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Establishment of Seed Production Area of *Tectona grandis* Linn. f. in Gujarat

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Abstract: Teak is a slow growing species and any tree improvement program will take 15-40 years before the timber from the first rotation of improved planting stock is harvested. Ten to fifteen years may pass from the initiation of an improvement program before improved seed is available. Developing seed production areas (SPAs) is one of the first steps in tree improvement program that can be used to obtain genetically improved seed for immediate planting but it is usually for the short term in nature. Though seeds obtained from this method do not yield large volume of genetic gain, it sometimes greatly improves tree quality. After survey of nearly 940 ha plantations of *Tectona grandis* at 15 locations in Gujarat, 85 ha at six sites were converted into seed production areas (SPAs) after inter-comparing with various other seed stands. After culling of inferior trees from these six stands, the average height, clear bole, girth at breast height, diameter at breast height and volume were shifted towards the higher side in all the stands. Seeds collected from these seed production area performed better in seed attributes than un-culled stands.

Key words: *Tectona grandis* Linn. f., seed production area, culling of inferior trees, Gujarat.

Teak (*Tectona grandis* Linn. f.), belonging to the family of Verbenaceae, is one of the most important tropical timber species, suitable for multiple end-uses. The name 'Tectona' has been taken from the Portuguese word teca, which is a derivative of Greek word tekton, meaning a carpenter. 'Grandis' in latin stands for large and as the qualities of teak wood are much appreciated by carpenters the literal meaning of teak (*Tectona grandis*) as carpenter's pride is most appropriate. Teak is a unique species whose timbers are most aristocrats amongst the timbers of India. Its durability is the gift of nature bestowed upon it. The other qualities are due to its matchless properties such as termite, fungus and weather resistance, lightness with strength, attractiveness, workability and seasoning capacity without splitting, cracking or materially altering shape. Its wood is also used for ship building, bridge building, piles, furniture, cabinet work, railcars, wagons, wheel spokes and general carpentry (Kaosa-ard, 1981).

It is native to the Indo-Malayan region and occurs naturally in some parts of India while in many others it has been planted. It produces one of the world's most valuable timbers of outstanding durability. Five teak-forest types have been recognised in India namely, very moist, moist, semi-moist, dry and very dry. The most important teak forests in India are in Madhya Pradesh, Maharashtra, Karnataka, Tamil Nadu and Kerala, and also in Uttar Pradesh, Gujarat, Orissa and Rajasthan (Troup, 1921). Plantations have also been made in Haryana, West Bengal, Assam, Meghalaya and Dadra and Nagar Haveli (Chakrabarti and Gaharwar, 1995).

The potential for growing and managing teak in different ecological zones and under different situations is being increasingly recognized, leading to intensive domestication and cultivation of the species in countries/ regions beyond its natural habitat (Perez and Kanninen, 2003).

Tectona grandis Linn. f. is tropical high grade heartwood species grown over approximately 6.0 million hectares worldwide (Bhat and Hwan, 2004). India (44%) and Indonesia (31%) contribute most among tropical Asia (94%) of the world. Other Asian countries like Thailand, Myanmar, Bangladesh and Sri Lanka contributes

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17% of total. Tropical Africa contributes 4.5% and rests are in Tropical America (Pandey, 1998).

Establishment of "teak seed origin sample plots" during the early thirties was the first step towards understanding the genetics of teak. Systematic teak improvement started with the submission of a report by Matthews (1961) to the Government of India. Kedharnath and Matthews (1962) formulated a program for the genetic improvement of teak. Following this, the improvement activities gained momentum and almost all the teak growing states have now joined the improvement programs. A stand of natural plant or group of stands, periodically rouged, and managed to enhance seed production is known as seed production area. Though the genetic quality of the seed is uncertain but it provides the seed of known origin from the best phenotypes available. The establishment of seed production areas is a stop-gap measure, designed to provide seed of the best possible quality until our seed orchards begin to bear. The degree of improvement to be expected from seeds from such areas is less then progeny tested stands but it is of considerable benefit just to have seed of known origin and to have seed collection concentrated on specific areas. Seed yield from such areas will vary per tree and also from year to year on the same tree or area. Such factors as spacing, diameter, crown length, period of time since release, inherent fruitfulness, insects, and disease and climatic conditions all have significant effects (Hosius *et al.*, 2006).

This paper deals with the establishment of seed production area of teak in Gujarat state.

