KFRI Research Report 102

GROWTH PERFORMANCE OF TEAK NURSERY STOCK FROM GENETICALLY BETTER SOURCES FOR DEVELOPING IMPROVED PLANTATION TECHNOLOGY

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May 1996 Pages: 49

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ABSTRACT

In India efforts were made to standardize the nursery practices in teak since 1840s.The effects of factors like genetic sources,graded seeds,sowing methods and seed rate on seedling growth have been tested by several workers since long, but the results were often contradictory and inconclusive. In this context,the present study was undertaken to suggest methods to improve the nursery technology.The project also envisaged to estimate the mean number of plantable stumps per bed in teak nurseries in Kerala and to suggest an easy and indestructive plantability criterion instead of the one based on stump diameter that is in vogue at present.

Performance of 31 teak nurseries located in different parts of Kerala has been analysed in detail with respect to total and plantable stumps.The results revealed that the total number of stumps per standard nursery bed varied from nursery to nursery and the proportion of non- plantable seedlings was found to be much higher in most of the nurseries.

From the data obtained from this study, a new plantability criterion was developed based on height of the seedlings with a value of $23 \leq H \leq 56$ cm.For evaluating the planting stock in any nursery,this criterion will be of much use since it is easier to adopt and at the same time non destructive.

The nursery experiments conducted in the KFRI nursery at Palappilly, revealed that fruits having higher germinability are preferable for better nursery stock irrespective of the genetic source and that through proper management of the nursery the proportion of plantable material can be raised to about 90 percent of the total seedlings in the nursery.The study also shows that the fruit size does not have any influence on seedling growth and hence, there is no need for grading of fruits.However, it was observed that fruits with less than 9 mm diameter give less number of seedlings, When the sowing methods were compared, broadcasting was found to be better than dibbling. The results have also shown that seed rate can be increased upto 8 kg per bed of standard size (12x 1.2m)for getting more plantable seedlings.

Experiments to compare pit planting and crow bar planting with stumps of different thickness indicated that pit planting is better than crow bar planting and that stumps of 1.5 to 2.0 cm diameter performed better than stumps of 1 to 1.49 cm

1. Introduction

Teak *(Tectona grandis* L.f.) has a high preference among tropical timber trees,for its superior wood qualities, faster growth and ease in establishment.The present trend for quick returns through shorter rotations lays greater emphasis on productivity improvement. Although there are several ways by which productivity can be increased, use of superior propagules is the basic and most important one.

Ever since the establishment of the first teak plantation in Nilambur during 1840s, there has been efforts to improve standards in plantation technology. Standardization of the nursery practices, stump planting practice, thinning schedules and rotation period are notable among them.

Attempts have been made in the past to correlate growth of plants with seed source, seed size, etc. Considering the need for use of good quality stumps for planting, attempts were also made to work out the optimum seed rate and method for sowing in nurseries.It has been reported that seed sources have influence on germinability and plant production (Gupta and Pattanath,l975; Anmol Kumar,1992). Several studies have been made to correlate germination percent, vigour and seedling growth with the size of fruits.Most of the results recommend bigger fruits (Eidmann,1934; Samapudhi, 1967;Banik,1978;Kumar,1979 and Syam,1988),whereas few other studies do not support this argument. (Anon,1955; Sarowart,1964).Tewari(1992)indicates that seed rate has direct effect on the early growth of teak plants.There is a wide variation of seed rates used in India. It varies between 3-4 kg (Reddy and Rao,1972) in Maharashtra while Tewari(1992) reports it to be 10-12 kg per bed in India as a whole.Studies conducted at Sri Lanka showed 12 lbs to be the ideal seed rate for a bed of 40 x 4' size (Wije Singhe, 1963). Generally in teak broadcasting of fruits is the widely employed method which ignores spacing.But experiments conducted in Andhra Pradesh suggests a 10 x l0cm spacing for larger stumps(Kadambi,l972). The results of most of these studies suggested the need for taking up regional experiments as the seed characteristics and the germination behaviour varied with agroclimaticregions.

In this context, this study was undertaken with the following objectives:

- to estimate the mean number of plantable stumps produced in teak nurseries in Kerala
- to suggest a new plantability criterion instead of that based on stump diameter
- to study the performance of nursery stock using genetically superior sources and
- to study the effect of sowing methods and grading of seeds on seedling growth.

This report is organized in eight sections: introduction (Section 1). availability of plantable stumps from teak nurseries in Kerala (Section 2), evolving a new criterion for plantability of teak seedlings (Section 3), effect of genetic sources on seed germination and growth (Section 4), effect of size-grading of seeds on germination and growth of seedlings (Section 5), effect of sowing methods and seed rate on germination of seeds and growth of seedlings (Section 6), stump quality in relation to soil compaction (Section 7) and conclusions (Section 8).

2. Availability of plantable stumps from teak nurseries in Kerala

2.1. Introduction

The adequacy of the number of stumps produced in a standard nursery bed (1 2x 1.2m) is often taken for granted.There has been no attempt to estimate the percentage of 'plantable' stumps.Information on availability of plantablc stumps is useful in planning thc planting programmcs and for ensuring the quality of the plantations. The plantability criterion of stumps based on stump diameter as defined by Griffith (l 939) has been regarded as standard by most planters.

2.2. Materials and methods

A standard teak stump (a root-shoot cutting prepared from one year old seedling) recommended for planting in the field should have a stump diameter[1] within the range 1 to 2 cm (Griffith, 1939). Using this plantability criterion, the mean number of plantable seedlings (stumps) per nursery bed was estimated through a sample survcy during the last week of May 1993 in 31 teak nurseries located in different parts of Kerala.

Of the 31 teak nurseries (Table 3) examined 26 were under the management of social forestry divisions and 5 under the territorial divisions. The number of beds in nurseries surveyed ranged from 38 to 400.

Most of the beds were of 12 m x 1.2 m size. However, there were beds of different lengths ranging from 8.4m to 22.2 m but they were having the standard width of 1.2m. Some beds had side supports of split bamboo.Quantity of seeds sown was 5 kg per standard bed in all the nurseries surveyed.

A stratified two-stage random sampling procedurc was adopted for selection of sample. Teak nurseries were treated as strata and beds in nurseries as first-stage units of sampling. Plots of size 0.6 x 1.2 m were taken as sccond-stage units of sampling[2]. Ten beds were selected at random from each nursery and 5 plots per bed were randomly laid on them. After pulling out the seedlings in the selected plots, stump diametcr was measured on every seedling using vernier calipers. Based on the data on numbcr of plantable seedlings (NPS) and total number of seed-

[1] Therootdiameter of the seedling at maximum thickness is referred to as stump diameter

[2] There were 20 such plotsin standard beds and the number of plots varied depending on the length of the bed

lings (TNS) in the selected plots of the selected beds in the h^{th} nursery collected through the survey, the mean NPS or mean TNS per plot in the h^{th} nursery, $\hat{Y}_h$, with the estimate of variance $V(\hat{Y}_h)$ were estimated using the formula given in Murthy (1981) as follows.

The mean NPS or the mean TNS per bed in the h^{th} nursery was estimated as 20 $\hat{Y}_h$, with an estimated variance of 400 $V(\hat{Y}_h)$, considering the fact that a standard teak nursery bed has a length of 12.0 m consisting of 20 plots of size 0.6 x 1.2 m

The mean NPS or mean TNS per plot representing all nurseries together, $\hat{Y}$, was estimated as

$$\frac{\hat{Y}}{Y} = \sum_{h=1}^{K} \left(\frac{Nh}{N}\right) \cdot \frac{\hat{Y}}{Yh}$$

with estimated variance, $V\left(\frac{\hat{Y}}{Y}\right)$, as

$$V\left(\frac{\hat{Y}}{Y}\right) = \sum_{h=1}^{K} \left(\frac{Nh}{N}\right)^2 V\left(\frac{\hat{Y}}{Yh}\right)$$

where N_h, N ana K denote number of beds in the h^{th} nursery, total number of beds of all nurseries surveyed and number of nurseries surveyed respectively. The mean NPS or TNS per bed representing all nurseries together was estimated as 20 $\hat{Y}$ with the estimate of variance 400 $V(\hat{Y})$.

2.3. Results and discussion

The estimated mean TNS and NPS per bed in teak nurseries in Kerala are 717 (Table 1) and 262 (Table 2) respectively (see Appendix-1 for nursery-wise information). The estimated mean TNS in nurseries of social forestry divisions is 629 (range 262 to 1984) whereas mean TNS in territorial divisions is 1170 (range 704 to 2110). The estimated mean NPS in nurseries of social forestry divisions is 234 (range 74 to 656) whereas mean NPS in territorial divisions is 409 (range 198 to 808). Thus considerable variation exists in the mean TNS and NPS among nurseries of social forestry divisions and those of territorial divisions. The percentage of mean NPS to TNS in nurseries in Kerala is 36.5 (range 11.67 to 60.30).

Table 1. Mean number of total seedlings (TNS) per bed in teak nurseries in Kerala

Forest Divisions	Mean TNS per bed		
	Mean	Minimum	Maximum
Social Forestry Divisions	629 (1	262	1984
Territorial Divisions	1170 (51.22)	704	2110
All combined	717 (16.62)	262	2110

* The figure in parenthesis is standard error

Table 2. Mean number of plantable stumps (NPS) per bed in teak nurseries in Kerala

Forest Division	Mean NPS per bed		
	Mean	Minimum	Maximum
Social Forestry Divisions	234 (8.74)*	74	656
Territorial Divisions	409 (30.76)	198	808
All combined	262 (8.93)	74	808

