set was 1.8 to 2.5 per cent. In *T.arjuna x T.tomentosa* combinations initiation of fruit set took 10 (acc.701 x acc.501) to 14 (acc.533 x acc.531) days and fruit set was 1.5 to 2.4 per cent. Similarly days taken for fruit initiation did not differ much in *T.tomentosa x T.arjuna* combinations and it ranged between 10 to 13 days in all the combinations in the present study, however, fruit set was 1.5 (acc.501 x acc.533) to 3.5 (acc.501 x acc. 615) per cent.

Table 1: Floral biology and fruit set percent in parent plants used in hybridization

#	Species	Accession No.	Days taken for opening of floral buds	No. of flower / receme	Pollen size (µm)	Pollen viability (%)	Stigma receptivity (days)	Days taken for fruit set initiation	Number of racemes tagged under open pollination condition	Fruit set (%) in tagged racemes in open pollinated condition	Fruit set (%) in bagged and Un-pollinated condition
1	*T.arjuna*	123	12	42	13.50±0.11	72.00±1.25	01	12	10	3.0	0.0
2	*T.arjuna*	143	18	45	15.04±0.14	83.08±1.54	01	12	10	2.1	0.0
3	*T.arjuna*	235	12	41	16.91±0.15	66.00±1.18	01	12	10	2.0	0.0
4	*T.arjuna*	236	14	42	14.90±0.11	80.20±2.01	01	12	10	2.0	0.0
5	*T.arjuna*	533	17	48	14.60±0.10	79.58±2.11	01	14	10	4.0	0.0
6	*T.arjuna*	615	15	40	14.50±0.14	84.50±2.14	01	14	10	2.9	0.0
7	*T.arjuna*	701	17	51	12.42±0.14	80.95±2.14	01	10	10	2.5	0.0
8	*T.arjuna*	702	12	58	14.38±0.12	87.10±1.98	01	12	10	3.0	0.0
9	*T.tomentosa*	501	14	73	14.80±0.12	87.69±1.99	01	12	10	3.0	0.0
10	*T.tomentosa*	531	14	53	16.18±0.11	87.30±2.10	01	14	10	3.2	0.0
± indicates standard error											

Table 2: Seed set per cent in various cross combinations

#	Parent combination	Accessions used in crosses	Days taken for fruit set initiation	Number of racemes bagged	Number of flowers pollinated in all the racemes	Number of fruit formed in all the racemes	Fruit set (%)
1	*T.arjuna X T.arjuna*	143X236	12	10	4500	86	1.9
2	*T.arjuna X T.arjuna*	123X533	12	10	4200	76	1.8
3	*T.arjuna X T.arjuna*	235X615	14	10	4100	102	2.5
4	*T.arjuna X T.tomentosa*	533X531	14	10	4800	105	2.2
5	*T.arjuna X T.tomentosa*	615X531	14	10	4000	96	2.4
6	*T.arjuna X T.tomentosa*	701X531	10	10	5100	92	1.8
7	*T.arjuna X T.tomentosa*	701X501	10	10	5100	77	1.5
8	*T.tomentosa X T.arjuna*	501X533	10	10	7300	110	1.5
9	*T.tomentosa X T.arjuna*	501X615	13	10	7300	256	3.5
10	*T.tomentosa X T.arjuna*	501X701	12	10	7300	132	1.8
11	*T.tomentosa X T.arjuna*	501X702	13	10	7300	234	3.2
12	*T.tomentosa X T.arjuna*	531X533	10	10	5300	160	3.0
13	*T.tomentosa X T.arjuna*	531X615	10	10	5300	154	2.9
14	*T.tomentosa X T.arjuna*	531X701	11	10	5300	133	2.5
15	*T.tomentosa X T.arjuna*	531X702	10	10	5300	117	2.2

Table 3: Single seed weight, seed length and diameter and germination percent in seeds harvested under various cross combinations.