Material and Methods

An assessment of available plantations for their growth, form and preponderance of superior trees by sampling and ranking them helps in selecting the best plantation for converting into seed production area (SPA). To compare the plantations selected for conversion into SPA and other plantations rejected, it is essential that some basic data on growth and form be recorded for comparison of the stands. Seed stands of *Tectona grandis*, established by State Forest Department of Gujarat, were surveyed, identified, marked and analysed for the establishment of seed production areas. The scoring was done for both qualitative and quantitative traits. The traits selected for scoring were:

- Total height
- Bole height
- Diameter/Girth at Breast Height (DBH/GBH)
- Form/Straightness
- Crown and branching
- Natural pruning ability
- Flowering and fruiting
- Insect/pest/diseases

The first three traits are quantitative measurements with high degree of heritability and higher correlation with volume production, whereas the rest of the traits are subjective assessments. The point grade method was followed for scoring the above traits. The maximum score a tree can have is 100. The traits such as Total Height, Bole Height and DBH/GBH were given maximum score of 76, as these are the primary economic traits with high heritability (Table 1).

The total height, bole height and girth at breast height of all trees in each sample plot were measured and average of each parameter in every plot was calculated. Scoring to each of these parameters was given on the basis of comparison of the population in the sample plot with the average. The trees measuring more than the averages were given +ve scoring while trees showing less values than the averages were assigned -ve values (from + 20 to - 20 for girth at breast height and total height and + 36 to - 36 for bole height). These scores were summed up for each plot and those scoring highest number in descending order were identified as superior stands. For form and straightness, maximum 10 points were given for very best trees. The range of scoring was from 1-10. The points were distributed as:

Straight (7-10): Best (10), Good (9), Medium (8), Poor (7)
Wavering (4-6): Light (6), Medium (5), Heavy (4)
Crooked (1-3): Low (3), Medium (2), Heavy (1)

Crown and branching were given five points for well developed crown. And zero points for shapeless structured plant. These structures are well defined and can be judged upon after visiting the area. Well developed

Table 1. Scoring for various traits in the sample plot of Tectona grandis

Scoring for total height/GBH		Scoring for bole height		Crown and branching	Score
Superiority of each tree in the sample plot over average of sample plot	Score	% Superiority of each tree in the sample plot over average of sample plot	Score		
< -0	-20	< -25	-36	Shapeless	0
-16 to -20	-16	-21 to -25	-30	Bushy	1
-11 to -15	-12	-20 to -16	-24	Narrow	3
-6 to -10	-8	-15 to -11	-18	Medium	4
-1 to -5	-4	-10 to -6	-12	Well developed	5
-0.9 to 0.9	0	-5 to -1	-6	Insect/pests	
				Heavy infestation	1
				Medium	2
				Healthy	3
1 to 5	4	-0.9 to 0.9	0	Natural pruning	
6 to 10	8	1 to 5	6	No pruning	1
11 to 15	12	6 to 10	12	Medium	2
16 to 20	16	11 to 15	18	Self pruning	3
> 20	20	16 to 20	24	Flowering/fruiting	
		21 to 25	30	Heavy	1
		> 25	36	Medium	2
				Very less	3

crown will bear more seeds in comparison of shapeless, bushy, narrow or medium crown. This is subjective assessment and will vary from site to site.

Forest managers are often more interested in estimating tree volume with greater accuracy as it is commercially an important character and information regarding volume production is very much required for future management of the tree stands/forests. Total wood volume (V) for *Tectona grandis* was computed using the equation given below (Chaturvedi, 1973).

$$V = 0.12170 + 0.0000226\ D^2H$$

where, V = Volume in m^3; D = Diameter at breast height; H = Total height

Results and Discussions

Teak seed stands spread in over 940 ha area at 15 locations in Gujarat were surveyed. In all, 55 sample plots of 20 m x 20 m were laid out in these surveyed stands for inter comparison between seed stands for desirable traits. The traits measured were total height, bole height, girth, straightness, flowering, fruiting and health. Seed stands were ranked as per their scores obtained. Within a sample plot, all the trees were scored using same method and the scores were summed up. Scores of all the sample plots representing a plantation for the selected area was summed and the average score for the stand was calculated.