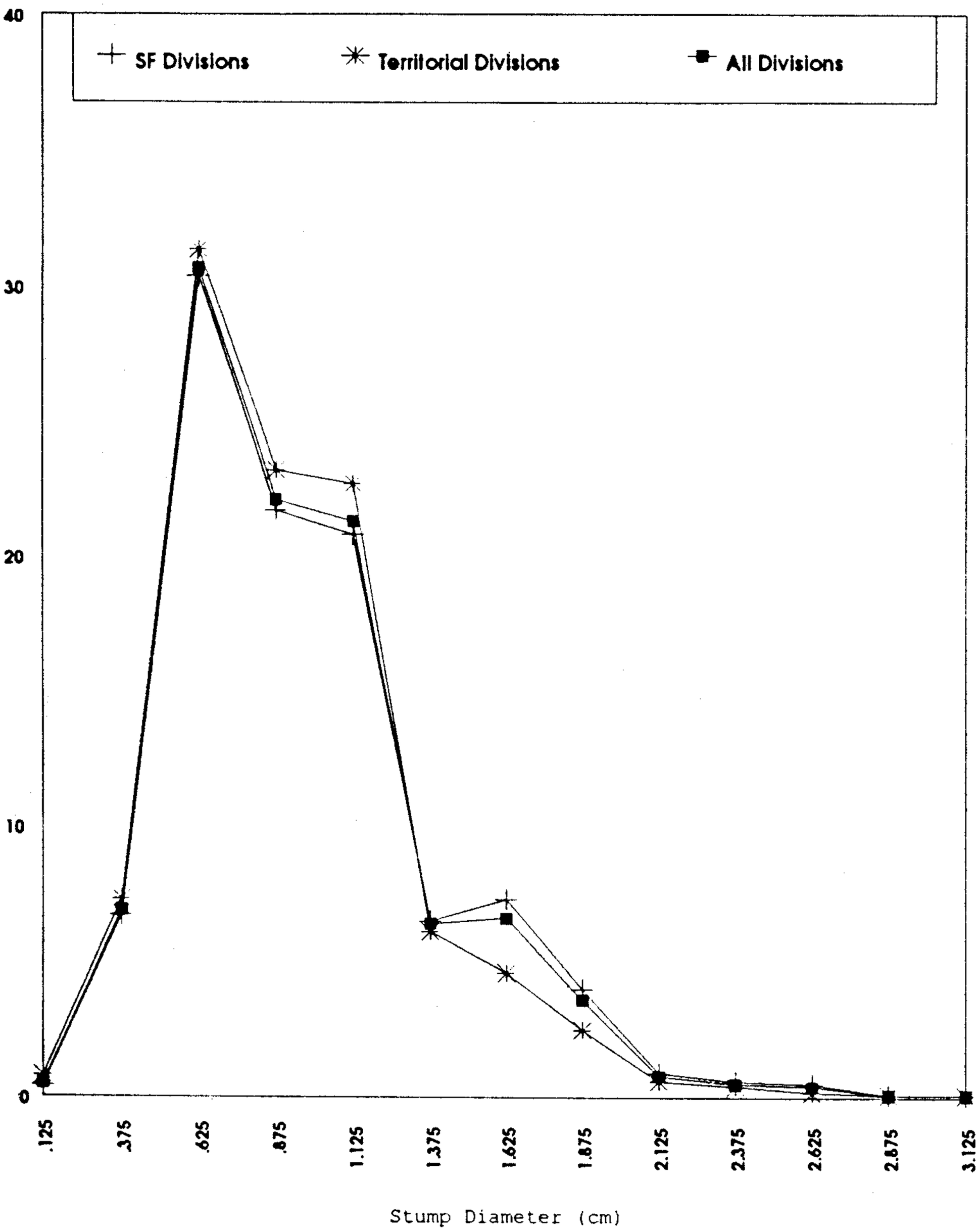
* The figure in parenthesis is standard error

The study revealed a very high proportion of sub-standard seedlings (below 1 cm diameter) in most of the nurseries (Table 3).The stump diameterclass distribution of seedlings (Appendix-2 &Fig.1) show that thesub-standard seedlings mostly belonged to the stump diameter class of 0.50 to 0.75cm.The over-grown seedlings are generally very few (0 to 3.7%) and about three fourth of the surveyed nurseries had only less than 3% overgrown seedlings

Table 3. Stump-size distribution of seedlings in teak nurseries in Kerala (percentage)

Nursery	Stump diameter (cm)		
	Below 1 cm (Sub-standard)	1-2 cm (Plantable)	Above 2 cm (Over-grown)
Kannamkuzhy	53.7	45.6	0.7
Moottumood	73.5	26.5	0.0
Poojapura	60.1	39.9	0.0
Eravankara	69.5	30.1	0.4
Puliyoor	70.4	28.9	0.7
Ponthala	63.0	37.0	0.0
Thykkattussery	76.6	23.1	0.3
Arayampara	77.0	22.3	0.7
Nallukodi	88.0	11.6	0.4
Alappara	77.0	21.0	2.0
Arivithara	75.9	22.7	1.4
Thacharikal	40.7	53.8	5.5
Chembankandom	32.1	60.0	7.9
Pananchery- 1	45.9	52.4	1.7
Pananchery-2	37.0	53.9	9.1
Paravattani	75.9	24.0	0.1
Pattikkad	32.9	60.3	6.8
Ponnukkara	31.8	58.5	9.7
Elavanchery	55.0	42.6	2.4
Patta	67.5	31.6	0.9
Muppini	48.2	49.6	2.2
Muttikadavu	44.6	46.1	9.3
Thovoor	53.1	46.1	0.8
Alavil	43.0	53.3	3.7
Iritty	56.1	42.6	1.3
Koodali	60.2	38.3	1.5
Ambalappad	61.6	38.3	0.1
Mayannur	74.0	25.4	0.6
Vadattupara	51.1	46.1	2.8
Vettingapadam	61.2	36.0	2.8
Panayangode	70.4	28.1	1.5

Fig1. Distribution of teak seedlings in nurseries by stump diameter class



3. Evolving a new criterion for plantability of teak seedlings

3.1. Introduction

Stump prepared from one year old seedling, is the most popular planting material for teak plantations.

An ideal stump should have a diameter of lcm-2cm at its thickest part on the tap root (referred to as 'stump thickness') and a shoot length of 2.5cm and tap root length of 15-20cm (Griffith, 1939). However, this standard can be applied only to seedlings uprooted from the nurseries.

For planning plantation programmes it is necessary to have an idea of the availability of the total number of plantable stumps.Sampling based on stump diameter is a destructive method. Hence,evolving a new criterion for evaluating the seedling stock even while the seedlings are standing on the nursery bed will be of much use.Therefore, this is an attempt to develop a proxy parameter such as seedling height or collar diameter' of seedling instead of stump diameter.

3.2. Materials and methods

For suggesting an alternative plantability criterion, establishment of a height-stump diameter or collar diameter-stump diameter relationship was attempted. Height(H), collar diameter(CD) and stump diameter(D) of each seedling. of one year old were collected through a sample survey during last week of May 1992 adopting a stratified 2-stage sampling plan in 5 nurseries treating the nurseries as strata.The beds in nurseries were treated as first-stage units and plots of size 0.6 x 1.2 m as second-stage units of sampling.Al1 the seedlings in the selected plots were pulled out, and height, collar diameter and stump diameter were measured on each seedling. Using this data, functional relationship of height with stump diameter as well as collar diameter with stump diameter were studied. Different regression functions were tried taking H,$H^{1}/_{2}$ and In H (or CD, $CD^{1}/_{2}$ and In CD) as regressand and D as regressor. The best fitting model was selected based on the Furnival index since the dependent variables vary from one set of models to another. The Furnival index was calculated as root mean square error multiplied by the inverse of the appro-

[1] The diameter of that portion where the shoot joins the root

priate geometric mean of the derivative of various dependent variables with respect to H (or CD). That is

Furnival index $= \sqrt{MSE}$, for H as dependent variable,

$= \sqrt{MSE}$ antilog $(\log 2 + \frac{1}{n}\sum_{i=1}^{n} \ln Hi)$, for $H^{1/2}$ as dependent variable and

$= \sqrt{MSE}$ antilog $(\frac{1}{n}\sum_{i=1}^{n} \ln Hi)$, for $\ln H$ as dependent variable,

where MSE is the mean square error obtained by fitting each equation to the data. The model which has the smallest Furnival index is considered as the best fitting model.

The best fitting models from among the relationships of height with stump diameter as well as collar diameter with stump diameter were selected. By comparing the adjusted R^2 values of these two selected models with regressand as height and collar diameter, the model with regressand as height was finally selected. Using this model, the height limits corresponding to the range of the stump diameter criterion of plantability were estimated. H_1 and H_2 represent the heights corresponding to the stump diameter D = 1 cm and D = 2 cm respectively, then the plantability criterion based on height (H) is $H_1 \leq H \leq H_2$ That is; seedlings with height in between H_1 and H_2 are considered as plantable.

3.3. Results and discussion

Different models showing the relationship of height with stump diameter along with adjusted R^2, mean square error (MSE) and Furnival index are presented in Appendix-1 and those of collar diameter with stump diameter in Appendix-2. The best fitting models from the two sets of models were selected using the adjusted R^2 and Furnival index. The selected models are the following:

$$H^{1/2} = \underset{(0.1937)}{-3.4448} + \underset{(0.1024)}{7.1773\, D^{1/2}} + \underset{(0.0893)}{1.0601\, D^{-1/2}},\ R^2\ 0.81$$

$$CD^{1/2} = \underset{(0.0041)}{0.2324} + \underset{(0.0076)}{0.5230\, D} \underset{(0.0031)}{-0.0428\, D^2},\ R^2\ 0.80$$

Based on the adjusted R^2values in the above two models, both the models are suggestive of deriving the new plantability criterion. Howcvcr, measurement of height of seedlings in nursery beds is practically easier than measuring collar diameter. Thcrefore, plantability criterion based on height of seedling is preferred to that based on collar diameter. Plantability criterion based on stump diameter is $1 \leq D \leq 2$ cm. The height limits corresponding to D = 1 cm and D = 2 cm are $H_1 = 23$ cm and $H_2 = 56$ cm respectively. Thus, the plantability criterion based on height is $23 \leq H \leq 56$ cm which means seedlings with height in between 23 and 56 cm are plantable.

The mean number of plantable stumps per bed in nurseries using the criteria based on stump diameter and both height and stump diameter were compared (see Appendix-3). Out of 31 nurseries surveyed, the percentage of mean number of plantable seedlings per bed based on stump diameter to that based on height and stump diameter was above 80% in 5 nurseries, above 70% in 10 nurseries and above 60% in 15 nurseries. Vide variation in the growth of seedlings in the remaining 16 nurseries may be due to untimely pre-monsoon
shower, difference in soil types and other biological factors.

4. Effect of genetic sources on seed germination and growth

4.1. Introduction

Seed source has been reported to influence germinability and plant production (Gupta and Pattanath,1975; Anmol Kumar, 1992). Some of the influencing factors are the climate including the precipitation at the seed production area. Gupta and Pattanath (1975) report that germination percent varies between seeds collected from different geographic origin and suggest that fertility index of the site has a more pronounced effect on the seed behaviour than precipitation. However, attempts to correlate the performance of seedlings/plantations with seed source led to no definite conclusions. Hence,experiments were conducted to study the effect of genetic sources on seed germination and seedling growth.

4.2. Materials and Methods

4.2.1. Seed collection:

Seeds were collected from natural stands, seed stands (plantations set apart specially for seed collection), plantations, seed orchards and a few individual plus trees in Kerala during January and February. Newly fallen fruits were picked up from plantations and seed stands while those from plus trees and seed orchards were gathered from the standing trees.
Hessian sheets were spread around each tree to avoid mixing up.

After collection, the fruits were dried and cleaned by removing the driedcalyx. Experimental samples were drawn from these lots and their seed weight estimated.

4.2.2. Nursery trial:

This experiment included 24 sourcesi.e. 6 plantations, 4 seed stands, 11 plus trees and 3 seed orchards (Table 4). Randomized block design with 3 replications was followed for the nursery experiment. Standard nursery beds of the size 12 x 1.2 x 0.3 m were made at Palappilly of Thrissur District and each bed was divided into ten equal sub plots of 1.2 m^2, each one representing one replication. In each subplot 24 x 24 (576) seeds were sown with an equal spacing of 5 cm x 5 cm.Each seed source was considered as a treatment.