#	Parent combination	Accessions used in hybridization	Single Fruit weight (g)	Fruit Length (cm)	Fruit diameter (cm)	Seed germination (%)
1	*T.arjuna X T.arjuna*	143X236	2.42±0.09	4.83±0.13	8.10±0.15	59.95
2	*T.arjuna X T.arjuna*	123X533	2.28±0.11	3.97±0.11	8.60±0.14	62.00
3	*T.arjuna X T.arjuna*	235X615	2.54±0.10	3.81±0.11	8.52±0.12	69.25
4	*T.arjuna X T.tomentosa*	533X531	2.51±0.09	4.54±0.12	8.67±0.111	68.50
5	*T.arjuna X T.tomentosa*	615X531	3.34±0.16	3.91±0.14	8.50± 0.14	64.00
6	*T.arjuna X T.tomentosa*	701X531	3.51±0.15	4.77± 0.13	8.40±0.15	54.50
7	*T.arjuna X T.tomentosa*	701X501	3.50±0.12	4.37±0.11	9.40±0.18	62.00
8	*T.tomentosa X T.arjuna*	501X533	2.74 ±0.11	4.83±0.10	10.83± 0.24	61.25
9	*T.tomentosa X T.arjuna*	501X615	1.61±0.05	4.85±0.14	9.60±0.11	69.00
10	*T.tomentosa X T.arjuna*	501X701	1.97±0.08	5.67±0.11	8.17±0.12	69.50
11	*T.tomentosa X T.arjuna*	501X702	2.23±0.10	4.85±0.12	10.47±0.25	70.00
12	*T.tomentosa X T.arjuna*	531X533	2.67±0.12	5.64±0.11	9.89±0.35	64.50
13	*T.tomentosa X T.arjuna*	531X615	2.75±0.11	5.25±0.11	8.50±0.39	62.00
14	*T.tomentosa X T.arjuna*	531X701	2.21± 0.11	4.98±0.28	8.88±0.67	52.00
15	*T.tomentosa X T.arjuna*	531X702	2.10±0.10	5.42±0.23	9.10±0.41	61.00

±indicates standard error

Table 4: Single seed weight, length and diameter and germination percent in open pollinated seeds of mother plants.

#	Species	Accession number	Single seed weight (g)	Seed length (cm)	Seed diameter (cm)	Seed germination (%)
1	*T.arjuna*	123	2.23±0.09	3.97±0.12	8.60±0.14	60.00
2	*T.arjuna*	143	3.56±0.11	4.55±0.11	8.21±0.15	62.00
3	*T.arjuna*	235	2.75±0.13	4.20±0.12	8.00±0.12	63.00
4	*T.arjuna*	236	2.86±0.10	4.50±0.11	8.35±0.13	63.00
5	*T.arjuna*	533	2.05±0.05	4.50±0.10	8.63±0.14	54.00
6	*T.arjuna*	615	2.10±0.08	3.52±0.09	8.15±0.16	62.00
7	*T.arjuna*	701	1.91±0.06	4.70±0.13	8.47±0.15	75.00
8	*T.arjuna*	702	2.18±0.09	4.52±0.12	10.10±0.18	71.00
9	*T.tomentosa*	501	2.81±0.08	4.83±0.14	11.83±0.21	64.00
10	*T.tomentosa*	531	3.22±0.11	5.62±0.16	10.82±0.19	70.00