Table 2 showed the comparative assessment of all the 15 seed stands of *Tectona grandis* surveyed and analyzed. The trees in each of the 55 plots were individually marked and data were recorded for various parameters. Point grade method was followed for each trait and proper scores were recorded for each tree in the sample plot. All these stands were ranked in a descending order based on the average score of all the trees in the sample plots representing them. Chikhali seed stand of 50 ha in Dang scored maximum (35.64) followed by Dhanpur stand of 100 ha in Dumka, Baria (23.53) and Devmogra stand of 100 ha in Rajpipla scored least (5.63).

After sample plot analysis, superior seed stands were identified for conversion into seed production areas (SPAs). All the selected seed stands were jointly enumerated and marked for further analysis, inferior marking and number of trees to be retained. Then the stands were selected for conversion into SPAs from the top

Table 2. Mean total height, clear bole, girth at breast height and total score of various selected seed stands of Tectona grandis in Gujarat State

Name of the plantations	Area (ha)	Total height (m)	Clear bole height (m)	Girth at breast height (cm)	Total score
Chikhali, Dang, South	50.0	17.07	4.12	92.61	35.64
Dhanpur, Dumka, Baria	100.0	16.71	3.81	86.91	23.53
Sathakashi, Surat	10.0	13.31	4.02	49.08	19.87
Limbani, Chhota Udaipur	50.0	16.95	3.09	74.70	17.62
Parnera, South Valsad	40.0	18.40	5.47	60.77	17.03
Achhala, Godhra	200.0	13.19	2.81	62.60	15.60
Balsad, Surat	25.0	15.69	2.67	65.94	11.37
Pada, Rajpipla	50.0	14.54	2.80	61.57	11.34
Malangdev, Surat	25.0	13.21	2.53	61.76	10.96
Beskatri, Dangs South	100.0	12.83	2.66	63.41	9.76
Jambugoda, Chhota Udaipur	50.0	12.43	2.61	64.60	8.93
Gaven, Surat	100.0	13.13	2.74	62.46	8.70
Limkheda, Baria	20.0	12.57	2.41	60.78	8.29
Rambhas, Dangs South	20.0	14.81	2.52	68.01	8.23
Devmogra, Rajpipla	100.0	13.16	2.54	61.49	5.63

of the list, based on the area required to meet the seed demand. Six seed stands, based on the average score 15.60 to 35.64 ha in a total area 85 ha, were selected for conversion into seed production areas in Gujarat state.

Table 3 provides the details of the stands converted into seed production area by removing/culling inferior trees of the stands. In Chikhali, a total of 1809 trees were available in the stand of 20 ha area, out of which quality trees of 963 were retained and 846 trees of inferior quality were culled. Similarly, in other stands also, inferior trees were removed and quality trees were retained. No tree below the desired standard was kept, regardless of spacing. It is essential that the crowns of the trees be exposed to full sunlight of at least three sides if good seed production is to be realized. At few places, several good phenotypes were also removed so that the remaining trees receive enough light. Also at many places, all inferior trees were removed resulted in a fairly large gap in the stands. There were only 20 trees ha^{-1} in Dumka seed production area compared to 433 trees ha^{-1} in Sathakashi seed production area.

Table 4 showed statistical parameters of all selected stands for various traits of trees of *Tectona grandis* standing in the seed stands at various locations before and after culling operation. The means of total height, bole height, volume, girth and diameter changed towards betterment. The range was narrowed down, which is an indication of lesser variability for the studied traits. At Chikhali stand, mean of height of the trees in the stand was 17.07±1.97 m, clear bole 4.12±2.41 m, girth at breast height 92.61±22.16 cm, diameter 29.92±7.05 cm and

Table 3. Location, total number of trees, number of trees retained and number of trees culled in the identified seed stands of Tectona grandis in Gujarat

Location	Area (ha)	Total no. of trees	No. of trees retained	No. of trees culled	Trees retained (per ha)
Chikhali, Dangs South	20.00	1809	960	849	48
Dhanpur, Dumka, Baria	10.00	510	200	310	20
Sathakashi, Surat	05.00	4179	2165	2014	433
Limbani, Chhota Udaipur	10.00	1493	1000	493	100
Parnera, South Valsad	20.00	7749	4400	3349	220
Achhala, Godhra	20.00	4010	1900	2110	95

Table 4. Changes in statistical parameters for different traits of Tectona grandis, before and after culling operation, in various seed stands in Gujarat