The seeds were soaked in water ovcr night and sown in nursery beds during June. Weeds were removed regularly and the nursery was maintained for one year.

Table 4. Seedsources used in nursery experiments.

Treatment No	Source & Locatior
1.	Plus tree No. 27 Arienkavu
2.	Plus tree No. 41 Arienkavu
3.	Plus tree No. 8 Nilambur
4.	Plus tree No. 15 Konni
5.	Plus tree No. 1 Nilambur
6.	Plus tree No. 47 Arienkavu
7	Plus tree No.43 Konni
8.	Plus tree No. 46 Arienkavu
9.	Plus tree No. 11 Nilambur
10.	Plus tree No. 5 Nilambur
11.	Plus tree No 3 Nilambur
12.	Plantation, Peechi, Trichur
13.	Plantation, Kummannoor, Konni
14.	Plantation, Naduvathamuzhy, Konni
15.	Plantation, Kanjirapara, Konni
16.	Plantation, Nilambur
17.	Plantation Arienkav, Thenmala
18.	Seed stand, Naduvathamuzhy, Konni
19.	Seed stand, Nilambur
20.	Seed stand, Parambikulam
21.	Seed stand, Arienkavu, Thenmala
22.	Seed orchard, Palappilly, Chalakudy
23.	Seed orchard, Arippa, Trivandrum
24.	Seed orchard, Walayar, Olavakkode

Each seed was observed daily for germination. Monthly height measurements of the seedlings for one year and final measurements on shoot length, root length, root depth, collar diameter and stump diameter were taken after careful removal of the seedlings from the nursery bed.Since germination percent,total number of seedlings (TNS) and plantable seedlings (NPS) are important with regard to nursery health, these were taken into consideration.Seed1ings which fall in between 1 to 2 cm. stump diameter were taken as plantable.

4.2.3. Field trial:

Seedlings of different seed sources (genetic sources) were field planted at a spacing of 2m x2m at Nilambur with 14 seed sources, and at Palappilly with 24 seed sources (Table5).Since some of the seed sources did not have enough seedlings they were not included in the field trial.

The height measurements of seedlings were taken after 9 months at Nilambur and after 15 months at Palappil1y.In the first year, growth of seedlings was very poor at Palappilly due to the poor soil conditions and hence height measurements could be taken only after 15 months. The data were analysed by analysis of variance test and treatments were compared following Duncan's multiple Range test (DMRT).

Table 5. Seed sources used for field planting

Nilambur planting		Paiappilly planting	
Treatment No.	Seed source	Treatment No.	Seed source
T1	Plus tree No.3	T1	Plus tree No.1
T2	Plus tree No.5	T2	Plus tree No.3
T3	Plus tree No.11	T3	Plus tree No.8
T4	Plus tree No.18	T4	Plus tree No.9
T5	Plus tree No.41	T6	Plus tree No.12
T6	Plus tree No.47	T5	Plus tree No.11
T7	Kummannoor plantation, Konni	T7	Plus tree No.14
T8	N.Moozhy plantation, Konni	T8	Plus tree No.16
T9	Peechi plantation, Trichur	T9	Plus tree No.18
T10	Nilambur plantation	T10	Plus tree No.20
T11	Arienkavu plantation, Thenmala	T11	Plus tree No.21
T12	N. Muzhy seed stand, Konni	T12	Plus tree No.33
T13	Parambikulam seed stand	TI3	Plus tree No.37
T14	Arienkavu seed stand, Thenmala	TI4	Plus tree No.41
		TI5	Plus tree No.4'7
		T16	N. Muzhy Plantation
		T17	Nilambur plantation
		T18	Arienkavu plantation
		T19	N. Muzhy seed stand
		T20	Nilambur seed stand
		T21	Arienkavu seed stand
		T22	Parambikulam seed stand
		T23	Palappilly orchard
		T24	Arippaorchard

4.3. Results and discussion

4.3.1. Nursery trial:

Analysis of variance tests (Table 7 &8) show that there is significant difference between sources with regard to number of total and plantable seedlings.The comparison of treatments for total and plantable seedlings was done through DMRT (Tables 9 &l0).

With regard to percentage of germination, there was great difference between seed sources and it varied from 0.97 to 32.99 (Table 6). The variation was 16.6 to 32.99 among platations, 6.11 to 32.15 among seed stands,2.08 to29.75 within the category of Plus trees and 0.97 to 16.39 among seed orchards.

Prasad and Jalil(l986) also observed that germination of seeds from orchards varied from 4.2 to 37.8% and seeds of natural stands varied from 13.93to 54.42%. Although Anmol Kumar (1992) reports that seeds from seed orchards show better germination than seeds from general collections,our observations do not agree with this and suggested that a categorization like plantation, orchard, seed stands etc. is not warranted in terms of seed germinabi1ity.Probably the fertility index of the site may have an effect on seed germination as reported by Gupta and Pattanath (1975).They also note two ther reasons,viz.the presence of water soluble germination inhibition the mesocarp of fruits and also the phenomenon of'after ripening period'.These aspects have to be investigated in detail to get a clear picture.

Table 6. Effect of seed sources on total and plantable seedlings in the nursery

Treatment No. Source	Germination %	%TNS to TSS	%TNS to seeds germinated	%NPS to TSS	%NPS to seeds germinated	%NPS to
1. PT27	21.99	18.05	82.17	15.17	68.99	83.96
2. PT41	29.75	24.55	82.52	23.36	78.51	95.13
3. PT8	12.64	10.34	81.87	8.89	70.33	85.91
4. PT15	5.28	4.65	88.16	4.10	77.63	88.06
5. PTI	15.28	12.64	82.73	12.08	79.09	95.60
6. PT47	18.75	17.08	91.11	16.18	86.30	94.72
7. PT43	38.89	16.04	84.93	14.44	76.47	90.04

contd...

Treatment No. Source	Germination %	%TNS to TSS	%TNS to seeds germinated	%NPS to TSS	%NPS to seeds germinated	%NPS
8. PT46	2.08	2.08	100.00	2.01	96.67	96.67
9. PT11	17.78	14.31	80.47	13.33	75.00	93.20
10. PT5	10.97	9.86	89.87	8.82	80.38	89.44
11. PT3	18.19	16.53	90.84	15.35	84.35	92.86
12. Plantation Peechi	16.60	14.10	84.52	13.26	79.92	94.55
13. Plantation Kummannoor Konni	32.99	27.64	83.79	22.78	69.05	82.41
14. Plantation N. Moozhi Konni	22.92	18.89	82.42	17.08	74.55	90.44
15. Kanjirappara Konni	31.25	28.26	90.44	26.53	84.89	93.86
16. Plantation Nilambur	26.39	23.61	89.47	21.88	82.89	92.65
17. Plantation Arienkavu	24.79	21.45	86.55	20.14	81.23	93.85
18. Seed stand N. Moozhy	19.51	17.50	89.68	16.6	85.05	94.84
19. Seed stand Nilambur	6.11	5.21	85.23	4.72	77.27	90.67
20. Seed stand Parambikulam	32.15	28.96	90.06	26.74	83.15	92.33
21. Seed stand Arienkavu	29.38	25.63	87.32	25.21	85.82	98.37
22. Seed orchard Palapilly	16.39	14.26	87.01	12.5	76.27	87.66
23. Seed orchard Arippa	7.71	6.81	88.29	5.97	77.48	87.76
24. Seed orchard Walayar	0.97	0.97	100.00	0.83	85.71	85.71

TSS - Total seeds sown
TNS - Total number of seedlings
NPS - Number of plantable stumps

The percentage of total number of seedlings produced varicd between 0.97 to 28.96 while the percentage of plantable seedling production varied between 0.83 to 26.74 (Table 6 & Figs.2-

When we consider the total number of seedlings at the end of one year, 80.47 to 100 percent of them survived. Hundred percent survival was noticed in those which had very low germination of 2.08 and 0.97 in seed sources No.8 and 24 respectively. In almost all other treatments 80-90 percent of the germinated seeds survived.

Out of the total germinated seeds, the percentage of plantable seedlings varied between 68.99 to 96.67. Out of the total seedlings 82.4 to 98.37 percent were plantable and in most cases this was approximately 90 percent.

Table 7. Effect of genetic sources on % NPS in the nursery

Source	DF	MSS	F
Main effects	25	0.949	16.481
Treatment	23	0.894	15.514'
Replication	2	1.357	23.56
2 way interaction	46	0.75	13.01

* Significant at 5% level

Table 8. Effect of genetic sources on % TNS in the nursery

Source	DF	MSS	F
Main effects	25	1.482	20.711
Treatment	23	1.398	19.544*
Replication	2	2.016	28.173
2 way interaction	46	1.188	16.604