±indicates standard error

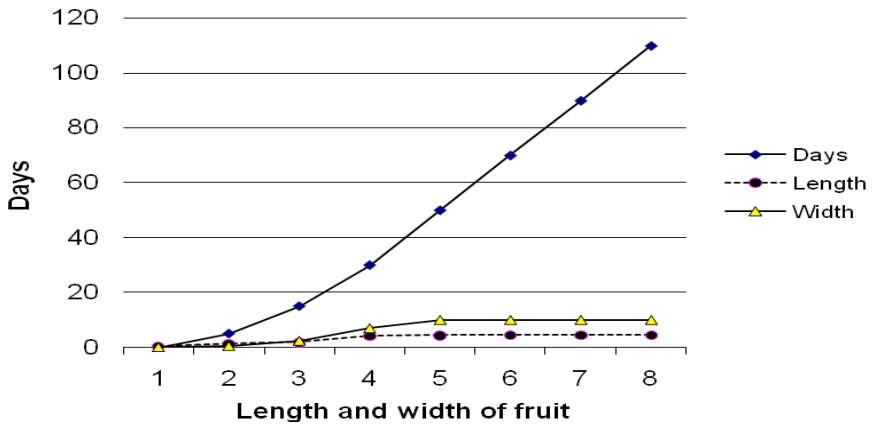

Fig.1: Fruit length and width in *T.arjuna* after fruit setting

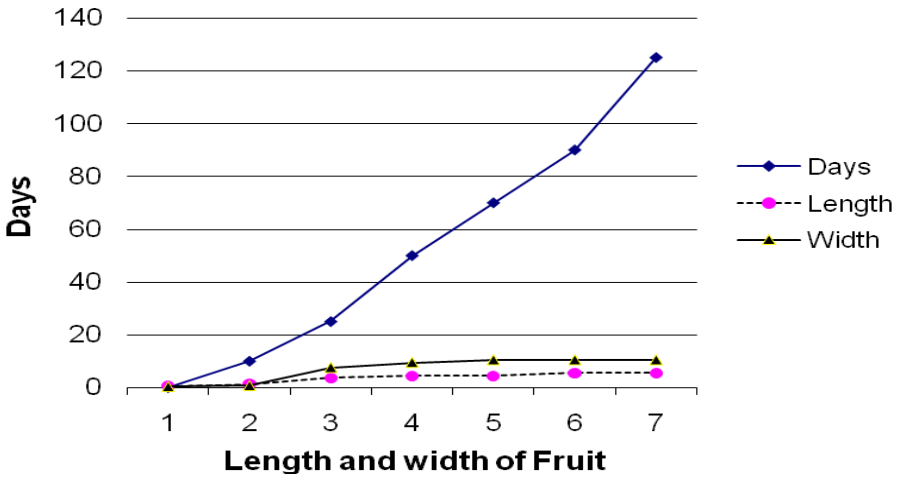

Fig.2: Fruit length and width in *T.tomentosa* after fruit setting

Results on mature single fruit weight, fruit length, fruit diameter and seed germination per cent in various cross combinations is given in Table 3. Single mature fruit weight ranged between 1.61g in *T.tomentosa x T.arjuna* (acc.501 x acc.615) to 3.51 g in *T.arjuna x T.tomentosa* (acc.701 x acc.531) whereas, in *T.arjuna x T.arjuna* combinations it was 2.28 to 2.54g. Range of fruit length was maximum (4.83 to 5.67 cm) in combinations of *T.tomentosa x T.arjuna*. In other combinations it varied between 3.81 cm to 4.83 cm in *T.arjuna x T.arjuna* and *T.arjuna x T.tomentosa* combinations. Fruit diameter was maximum (10.83 cm) in *T.tomentosa x T.arjuna* (acc.501x acc.531) and minimum (8.10 cm) in accessions 143 x 236 of *T.arjuna*. Seed germination ranged between 52 to 70% in *T.tomentosa x T.arjuna* combinations.

Studies indicate that inter-specific hybridization is possible in *T.arjuna* and *T.tomentosa* and new hybrid varieties can be developed through inter-specific hybridization having higher yield in comparison to the existing genotypes. Evolution of high leaf yielding superior varieties has also been achieved through inter-specific hybridization between different mulberry species by Das and Krishnaswamy (1965) and Dandin *et al*., 1987. Mature single fruit weight, fruit length and diameter and seed germination per cent in mother plants under open pollinated condition is presented in Table 4. Single mature fruit weight was maximum (3.56 g) in accession 143 of *T.arjuna.* However, Fruit length and diameter was maximum (5.62 to 11.83 cm) in accessions 531 and 501 of *T.tomentosa*, respectively. Seed germination ranged from 54 % to 71 % in accession 533 and 702, respectively of *T.arjuna.* In the present study no fruit set was observed under covered and un-pollinated flowers (selfing). These results suggest that *T.arjuna* and *T.tomentosa* are self incompatible. The fruit set in open pollinated as well as controlled condition was low. It is probably due to the shortage of pollinators and inadequate transfer of compatible pollens in these species. The low fruit to flower ratio in hermaphrodic and protandrous flowers and stigma position above the level of the stamens observed in present study is also one of the major factors for low fruit set. Our results are in accordance with the findings of Zimmerman and Pyke (1988) in *Polemonia*, Wheelan and Goldingay (1989) in *Telopea speciossima*, Dhillon *et al*., (2009) in *Pongamia pinnata* L. Pierre. and Vasudev and Sarin (2011) in *Delbergia sisso*. They concluded that low fruit set under controlled pollination condition as compared to natural crossing and no fruit set in covered and un-pollinated flowers is due to self incompatibility in these genera.

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