Parameters	Total height (m)		Bole height (m)		GBH (cm)		Diameter (cm)		Volume (m^3)	
	Before	After	Before	After	Before	After	Before	After	Before	After
Chikhali, Dangs south, Gujarat										
Mean	17.07	17.53	4.12	5.70	92.61	102.00	29.92	32.48	0.49	0.56
SD	1.97	1.84	2.41	1.30	22.16	16.89	7.05	5.38	0.18	0.17
Minimum	12.50	14.00	0.10	3.40	35.00	70.00	11.14	22.29	0.16	0.30
Maximum	21.50	21.50	7.80	7.80	134.00	134.00	42.67	42.67	0.97	0.97
Dhanpur, Dumka, Baria, Gujarat										
Mean	16.71	18.33	3.81	5.73	86.91	101.42	29.45	32.30	0.49	0.58
SD	3.06	2.28	2.48	1.47	22.86	21.13	7.28	6.72	0.21	0.21
Minimum	9.50	14.00	0.10	3.40	48.00	61.00	15.28	19.42	0.17	0.26
Maximum	21.50	21.50	8.00	8.00	134.00	134.00	42.67	42.67	0.97	0.97
Sathakashi, Surat, Gujarat										
Mean	13.31	13.53	4.02	5.92	49.08	52.12	15.58	16.59	0.19	0.21
SD	2.06	1.63	2.38	1.51	10.10	8.39	3.21	2.67	0.03	0.03
Minimum	7.50	8.50	0.30	4.00	23.00	31.00	7.32	9.87	0.13	0.14
Maximum	17.00	17.00	8.50	8.50	76.00	76.00	24.20	24.20	0.32	0.32
Limbani , Chhota Udaipur, Gujarat										
Mean	16.95	18.55	3.09	5.38	74.70	94.00	23.99	29.93	0.37	0.52
SD	2.33	1.90	2.21	1.27	23.08	19.05	7.35	6.06	0.18	0.21
Minimum	10.50	15.80	0.10	4.00	40.00	61.00	12.73	19.42	0.16	0.27
Maximum	21.50	21.50	8.00	8.00	131.00	131.00	41.71	41.71	0.97	0.97
Parnera, South Valsad, Gujarat										
Mean	18.40	18.60	5.47	6.37	60.77	62.03	18.44	19.75	0.31	0.33
SD	3.52	3.58	1.75	1.18	24.80	26.06	7.89	8.30	0.16	0.18
Minimum	8.00	8.00	2.00	3.50	18.00	21.00	5.73	6.68	0.13	0.13
Maximum	24.00	24.00	9.00	9.00	113.00	113.00	35.98	35.98	0.82	0.82
Achhala, Godhra, Gujarat										
Mean	13.19	14.01	2.81	4.20	62.60	69.82	19.89	22.24	0.25	0.28
SD	2.13	1.47	1.84	1.22	13.27	10.61	4.23	3.38	0.06	0.05
Minimum	5.50	10.50	0.10	2.80	38.00	49.00	12.10	15.61	0.14	0.19
Maximum	17.00	16.00	7.00	7.00	89.00	89.00	28.34	28.34	0.39	0.39

volume 0.49 m^3 before culling operation and it changed towards betterment for all the traits viz., height (17.53±1.84 m), clear bole (5.70±1.30 m), girth (102.00±16.89 cm), diameter (32.48±5.38 cm) and volume (0.56 m^3). All the trees were able to receive fair amount of sun light from all sides. In Dumka seed stand also, average plant height changed for betterment from 16.71±3.06 m to 18.33±2.28 m. Clear bole increased from 3.81±2.48 m to 5.73±1.47 m. Girth, diameter and volume also moved from 86.91±22.86 cm to 101.42±21.13 cm, 29.45±7.28 to 32.30±6.72 cm and 0.49±0.21 m^3 to 0.58±0.21 m^3, respectively after thinning operation which removed 310 inferior trees and retained only 200 good quality trees in 10 ha area. There was enough space for crown to receive full sun light from all sides.