* Significant at 5% level

Rg.2 Seedsfrom Plus Trees

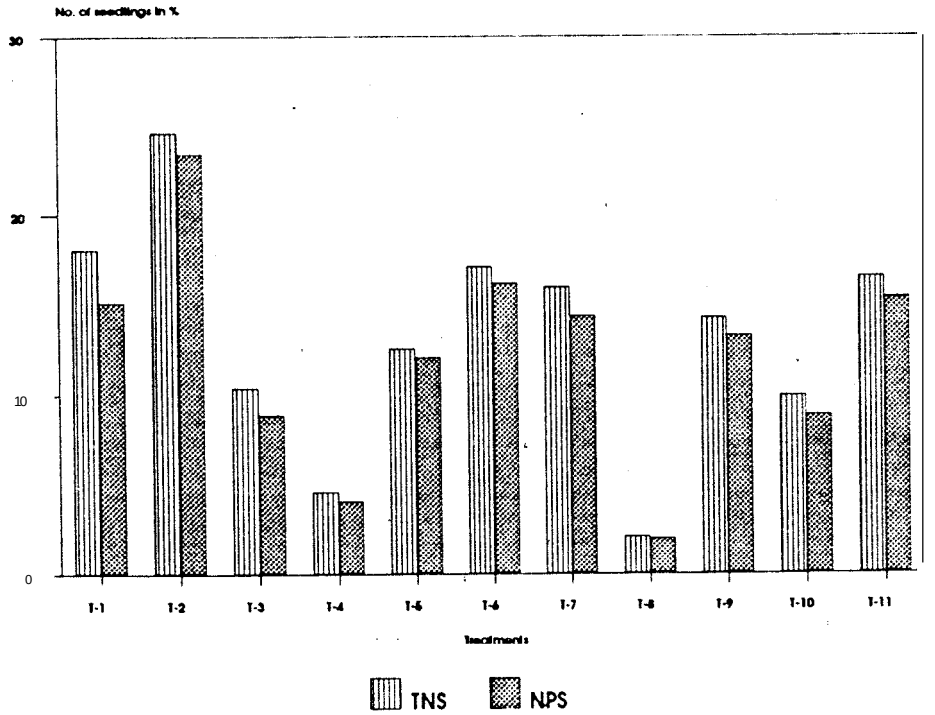
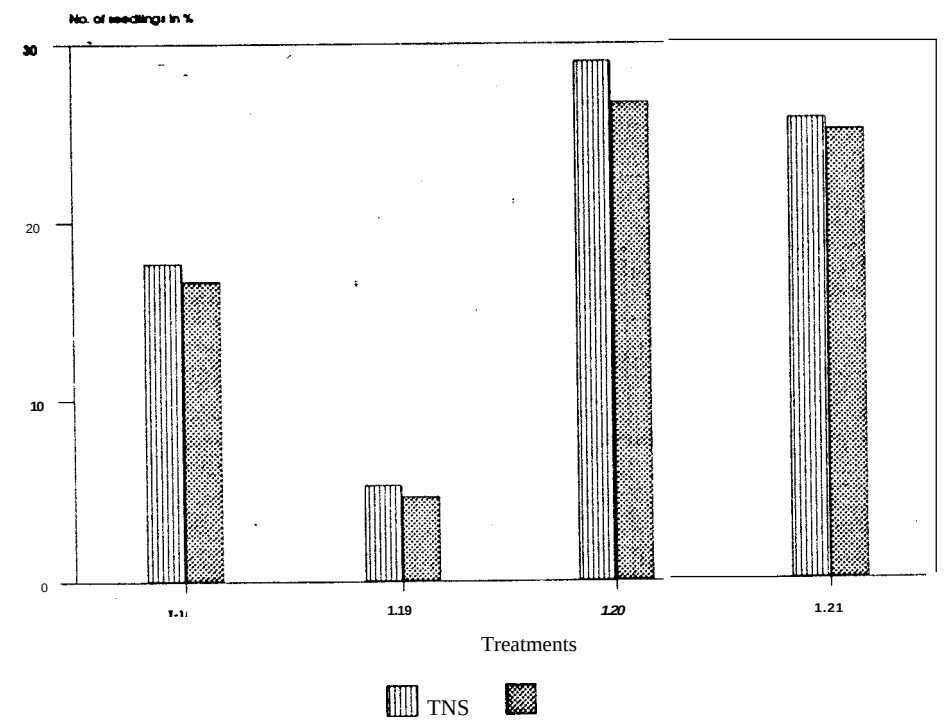
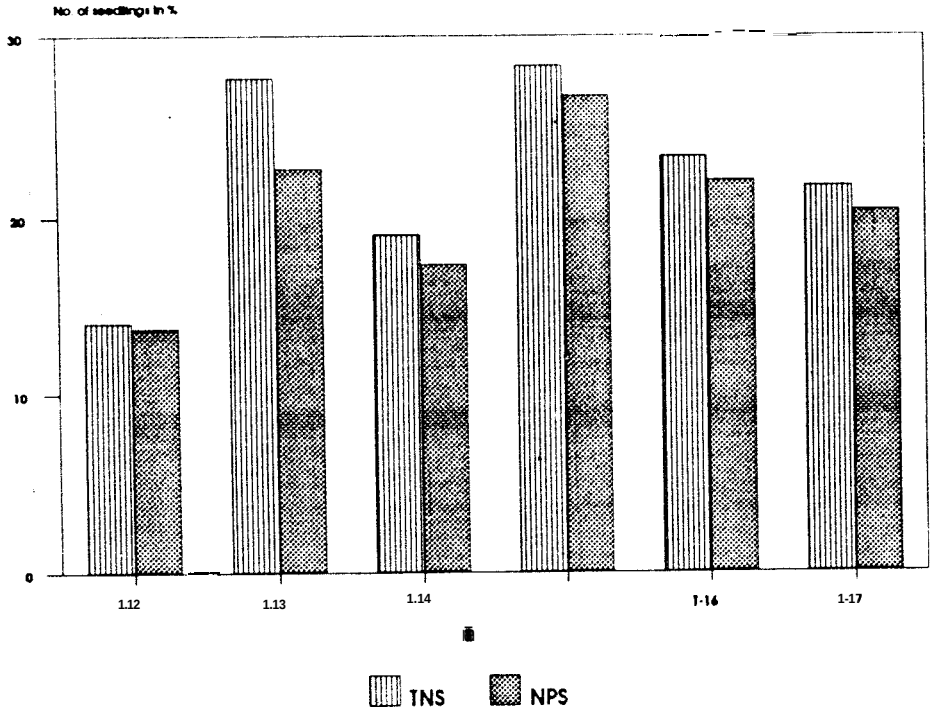


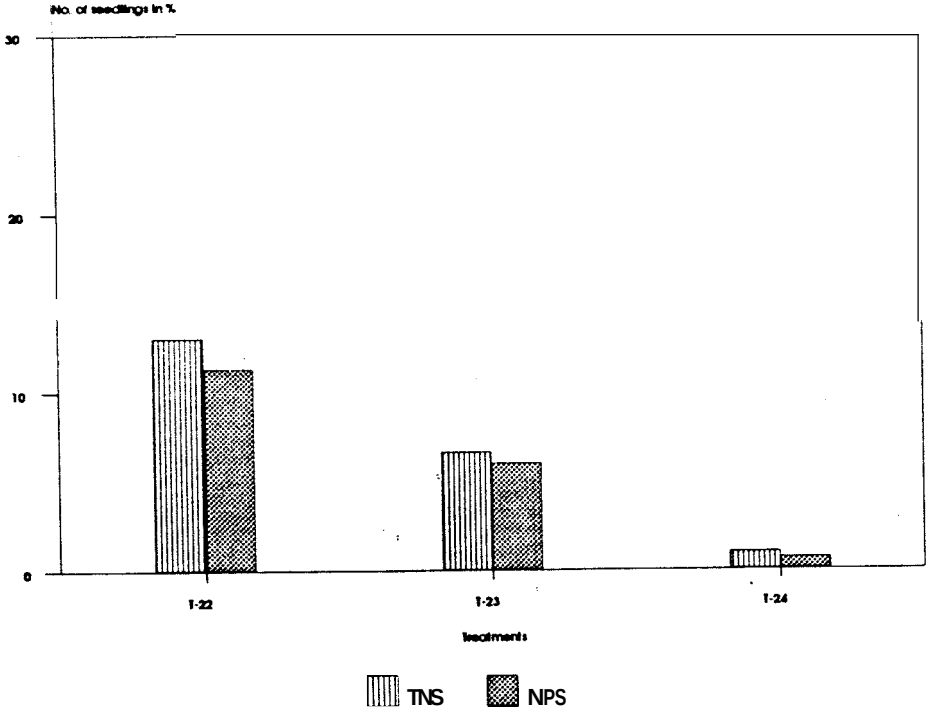
Fig.3 Seeds from Seed Stand



Rg. 4 Seeds from Plantations



Rg.5 Seeds from food Orchards



Hence, it may be concluded that percentage of germination of the seed source is the main factor controlling the number of total and plantable seedlings in teak nursery and hence, seeds having high viability have to be used for efficient establishment and management of teak nurseries.

Table 9. Effect of genetic sources - DMRT comparison with respect to % NPS in the nursery

Mean	Group	24	8	4	19	23	10	3	5	12	9	22	7	11	6	18	1	14	17	16	2	21	13	15	20
0.83	24																								
2.00	8																								
4.10	4																								
4.72	19																								
6.00	23																								
8.82	10	*																							
8.89	3	*																							
12.08	5	*	*	*	*																				
12.5	22	*	*	*	*																				
13.3	9	*	*	*	*																				
13.3	12	*	*	*	*																				
14.44	7	*	*	*	*	*																			
15.17	1	*	*	*	*	*																			
15.35	11	*	*	*	*	*																			
16.18	6	*	*	*	*	*																			
16.67	18	*	*	*	*	*	*																		
17.06	14	*	*	*	*	*	*	*																	
20.14.	17	*	*	*	*	*	*	*	*	*															
21.88	16	*	*	*	*	*	*	*	*	*	*	*													
22.78	13	*	*	*	*	*	*	*	*	*	*	*	*	*											
23.36	2	*	*	*	*	*	*	*	*	*	*	*	*	*											
25.21	21	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*							
26.53	15	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*							
26.74	20	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*							

Table 10. Effect of genetic sources - DMRT Comparison with respect to %TNSin the nursery

[Mean	Group	24	8	4	19	23	10	3	5	12	9	22	7	11	6	18	114	17	16	2	21	13	15	20
0.97	24	*																						
2.08	8	*																						
4.67	4	*	*																					
5.21	19	*	*	*	*																			
6.81	23	*	*	*	*																			
9.86	10	*	*	*	*	*																		
10.33	3	*	*	*	*	*																		
12.64	5	*	*	*	*	*																		
14.10	12	*	*	*	*	*																		
14.3	9	*	*	*	*	*																		
14.3	22	*	*	*	*	*	*																	
16.04	7	*	*	*	*	*	*																	
16.53	11	*	*	*	*	*	*																	
17.08	6	*	*	*	*	*	*																	
17.5	18	*	*	*	*	*	*																	
18.05	1	*	*	*	*	*	*	*																
18.89	14	*	*	*	*	*	*	*	*	*														
21.45	17	*	*	*	*	*	*	*	*	*	*	*	*											
23.61	16	*	*	*	*	*	*	*	*	*	*	*	*											
24.55	2	*	*	*	*	*	*	*	*	*	*	*	*	*	*									
25.63	21	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*						
27.64	13	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*						
28.31	15	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*						
28.96	20	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*						

4.3.2 Field trial

The analysis of variance for the height measurements showed that the treatments are significantly varying (Table 11 & 12). The grouping through Duncan's multiple Range test is as shown in Table 13 (Nilambur trial) and Table 14 (Palapilly trial). Some of the plus tree seedlings performed well at Nilambur while seeds from Nilambur plantations had shown very poor growth. At the same time, seeds from Naduvathamuzhy and Nilambur plantations had the best performance at palappilly. The seeds from the same 11 genetic sources planted at Palappilly and Nilambur performed differently and their ranking is as given in Table 15.

The genetic sources being same, this difference in early growth performance may be due to the environmental factors or due to the interaction of both environmental and genetic factors. Performance of one year old seedlings need not indicate the growth of the mature trees since rarely can we see good juvenile-mature correlation. To idcntify the genetic sources of high potential the field trials have to be continued for some more years.

Table 11. Effect of seed sources on field planted seedling height - Nilambur trial

Source	DF	MSS	F
Main effects	15	1183.832	6.373
Treatment	13	832.721	4.483*
Replication	2	3027.012	16.296*
2 Way interaction	26	1613.923	8.688

* Significant at 5% level

Table 12. Effect of seed sources on field planted seedling height - Palappilly

Source	DF	MSS	F
Main effects	25	1594.685	5.378
Treatment	23	902.600	3.044*
Replication	2	9312.551	31.406
2 way interaction	46	1057.069	3.565*

* Significant at 5% level

Table 13. DMRT Comparison with respect of height (0.05 level) - field planted teak at Nilambur

Mean	Group	10	4	13	9	14	6	2	7	12	8	11	5	1	3
16.60	10														
19.95	4														
21.56	13														
24.73	9														
25.46	14														
26.31	6	*													
26.50	2	*													
26.83	7	*													
27.09	12	*													
28.71	8	*	*												
31.02	11	*	*	*											
32.13	5	*	*	*											
32.49	1	*	*	*											
34.80	3	*	*	*	*	*	*								

Table 14.DMRT comparison with respect to height(0.05level)-field planted teak at Palappilly

Mean	Group	12	14	8	7	24	3	11	10	1	9	13	20	15	5	2	21	18	22	6	4	19	23	16
28.17	12																							
30.40	14																							
32.51	8																							
32.79	7																							
32.89	24																							
33.14	3																							
33.50	11																							
33.55	10																							
33.98	1																							
34.00	9																							
35.44	13																							
36.63	20																							
36.88	15																							
37.97	5																							
38.26	2																							
38.48	21	*																						
39.10	18	*																						
39.16	22	*																						
39.37	6	*																						
39.91	4	*																						
40.53	19	*	*																					
42.21	23	*	*																					
46.70	17	*	*	*	*	*	*	*	*	*	*	*	*	*	*									
47.51	16	*	*	*	*	*	*																	

Table 15. Field performance of teak at Palappilly and Nilambur (in decending order of performance)

Palappilly	Nilambur
Naduvathamuzhy	Plus tree 11
Nilambur plantation	Plus tree 3
Naduvathamuzhy seed stand	Plus tree 41
Parambikkulamseedstand	Arienkavu plantation
Arienkavu plantation	Naduvathmuzhy plantation
Arienkavu seed stand	Naduvathamuzhy seed stand
Plus tree 3	Plus tree 47
Plus tree 11	Arienkavu seed stand
Plus tree 47	Parambikulam seed stand
Plus tree 18	Plus tree 18
Plus tree 41	Nilambur plantation

5. Effect of size-grading of seeds on germination and growth of seedlings

5.1. introduction

Studies to correlate germination percentage, vigour and seedling growth with size of seeds, though generally favour use of larger seeds (Eidmann, 1934; Samapudhi, 1967; Banik, 1978; Kumar, 1979 and Syam, 1988), few other studies disagree with this for want of supporting evidence (Anon., 1955; Sarowart, 1964). Moreover, the conclusions, in most cases, are based on smaller samples. Even if the superiority of a particular seed size grade is established, the adequate availability of the preferred seed grade in the seed lots is a major factor deciding its application at field level. This aspect has not been hitherto looked into.

5.2. Materials and Methods

Seed collection was done as explained in Section 4.The fruits were then graded according to their size.

5.2.1. Size grading:

The fruits were size graded using sieves of size 50cm x 50cm with different mesh sizes, The different size-grades were 6mm pass (<6mm), 6mm retained (6mm-9mm), 9mm retained (9mm-12mm), 12mm retained (12mm-l5mm), 15mm retained (15mm-18mm) and 18mm retained (above 18mm dia). The smallest (6 mm pass) and the biggest fruits were discarded since most of the smallest fruits were illdeveloped and biggest fruits were either absent or very few.

5.2.2. Nursery trial

In this experiment 4 seed grades (6 mm retained, 9 mm ret, 12 mm ret, 15 mm ret) in each of plantation source and seed stand were used with 8 treatments (Table 16). The seeds were sown in the nursery and observations were taken periodically as described in Section 4.

Table 16. Different fruit grades used for nursery trial

Treatments	Size grade	Seed source
T1	15 mm retained	Plantation
T2	12 mm retained	,,
T3	9 mm retained	"
T4	6 mm retained	"
T5	15 mm retained	Seed stand
T6	12 mm retained	"
T7	9 mm retained	"
T8	6 mm retained	,,

5.3. Results and discussion

5.3.1. Seed characters

Table 17 shows that most seeds (65.2 to 85.55% by number and 60.88 to 77.73% by weight) belong to 9mm retained (in 9 - 12mm size) category. Also it is evident that the number and weight of seeds above 9mm category forms significant proportion of the seeds (97.94 to 99.32% by number and 98.89 to 99.35% by weight). The number of seeds in the catagory of above 9mm size was 1761 per kg to 2011 per kg with an average of 1885 per kg.

Table 17. Percentage number and weight of teak 'seeds'(fruits) in different size grades

Source	Size grade											
	18mm retained		15 mm retained		12mm retained		9mm retained		6 mm retained		6 mm pass	
	% No.	% weight	% No.	% weight	% No.	% weight	% No.	% weight	% No.	% weight	No.	% weight
Natural Forest (n=19)	0	0	14.66	20.42	4.20	6.27	80.46 (99.32)	72.66 (99.35)	0.68	0.66	Nil	Nil
Plantation (n=18)	0.003	0.006	28.12	3127	4.93	7.12	65.21 (98.26)	60.88 (99.28)	1.67	0.69	0.08	026
Seed orchard (n=72)	0	0	11.19	16.65	4.20	4.51	82.55 (97.94)	77.73 (98.89)	2.06	1.11	Nil	Nil
Plus tree (n=55)	0	0	21.82	30.88	5.76	6.62	70.47 (98.05)	6i.80 (99.3)	1.82	0.65	0.13	0.04
Seed stand	0	0	19.00	28.48	5.39	6.14	73.63 (98.02)	64.68 (99.3)	1.76	0.61	0.24	0.09

• Figures in parenthesis under '9 mm retained indicate cumulative figures for size grades above 9 mm.

Table 18. Number of teak seeds (per kilogram) in different size grade

Source	Size grade					
	retained	5 mm retained	12 mm retained	9 mm retained	6 mm retained	Mean
Natural Forest (n=19)	NA	1357	1419	2060	2333	1335
Plantation (n=18)	1000	1411	1556	2100	5576	1804
Seed orchard (n=72)	NA	1389	1463	2190	4259	1550
Plus tree . (n=55)	NA	1335	1621	2167	5124	1458
Seed stand (n=21)	NA	1389	1463	2190	4259	1550
Mean	1000	1356	1534	2139	4542	1501

NA - Not available

5.3.2. Seed germination and seedling growth

The analysis of variance shows that there is significant difference between treatments for percentage of plantable and total seedlings (Table 19 and 20). Treatment comparison (Table 22) shows that within sources 1 and 2 there is no significant difference between grades 15-18,12-15, and 9-12 mm for total no. of seedlings.Treatment No. 4 and 8,which were in grade 6-9 mm, performed badly. There was difference in total number of seedlings between seed sources because the germination percent of the two seed sources varied much.

Table 19. Effect of seed grading on % NPS

Source	DF	MSS	F
Main effects	4	182.806	15.096
Source	1	418.133	34.528''
Grade	3	104.364	8.618''
2 Way interaction	3	18.386	1.518

** Significant at 1% level

Table 20. Effect of seed grading on % TNS

Source	DF	MSS	F
Man effects	4	272.269	16.877
Source	1	563.333	34.919**
Grade	3	175.247	10.863**
2 way interaction	3	26.403	1.637

** Significant at 1% level

Table 21. Effect of grading - DMRT comparison with respect to % NPS (0.05 level)

Mean	Group	4	8	3	1	2	7	6	5
2.5	4								
5.21	3								
6.67	8	*	*						
7.29	1	*	*	*					
11.11	2	*	*	*	*				
15.28	7	*	*	*	*				
16.15	6	*	*	*	*				
17.36	5								

Table 22. Effect of grading - DMRT comparison with respect to % TNS (0.05 level)

Mean	group	8	4	1	3	2	7	6	5
4.17	8								
7.92	4	*	*						
10.07	1	*	*						
10.42	3	*	*						
14.41	2	*	*	*	*	*			
20.83	6	*	*	*	*	*			
21.18	7	*	*	*	*	*			
22.22	5								

Table 23. Effect of grading on total and plantable seedlings

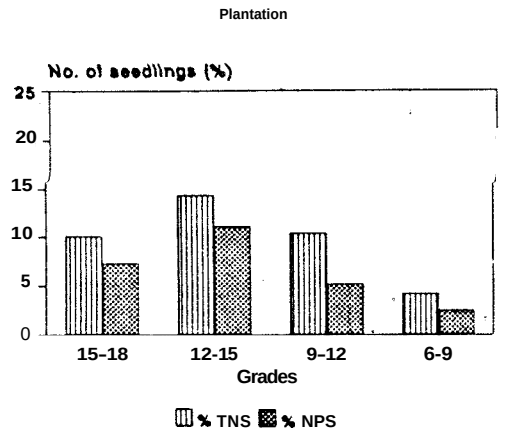
Treatment	Germi-iation %	%TNS to TSS	%TNS to seeds germinated	%NPS to TSS	%NPS to seeds germinated	%NPS toTNS
Plantation seeds						
1. (Gr.15-18mm)	13.54	10.07	74.37	7.29	53.84	72.4
2. (Gr.12-15mm)	17.88	14.41	80.59	11.11	62.14	77.1
3. (Gr.9-12mm)	14.02	10.42	74.32	5.21	37.16	50.0
4. (Gr.6-9mm)	5.58	4.17	78.98	2.5	47.35	60.0
Seed stand						
5. (Gr. 15-18mm)	30.38	22.22	73.14	17.36	57.14	78.1
6. (Gr. 12-18mm)	26.30	20.83	79.2	16.15	61.41	77.5
7. (Gr.	26.69	21.18	57.25	15.28	57.25	72.1
8. (Gr. 6-9mm)	10.56	7.92	75.00	6.67	63.16	84.0

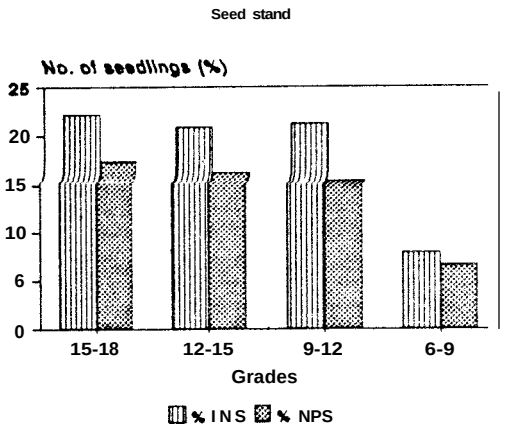
TNS - Total number of seedling
TSS - Total seeds sown
NPS - Number of plantable stumps

With regard to the percentage of plantable stumps, grades 9-12, 12-15 and 15-18 mm in source 2 are not significantly different. But in source 1, fruits of above 12 mm grades can be grouped together while 9-12 mm falls in another group (Table21)In both the sources, 6-9 mm grade performed poorly (Fig. 6).

Percentage of total and plantable seedlings out of the total seeds sown was quite low for fruits of the size 6-9 mm grade, but percentage of plantable seedlingsout of total plants, was equally high as in other grades (Table 23).From the above ,it is evident that grading is necessary only for higher germination percentage and not for healthier seedlings.It is also evident that except 6-9 mm grade which was having poor germination, other grades fall in same group and once the seed is germinated, there is no difference between seedlings of different grades. Hence, size of the fruits is not the determining factor of health of seedlings which agrees with Anon (1955). Sarowart (1964) also found that there is no correlation between fruit size and root collar diameter. In some other species, it is reported that larger seeds have the advantage over smaller seeds in germination and seedling growth possibly due to larger embryo, gametophytic tissue, more cotyledonous tissue or greater initial leaf area (Farmer, 1980). But in teak,big fruit does not mean that seeds inside will be bigger (personal observation).