Seeds were collected from established seed production areas and also from inferior stands. The viability of seeds was estimated through tetrazolium staining procedure. This test involves soaking the seed first in water to fully imbibe the seed and soften it for cutting. It is extremely important that no damage occur to the embryonic axis when a seed is cut. Usually forceps and sharp single-edged razor blades were used to cut open the seeds. The solution of tetrazolium (TZ) test is colorless. It is made by

Table 5. 100 stone weight, per cent viability and seeds/100 stones in teak seeds collected from seed production area and outside stands in Gujarat

Seed production area	100 stone weight (g)	% viability	Seeds/100 stones
Chikhali, Dangs South	40.62±1.73	50±5.00	180±3.00
Dhanpur, Dumka, Baria	41.78±4.17	45±4.00	170±6.00
Sathakashi, Surat, Gujarat	40.82±3.29	35±3.50	145±4.00
Limbani, Chhota Udaipur	40.43±1.57	35±3.38	180±3.00
Parnera, South Valsad	40.97±2.59	55±4.12	170±5.00
Achhala, Godhra	43.57±1.28	45±4.50	200±5.00
Mean	41.37±1.18	44.17±8.01	174.17±18.00
Outside collection	38.29±0.50	34±3.50	140±11
% improvement over seed stand on seed parameters	8.04	29.91	24.29

± Standard deviation.

dissolving 2, 3, 5-triphenol tetrazolium chloride in a phosphate buffer at pH 7.4, which is the optimum pH for the TZ reaction. The seeds were incubated for 24 h in the solution. Tissues that are alive and respiring stained and were counted.

Hundred fruit (stone) weight, seeds per 100 stones and seed viability of *Tectona grandis* varied from 40.62±1.73 g in Chikhali seed production area to 43.57±1.28 g in Achhala, 145±4.00 in Sathakashi, 200±5.0 in Achhala, 35±3.38 in Limbani and 55±4.12 in Parnera seed production area. Outside collection showed only 38.29±0.50 g stone weight, 140±11 seeds per 100 stones and 34±3.50% viability. Overall tested seed attributes showed improvement for 100 stone weight (8.04%), viability (29.91%) and seeds/100 stones (24.29%) in seeds of seed production areas compared to un-culled stands (Table 5).

Well stocked seed stands after removal of inferior trees, termed as Seed Production Area (SPA), are quite widely used in plantation programs. A seed production area is phenotypically superior stand made up of vigorously growing healthy trees, upgraded by thinning to remove poorer phenotypes and treated and managed to ensure abundant seed production. Since they are rarely progeny tested, both the parents are selected based on phenotypic qualities. Therefore, they are generally used as intervening sources of seed in forest tree improvement and are phased-out as better genetic seed becomes available from seed orchards. Seed production areas have greater utility in a number of tropical and sub-tropical countries (Goel and Behl, 2001).

There is a great need to make forestland more productive. Increased productivity is especially important for the tropical forest regions. It is now generally recognized that one major way to increase yield and quality from forestland is through tree improvement (Tybirk, 1989; Ertekin, 2010, 2012). However, if this aspect of silviculture is to be fully utilized, gains and improvements must be quantified and subjected to benefit-cost analyses. Tree improvement benefits may take several forms, such as greater adaptability, increased volume production, better quality of the wood produced, and other forms that will result in an improved final product. Shortening the optimal rotation age to obtain the desired product and developing greater uniformity in the trees produced are major potential benefits. It is clear that these are all interrelated and cannot be assessed independently (Sheik, 1989).

In teak, there is evidence of inherent variation in stem straightness, size, shape, color and texture of the leaves, winter susceptibility and resistance to insect and pests and site requirements (Kedharnath and Matthews, 1962; Ball *et al*., 2000; Lee, 2007; Harwood *et al*., 2007). In teak lot of natural variation is available due to its wide distribution within India and in other countries (Zobel, 1978; Indira and Mohanadas, 2002). Variation is the most important genetic resources for bringing in genetic improvement in species (Zobel and Talbert, 2003). Therefore, there is plenty of scope to improve teak through selection and hybridisation. Advance techniques like mutation, polyploidy, biotechnology and genetic engineering can be of immense use for the genetic improvement of teak (Roche, 1979).

The emphasis on quality is important since the selection of the original stand and of the trees to be left on the area and its isolation zone determines the degree of improvement in genetic quality that will be obtained. We can not be positive that any improvement in genetic quality has been effected until these areas have been progeny-tested; but surely this will counter the dysgenic effect of using seed collected without regard to its parentage or origin.

The most important requirement is that it be a well-stocked stand of good quality that has not suffered any sort of high grading. In addition, the trees should be large enough to produce enough seeds. Desired attributes of the trees left in a seed production area are similar to, but less rigorous than, the qualifications required for a select tree to be used in an intensive tree improvement program. For existing mature stands that will be converted, trees showing potential for good seed production are given preference, although the evidence of past seed production is not essential if the trees have been growing in a tightly closed stand. Excellent seed crops are often produced after heavy thinning by trees that showed little seed production prior to thinning.

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