Fig.6. Comparison between performance of graded seeds





6. Effect of sowing methods and seed rate on germination of seeds and growth of seedlings

6.1. Introduction

Optimum seed rate (quantity of seeds sown in nursery beds) is important for a good nursery. Tewari(l992)indicates that intensity of sowing has direct effect on the early growth of teak plants.He also notes that in India the normal seed rate is 10-12 kg. per standard bed .But report from Maharashtra shows that only 3-4 kg.seeds are sown normally (Reddy and Rao, 1970). In Kerala 3 to 5 kg seeds are used per standard nursery bed. Wije Singhe (1963) reports that 12 lb is the best seed rate for a bed of the size 40' x 4'. Use of low seed rates in Thailand has given higher germination,and survival of seedlings and produced more of usable plants (Tewari, 1992). Thus, conclusions drawn in different regions do not suggest a definite seed rate for field use.Hence,there is a need for evolving region specific seed rates.

Seed broadcasting is the widely employed method of sowing.Trials in the Upper Godavari Division of Andhra Pradesh suggest line sowing with a seed spacing of l0xl0cm to be better than broadcasting for production of larger stumps (Kadambi, 1972).

6.2. Materials and Methods

Seed collection and pre-treatment of seeds were done as mentioned in Section 4.1n this experiment two sowing methods, line sowing and broadcast sowing, were tried with five different seed rates. Accordingly the ten treatments are given in Table 24. For both line and broadcast sowing 1.2 m^2 area was provided for each replication.

Nursery was raised and the same observations as mentioned in Section 4 were taken.

Table 24. Sowing methods, different escapement and seed quantity

Treatments	Method of sowing	Spacing between seeds (cm)	No. of seeds
T1	Line sowing	3 x 3	1600
T2	"	4 x 4	900
T3	"	5 x 5	576
T4	"	6 x 6	400
T5	"	7 x 7	288
T6	Broadcast sowing		1600
T7	,,		900
T8	,,		576
T9	,,		400
T 10	,,		288

6.3. Results and discussion

Table No. 29 shows the germination percentage and the effect of different sowing methods and seed quantity on the growth of seedlings in the nursery. Analysis of variance (Table 26) shows that there is no significant difference between sowing methods and between different quantities of seeds with regard to production of seedlings.But for percentage of plantable seedlings there is significant difference between sowing methods,(Table 25) where broadcasting was found to be better. There is no significant difference between seed rates on percentage of plantable seedlings.When the treatments are compared (Table 27 and 28), it was clear that broadcasting is better than line sowing,though equal spacing was provided in dibbling.This finding contradicts earlier reports where seeds sown in beds at 4 x 4" spacing produced better stumps than broadcasting (Kadambi,l972) and that line sowing or dibbling has the advantage of better germination, survival,uniformity of stump size and more planting stock (Tewari, 1992).

Table 25. Effect of sowing method and seed rate on % NPS

Source	DF	MSS	F
Main effects	5	24.33	2.931
Sowing methods	1	78.40	9.446*
Seed rate	4	10.813	1.303
2 way interaction	4	1.713	0.206

* Significant at 5% level

Table 26. Effect of sowing method and seed rate on % TNS

Source	DF	MSS	F
Main effects	5	20.05	2.148
Sowing methods	1	32.4	3.471
Seed rate	4	16.963	1.817
2 way interaction	4	0.212	0.023

Table 27. Effect of sowing method and seed quantity - DMRT comparison with respect to % NPS (0.05 level)

Mean	Group	1	2	3	4	5	6	3 '	7	0	8	9
9.0000	I											
9.75	2											
10.63	5											
10.88	4											
10.95	6											
11.28	3											
13.37	7											
13.42	10											
13.89	8	*	*									
14.45	9											

Table 28. Effect of sowing method and seed quantity - DMRT comparison with respect to % TNS (0.05 level)

Mean	Group	1	6	2	5	4	0	3	7	9	8
10.19	1										
11.78	6										
12.00	2										
12.57	S										
13.00	4										
13.75	10										
14.00	3										
14.25	**7**										
14.80	9	*									
15.66	8										

Table 29. Effect of sowing method and seed quantities

Treatment	TSS/bed	Gemi-nation %	TNS/bed	%TNS to TSS	%TNS to germi nated seeds	NPS/bed	%NPS to TSS	% NPS to germina-ted seeds	%NPS to TNS
1.3x3cmL.S	16,000	19.44	1630	10.19	52.42	1435	8.97	46.14	88.0
2.4x4cmL.S	9,000	12.47	1072	11.91	95.50	882	9.8	78.59	82.3
3.5x5cm L.S	5,760	15.32	812	14.1	92.01	650	11.28	73.63	80.0
4 . 6 x 6m L.S	4,000	14.06	518	12.95	92.1	435	10.88	77.38	84.0
5.7x7cm L.S	2,880	13.19	362	12.57	95.3	308	10.69	81.05	85.1
6. Broadcasting	16,000	16.54	1885	11.78	71.22	1752	10.95	66.20	92.9
7. "	9,000	14.33	1282	14.24	99.37	1208	13.42	93.65	94.2
8. "	5,760	15.93	902	15.66	98.31	800	13.89	87.19	88.7
9. "	4,000	15.25	592	14.8	97.05	578	14.45	95.75	97.6
10. "	2,880	14.67	395	13.72	93.52	385	13.37 .	91.14	97.5

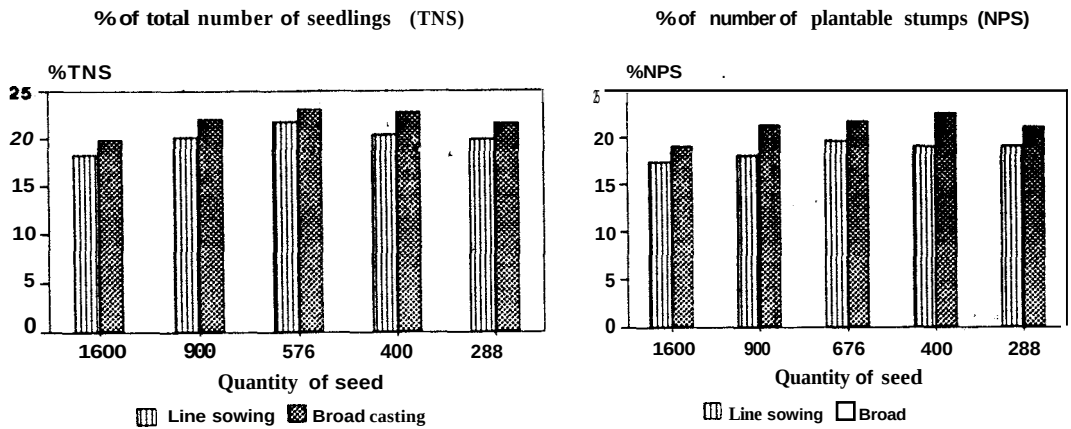
LS - Line sowing, TNS - Total number of seedlings, TSS - Total seeds sown
NPS - Number of plantable stumps

Percentage of plantable stumps out of total seedlings was more in case of broadcasting (Table 29). For all the 5 seed rates tested, in each and every case, broadcasting was found to be better (Fig. 7) for obtaining higher percentage of total seedlings as well as for plantable seedlings from the nursery. Al1 these observations lead to the conclusion that in teak broadcasting is better than dibbling which is also less labour intensive.

The result shows that percentage of total and plantable seedlings out of total germinated ones were found to be low in 1600 seed/sub plot showing that survival percentage is slightly less in this category thar others. But even then upto 1752 plantable seedlings/bed could be obtained when 16000 seeds are broadcast and 1435 plantable seedlingshed when I6000 seeds are dibbled.

If the space and cost of nursery management are taken into account, it is better to use 16000 seeds weighing roughly 8 kg of seeds per bed (on an average 1885 fruits/kg is estimated in teak). If seeds are expensive such as improved seeds, 3 to 4 kg seeds may be ideal since survival percentage is slightly less in plots of high seed rate. If germination percentage is low, more seeds have to be broadcast to compensate for the low germination.

Fig.7. Comparison between line sowing and broadcasting with different quantities of seed



7. Stump quality in relation to soil compaction

7.1. Introduction

The quality of stumps presently used in teak plantations are based on the standardization of stumps by Griffith (1939). This standardization, based on stump thickness and stump length did not take into consideration the degree of soil compaction. Most of the second and third rotation plantation areas, now planted with stumps have compact soils. Therefore, this study was undertaken to evaluate the performance of two grades of stumps in two levels of soil compaction.

7.2. Materials and methods

One year old teak seedlings were collected from a standard nursery at Nilambur. Stumps with 15cm length and lcm-2cm diameter were made out of them and classified into two diameter classes as lcm-1.49cm and 1.50cm-2cm. They were planted in pits (20cm x 20cm x 20cm) refilled with soil and also in crowbar holes.

The treatments were as follows

Code	Treatment	
TI	Stump diameter lcm-l.49cm	; Pit planting
T2	Stump diameter 1.5cm-2.0cm	; "
T3	Stump diameter 1.0cm-1.49cm	; Crowbar planting
T4	Stump diameter 1.5cm-2.0cm	; "

Each treatment had 150 stumps, equally divided into 5 replicates planted in a randomized block design during June, 1992. Periodic height measurements were taken for 18 months after planting.

7.3. Results and discussion

Mean height and survival of plants during the 6, 12 and 18 months after planting is presented in tables 30 and 31.

Table 30. Mean height of seedling at different months after planting

Stump size	6 months after planting (December 1992)			12 months after planting (June 1993)			18 months after planting (July 1993)			Control
	Pit	Crowbar	Mean	Pit	Crow bar	Mean	Pit	Crowbar	Mean	
	T1	T3		T1	T3		T1	T3		
lcm-1.49cm	13.169 (0.605)	14.324 (0.442)	13.753 (0.374)	20.191 (0.708)	20.323 (0.579)	20.258 (0.456)	36.73 (1.35)	34.368 (0.946)	35.536 (0.821)	NA
	T2	T4		T2	T4		T2	T4		
I.5cm-2cm	18.542 (0.725)	15.084 (0.511)	16.807 (0.454)	24.540 (0.909)	20.766 (0.674)	22.667 (0.577)	42.51 (1.40)	35.98 (1.10)	39.268 (0.909)	NA
Mean	15.914 (0.500)	14.709 (0.339)	15.307 (0.302)	22.430 (0.594)	20.548 (0.445)	21.489 (0.373)	39.717 (0.985)	35.185 (0.727)	37.447 (0.619)	20.534 (0.890)

Figures in parenthesis indicate SE of mean
NA - Not applicable

Table 31. % survival at different month after planting

Stump size	6 months after planting (December 1992)			12 months after planting (June 1993)			18 months after planting (July 1993)			Control
	Pit	Crowbar	Mean	Pit	Crow bar	Mean	Pit	Crowbar	Mean	
	T1	T3		T1	T3		T1	T3		
lcm-l.49cm	91	93	92	87	89	88	87	89	88	NA
	T2	T4		T2	T4		T2	T4		
1.5cm-2cm	95	95	95	93	91	92	93	91	92	NA
Mean	93	94	94	90	90	90	90	90	90	99

NA - Not applicable

7.3.1. Height

It is evident from table 20 that thicker stumps planted in pits (T2) gave consistently higher growth when compared to the overall mean. The increase was 21% at 6 months, 14% at 12 and 18 months. A comparison with control (nearby forest department plantations raised in the same year) indicates an increase of 107% . The result suggests the use of thicker stumps and planting in pits to improve growth of teak in plantations.

7.3.2. Survival

The survival rate of seedlings was not affected by the planting method. Stumps of 1.5-2cm diameter were slightly better than those of 1-1.49cm diameter.

8. Conclusions

8.1. The total number stumps per standard nursery bed (12m x 1.2m) in Kerala Forest Department nurseries varied from 262-2110 with a mean of 717. The number of plantable stumps per bed was much lower; it varied from 74-808 with a mean of 262.

8.2. Instead of stump diameter as the plantability criterion, height of seedlings is suggested and seedlings with in the height range of 23cm-56cm is regarded as plantable.

8.3. Considerable variation in germination exists between seed sources. About 80%-90% of the germinating seeds survive and of this 90% attain plantable standards under ideal nursery conditions. Higher germination percent of seeds leads to better nursery stock with more plantable seedlings.

8.4. Most of the teak seeds (65 - 86 % by number and 61 - 78 % by weight) belong to 9mm retained (9 - 12mm size) size category. The seeds above 9mm category forms more than 98% (by number and weight) of the seed lots in Kerala and 1885 graded seeds (above 9mm) weigh a kilogram. Maximum germination is also recorded in this size category. However, there is no positive correlation between fruit size and seedling growth.

8.5. Broadcast sowing was found better than dibbling.

8.6. Pit planting was found to be better than crow bar planting. Stumps of 1.5 - 2.0 cm diameter had shown better performance than stumps of 1.0 - 1.49cm diameter.

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Appendix-1

Mean number of seedlings and plantable stumps per bed in teak nurseries in Kerala

Forest Division	Nursery	Total no. of beds	Mean no.of plantable stumps/bed	Mean total no. of seedling/bed	% of no. of plantable stumps to total no. of seedling
a. Social Forestry Divisions					
Thiruvananthapuram	Kannamkuzhy	80	558.0	1224.0	45.6
				(84.8)*	(148.8)
	Moottumood	80	198:0	746.0	26.5
				(40.8)	(81.6)
	Poojapura	50	218.0	546.0	39.9
				(35.0)	(48.8)
	Alappuzha				
	Eravankara	109	156.0	518.0	30.1
				(33.6)	(59.0)
	Puliyoor	106	116.0	402.0	28.9
			(41.0)	(26.0)	
	Ponthala	55	134.0	362.0	37.0
			(10.4)	(18.8)	
	Thykkattussery	52	78.0	338.0	23.1
			(30.0)	(41.6)	
Kottayam					
	Arayampara	400	146.0	656.0	22.3
			(30.4)	(65.2)	
	Nallukody	100	74.0	634.0	11.6
			(42.0)	(59.8)	
	Alappara	150	112.0	532.0	21.0
			(26.4)	(33.8)	
	Arivithara	115	136.0	598.0	22.7
			(25.2)	(53.8)	
	Thacharikal	42	198.0	368.0	53.8
			(50.4)	(55.8)	
Thrissur					
	Chembankandom	101	498.0	830.0	60.0
			(55.8)	(84.29)	
	Pananchery- 1	70	306.0	584.0	52.4
			(19.6)	(56.0)	
	Pananchery-2	69	206.0	382.0	53.9
			(24.5)	(39.6)	

*The figures in parentheses are standard errors

Cont...

Appendix-1 Cont...

Forest Division	Nursery	Total no. of beds	Mean no.of plantable stumps/bed	Mean total no. of seedling/bed	% of no. of plantable stumps to total no. of seedling
Thrissur					
	Paravattani	38	476.0 (88.43)*	1984.0 (238.4)	24.0
	Pattikkad	100	158.0 (24.58)	262.0 (37.8)	60.3
	Ponnukkara	98	288.0 (16.6)	492.0 (24.2)	58.5
Palakkad					
	Elavanchery	100	122.0 (28.2)	286.0 (35.4)	42.6
	Patta	100	212.0 (24.0)	670.0 (66.0)	31.6
Malappuram					
	Muppini	100	656.0 (64.0)	1322.0 (183.4)	49.6
	Muttikadavu	100	178.0 (30.0)	386.0 (44.8)	46.1
	Thovoor	100	518.0 (57.6)	1124.0 (122.0)	46.1
Kannur					
	Alavil	108	442.0 (58.8)	830.0 (86.6)	53.3
	Iritty	70	202.0. (63.2)	474.0 (120.8)	42.6
	Koodali	119	114.0 (43.0)	298.0 (62.6)	38.3
b. Territorial Divisions					
Thrissur					
	Ambalappad	114	808.0 (106.4)	2110.0 (166.2)	38.3
	Mayannur	123	214.0 (42.89)	844.0 (85.8)	25.4
Malayattur					
	Vadattupara	60	432.0 (53.4)	936.0 (96.6)	46.1
Chalakudy					
	Vettingapadam	100	414.0 (61.2)	1150.0 (106.2)	36.0
Nilambur					
	Panayangodu	110	198.0 (41.05)	704.0 (69.0)	28.1

*The figures in parentheses are standard errors.

Appendix-2

Stump diameter class distribution of seedlings in teak nurseries in Kerala

NURSERY	Stump diameter(cm)												
	Sub-standard				Plantable				Over-grown				
	0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-1.25	1.25-1.50	1.50-1.75	1.75-2.00	2.00.2.25	2.25-2.50	2.50-2.75	2.15-3.00	>3.00
Kannamkuzhy	0.0	2.2	36.8	14.7	27.7	11.4	5.0	1.5	0.4	0.2	0.1	0.0	0.0
Moottumood	3.1	7.7	48.7	17.0	11.5	3.0	1.5	0.5	0.0	0.0	0.0	0.0	0.0
Poojapura		0.9	33.9	25.3	32.1	6.1	1.5	0.2	0.0	0.0	0.0	0.0	0.0
Eravankara	1.4	0.3	23.8	44.0	21.1	4.7	3.1	1.2	0.3	0.0	0.0	0.0	0.1
Puliyoor	0.0	1.4	36.2	32.8	19.0	4.5	4.7	0.7	0.4	0.1	0.2	0.0	0.0
Ponthala	0.0	1.7	26.3	35.0	26.8	6.6	2.4	1.2	0.0	0.0	0.0	0.0	0.0
Thykkattussery	0.1	1.2	39.6	35.7	17.6	1.5	2.6	1.4	0.1	0.1	0.0	0.1	0.0
Arayampara	0.1	8.4	46.5	22.0	11.1	4.5	3.5	3.2	0.4	0.1	0.0	0.0	0.2
Nallukody	0.0	7.8	62.6	17.6	3.7	4.0	2.8	1.1	0.3	0.1	0.0	0.0	0.0
Uappara	1.3	15.4	43.7	16.6	8.4	6.3	4.1	2.2	1.2	0.7	0.1	0.0	0.0
Arivithara	0.0	7.4	41.3	27.2	12.9	4.0	3.0	2.8	0.5	0.7	0.2	0.0	0.0
Thacharikal	0.6	4.5	20.1	15.5	19.5	8.2	11.5	14.6	3.5	1.7	0.2	0.0	0.1
Chembankandon	0.0	3.8	14.7	13.6	20.0	11.7	16.9	11.4	2.7	2.3	1.9	0.5	0.5
Pananchery-1	0.3	10.0	21.1	14.5	24.8	9.8	11.8	6.0	0.8	0.5	0.3	0.1	0.0
Pananchery-2	1.2	7.0	16.8	12.0	24.1	10.3	11.0	8.5	2.9	1.9	3.2	0.5	0.6
Paravattani	0.4	16.8	39.0	19.7	16.9	3.8	2.7	0.6	0.0	0.0	0.0	0.0	0.1
Pattikkad	0.0	3.4	15.8	13.7	26.8	10.7	12.2	10.6	2.9	2.8	0.6	0.5	0.0
Ponnukkara	0.1	3.3	14.6	13.8	22.8	11.1	13.0	11.6	2.7	2.8	2.7	0.7	0.8
Elavanchery	0.0	0.8	23.1	31.1	17.9	10.9	8.3	5.5	0.3	1.3	0.8	0.0	0.0
Patta	0.1	5.8	35.5	26.1	19.2	3.7	6.7	2.0	0.3	0.2	0.1	0.2	0.1
Muppini	0.1	3.5	15.9	28.7	25.5	4.2	14.0	5.9	0.8	0.4	0.5	0.4	0.1
Muttikadavu	0.6	11.9	18.6	13.5	20.0	4.7	12.5	8.9	4.3	12	2.9	0.4	0.5
Thovoor	0.0	2.2	26.2	24.7	26.1	2.8	13.6	3.6	0.2	0.1	0.3	0.1	0.1
Alavil	1.2	6.5	14.8	20.5	25.4	12.6	8.5	6.8	1.8	1.2	0.4	0.1	0.2
Iritty	1.9	9.5	21.1	23.6	21.1	10.1	7.6	3.8	0.4	0.6	0.2	0.0	0.1
Koodali	0.2	14.9	26.8	18.3	22.6	7.0	4.9	3.8	0.7	0.7	0.1	0.0	0.0
Nurseries in SF. Divisions	0.4	6.7	30.4	21.7	20.8	6.5	7.3	4.0	0.9	0.6	0.5	0.1	0.1
Ambalappad	0.4	3.5	29.9	27.8	29.6	5.3	2.8	0.6	0.1	0.0	0.0	0.0	0.0
Mayannur	0.4	7.8	42.4	23.4	16.6	4.1	3.4	1.3	0.3	0.1	0.1	0.0	0.1
Vadattupara	0.3	6.5	21.1	23.2	25.8	9.4	6.5	4.4	0.9	1.0	0.5	0.1	0.3
Vettingapadom	2.4	15.3	28.3	15.2	16.3	8.4	6.5	4.8	1.4	0.8	0.3	0.2	0.1
Panayangode	0.2	5.8	41.9	22.5	15.4	3.1	6.0	3.6	0.5	0.4	0.2	0.1	0.3
Nurseries in Ter-rittorial Division	0.8	7.3	31.4	23.2	22.7	6.1	4.6	2.5	0.6	0.4	0.2	0.1	0.1
All nurseries	0.5	6.9	30.7	22.1	21.3	6.4	6.6	3.6	0.8	0.5	0.4	0.1	0.1

Appendix - 3

Relationship between height (H) and stump diameter (D) of seedlings in teak nurseries

Sl. No.	Estimated regression equation	R^2	MSE	Furnival index
1	$H = -5.7426 + 29.8110\,D$ (0.1306)* (0.1262)	0.821	31.1019	5.5769
2.	$H = -2.0273 + 22.3160\,D + 3.2048\,D^2$ (0.2663) (0.4861) (0.2011)	0.825	30.4662	5.5196
3.	$H = 26.3003 + 27.5031\,\ln D$ (0.0643) (0.1491)	0.737	45.7272	6.7622
4.	$H = 23.6811 + 32.2845\,\ln D + 17.4065(\ln D)^2$ (0.0635) (0.1384) (0.2309)	0.821	31.1606	5.5822
5.	$H=46.2054 - 18.9478D^{-1}$ (0.1994) (0.1480)	0.574	73.9904	8.6018
6.	$H = 71.0634 - 57.2123\,D^{-1} + 12.4440D^{-2}$ (0.3196) (0.4452) (0.1399)	0.742	44.8091	6.6939
7.	$H = -34.1274 + 59.4050\,D$ (0.2697) (0.2762)	0.792	36.1592	6.0133
8.	$H = 9.4958 - 31.0648\,D^{1/2} + 44.9861\,D$ (0.9458) (1.9100) (0.9414)	0.825	30.4419	5.5174
9.	$H\ 42.7775 + 33.2611\,D + 3.017\,D^{-1}$ (0.4658) (0.2525) (0.1919)	0.8246	30.4845	5.5213
10.	$H=-117.2353 + 102.2118\,D^{1/2} + 38.6599D^{1/2}$ (1.8473) (0.9767) (0.8514)	0.822	30.9172	5.5603
11.	$H = 26.3968 + 27.2095\,\ln D + 0.0740(\ln D)^{-1}$ (0.0684) (0.1608) (0.0108)	0.752	46.2869	6.8034
12.	$H1/2=-1.1659 + 6.0036\,D^{1/2}$ (0.0263) (0.0269)	0.803	0.3442	5.1543
13.	$H1/2= -0.1737 + 3.9458\,D^{1/2} + 1.0232D$ (0.1001) (0.2022) (0.0997)	0.805	0.3412	5.1318

• The figures in parentheses are standard errors of the coefficients

Cont...

Appendix-3 Cont.....

Sl. NO.	Estimated regression equation	R^2	MSE	Furnival index
14.	$H^{1/2} = 1.7619 + 2.9507\,D$ (0.0139) (0.0134)	0.799	0.3519	5.2116
15.	$H^{1/2} = 1.2863 + 3.9464\,D - 0.4262\,D^2$ (0.0281) (0.0514) (0.0213)	0.805	0.3407	5.1281
16.	$H^{1/2} = -3.4448 + 7.1773D^{1/2} + 1.0601D^{1/2}$ (0.1937) (0.1024) (0.0893)	0.806	0.3402	5.1243
17.	$\ln H = 1.7622 + 1.2529\,D$ (0.0071) (0.0069)	0.729	0.0934	5.8916
18.	$\ln H = 1.2082 + 2.3705\,D - 0.4784\,D^2$ (0.0136) (0.0248) (0.0103)	0.770	0.0793	5.4287
19.	$\ln H = 3.1217 + 1.2573 \ln D$ (0.0027) (0.0062)	0.770	0.0794	5.4321
20.	$\ln H = 3.1072 + 1.2802 \ln D + 0.0964(\ln D)^2$ (0.0032) (0.0070) (0.0116)	0.771	0.0789	5.4150
21.	$\ln H = 4.1131 - 0.9315\,D^{-1}$ (0.0075) (0.0060)	0.698	0.1043	6.2258
22.	$\ln H = 4.8334 - 2.0403\,D^{-I} + 0.3606\,D^{-2}$ (0.0135) (0.0189) (0.0059)	0.769	0.0798	5.4458
23.	$\ln H = 0.4690 + 2.6015\,D$ (0.0128) (0.0131)	0.764	0.0816	5.5068
24.	$\ln H = -0.5181 + 4.6485\,D - 1.0179\,D$ (0.0481) (0.0971) (0.0479)	0.772	0.0786	5.4047
25.	$\ln H = 2.7529 + 0.7670\,D - 0.4250\,D^{-1}$ (0.0240) (0.0130) (0.0099)	0.765	0.0811	5.4899
26.	$\ln H = 2.1748 + 1.7228\,D^{1/2}\ 0.7935\,D^{-1/2}$ (0.0936) (0.0495) (0.0431)	0.770	0.0794	5.4321
27.	$\ln H = 3.1125 + 1.2340 \ln D + 0.0027(\ln D)^{-I}$ (0.0029) (0.0067)	0.781	0.0805	5.4696

* **The figures in parentheses are standard errors of the coefficients**

Appendix- 4

Relationship between collar diameter (CD) and stump diameter (D) of seedlings in teak nurseries

Sl. No.	Estimated regression equation	R^2	MSE	Furnival index
1.	$CD = 0.1117 + 0.6478\ D$ (0.0031) (0.0030)	0.783	0.0186	0.1364
2.	$CD = 0.0064 + 0.4096\ D + 0.1019\ D^2$ (0.0065) (0.0118) (0.0048)	0.791	0.0180	0.1342
3.	$CD = 0.5841 + 0.5937\ \text{In}\ D$ (0.0015) (0.0036)	0.694	0.0263	0.1622
4.	$CD = 0.5242 + 0.7030\ \text{In}\ D + 0.3977\ (\text{In}\ D)^2$ (0.0016) (0.0056) (0.0034)	0.782	0.0187	0.1367
5.	$CD = 1.0119 - 0.4076\ D^{-1}$ (0.0046) (0.0034)	0.537	0.0398	0.1994
6.	$CD = 1.5461 - 1.2299\ D^{-1} + 0.2674\ D^{-2}$ (0.0077) (0.0034) (0.0108)	0.694	0.0264	0.1624
7.	$CD = -0.7241 + 1.286\ D^{1/2}$ (0.0065) (0.0067)	0.750	0.0214	0.1463
8.	$CD = 0.3470 - 0.9351\ D^{1/2} + 1.1046\ D$ (0.0230) (0.0465) (0.0229)	0.790	0.0180	0.1342
9.	$CD = -0.3039 + 0.7420\ D + 0.0825\ D^{-1}$ (0.0113) (0.0047) (0.0061)	0.789	0.0181	0.1345
10.	$CD = -2.6907\ \ 2.2992\ D^{1/2} + 0.9148\ D^{-1/2}$ (0.0452) (0.0239) (0.0208)	0.784	0.0185	0.1300
11.	$CD = 0.5893 + 0.5927\ \text{In}\ D + 0.0009(\text{In}\ D)^{-1}$ (0.0016) (0.0039) (0.0002)	0.707	0.0272	0.1649
12.	$CD^{1/2} = -0.1355 + 0.8583\ D^{1/2}$ (0.0039) (0.0039)	0.791	0.0076	0.1151
13.	$CD^{1/2} = 0.0717 + 0.4286\ D^{1/2} + 0.2137\ D$ (0.0147) (0.0298) (0.0147)	0.795	0.0074	0.1136

* The figures in parentheses are standard errors of the coefficients

Cont..

Appendix4 Cont.....

Sl. No.	Estimated regression equation	R^2	MSE	Furnival index
14.	$CD^{1/2} = 0.2819 + 0.4230\,D$ **(0.0020) (0.0019)**	0.792	0.0076	0.1151
15.	$CD^{1/2} = 0.2324 + 0.5230\,D - 0.0428\,D^2$ **(0.0041) (0.0076) (0.003)**	0.795	0.0074	0.1136
16.	$CD^{1/2} = 0.5258 + 1.0594\,D^{1/2} + 0.1816\,D^{-1/2}$ **(0.0286) (0.0152) (0.0132)**	0.795	0.0075	0.1144
17.	$\ln CD = -1.9594 + 1.1831\,D$ **(0.0067) (0.0065)**	0.731	0.824	**0.125**
18.	$\ln CD = -2.4387 + 2.1501\,D - 0.4139\,D^2$ **(0.0129) (0.0236) (0.0097)**	0.766	0.718	0.1169
19.	$\ln CD = -0.6758 + 1.1820 \ln D$ **(0.0025) (0.0058)**	0.770	0.0706	0.1159
20.	$\ln CD = -0.6883 + 1.2048 \ln D + 0.0831(\ln D)^2$ (0.0030) (0.**0065**) **(0.0109)**	0.771	0.0703	0.1156
21.	$\ln CD = 0.2630 - 0.8816\,D^{-1}$ **(0.0070) (0.0052)**	0.703	0.0911	0.1316
22.	$\ln CD = 0.8724 - 1.8196\,D^{-1} + 0.3051D^{-2}$ **(0.0129) (0.0180) (0.0057)**	0.760	0.0736	0.1187
23.	$\ln CD = -3.1772 + 2.4531\,D^{1/2}$ **(0.0121) (0.0123)**	0.764	0.0725	0.1174
24.	$\ln CD = -4.0148 + 4.1902\,D^{1/2}\ 0.8638\,D$ **(0.0455) (0.0918) (0.0452)**	0.777	0.0704	0.1157
25.	$\ln CD = -1.0051 + 0.7151\,D - 0.4093\,D^{-1}$ **(0.0225) (0.0121) (0.0093)**	0.769	0.0710	0.1162
26.	$\ln CD = -1.5032 + 1.5909\,D^{1/2} - 0.7787\,D^{-1/2}$ **(0.0881) (0.0466) (0.0406)**	0.771	0.0704	0.1157
27.	$\ln CD = -0.6785 + 1.1753 \ln D + 0.0009(\ln D)^{-1}$ **(0.0027) (0.0064) (0.0004)**	0.779	0.0725	0.1174

Appendix-5

Comparison between mean number of plantable stumps per bed in teak nurseries in Kerala using the criteria based on D and both D and H

Nursery	Criterion		
	$1 \leq D \leq 2cm$	$1 \leq D \leq 2cm$ and $23 \leq H \leq 56cm$	Percentage of (3) to (2)
1	2	3	4
Moottumood	198	30	15.2
Poojapura	218	76	34.7
Eravankara	156	60	38.5
Puliyoor	116	23	19.8
Ponthala	134	68	50.9
Thykkattussery	78	12	15.4
Arayampara	146	82	56.2
Nallukody	74	36	48.6
Alappara	112	46	41.1
Arivithara	136	88	64.7
Thacharikal	198	130	65.7
Chembankandom	498	372	74.7
Pananchery-1	306	222	72.5
Pananchery -2	206	145	70.4
Paravattani	476	228	47.9
Pattikkad	158	108	68.4
Ponnukkara	288	198	68.8
Elavanchery	122	43	35.2
Patta	212	159	75.0
Muppini	654	578	88.4
Muttikadavu	178	150	84.3
Thovoor	518	450	86.9
Alavil	442	221	50.0
Iritty	202	50	24.8
Koodali	114	37	32.5
Ambalappad	808	160	19.8
Mayannur	214	95	44.4
Vadattupara	432	297	68.8
Vettingapadam	414	334	80.7
Panayangodu	198	169	85.4