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Variability in Drupe Characters and their Relationship on Seed Germination in Teak (*Tectona grandis* L.f.)

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Abstract

Seeds of teak (*Tectona grandis* L.f.) were collected from 30 sources covering India, Bangladesh and Laos and germination trials were conducted. Variability in drupe and germination characteristics was observed. Correlation studies carried out between drupe characters and seed filling percentage showed a positive correlation between drupe weight and seed filling percentage. The mesocarp weight and drupe/shell weight ratio were negatively correlated with germination percentage. A polynomial regression for prediction of germination percentage using drupe/shell weight ratio was established (R^2 = 0.599). Germination percentage was found to be correlated with percentage of two seeded drupes.

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Key words: Seed source, Teak, *Tectona grandis*, Germination, Drupe characters, variability studies, correlation.

Introduction

One of the world's most valuable and widely planted tropical tree species is teak. It has a wide natural range, which covers India, Burma, Thailand, Laos, Malaysia and Indonesia. Teak has mostly been planted in tropical regions including Asia, Africa and Central America (KADAMBI, 1972). Teak exhibits a great variability between provenances and land races in various quantitative and qualitative traits (KEIDING *et al.,* 1986). Variation in drupe physical characteristics and germination behaviour was observed in seven provenances from the Kerala state of India (JAYASANKAR *et al.,* 1999).

Studies on variability in seed characters and germination behaviour of a species will help in identifying own seed lots for a planting program (KERTADIKARA and PRAT, 1995). Germination behaviour of teak drupes was observed to be highly variable from source to source (DASAPPA, 1990; INDIRA and BASHA, 1999). Variation in teak drupe characters of different seed sources with reference to seed germination behaviour was studied. A multiple regression model for prediction of germination percentage was developed using seeds from provenances of Kerala (JAYASANKAR *et al.,* 1999).

The present study concentrates on the variability in various drupe physical characters, germination and viability percentages in the seed sources of India, Bangladesh and Laos. Possible methods for predicting seed germination in teak are discussed.

Materials and Methods

Seed Collection

Seeds were collected from thirty different seed sources covering India, Bangladesh and Laos (*Table 1*). Seeds were collected from 10 randomly selected trees per seed source avoiding diseased, malformed and suppressed trees. The minimum distance between selected trees was greater than 500 m. Seeds were collected by spreading polyurethane sheets below the tree and shaking the branches. Fresh drupes collected during February, 2000 were used for the study. Seeds collected from the individual trees were mixed thoroughly and a 5 kgs sample from each source was used in this study.

Table 1. – Location of the seed sources.

Sl No.	Name of the seed source	State	Country	Latitude	Longitude
1	Syyabury	-	Laos P.D.R	-	-
2	Chittakoog	-	Bangladesh	22° 19' N	91° 41" E
3	Lanka	Assam	India	-	-
4	Tura	Megalaya	India	25° 31' N	90° 13' E
5	Bagafa	Tripura	India	-	-
6	Tarai	Uttar Pradesh	India	24° 39' N	78° 12' E
7	Dehra Dun	Uttranchal	India	30° 20' N	78 ° 02' E
8	Kottiwara	Madhya Pradesh	India	20° 29' N	74° 08' E
9	Kariar Road, Nuwapada	Orissa	India	20° 48' N	82° 32' E
10	Jimalgatt	Maharashtra	India	19° 05' N	80° 10 E
11	Umari	Maharashtra	India	20° 06' N	78° 58' E
12	Darekasa	Maharashtra	India	21° 15' N	80° 35' E
13	Dongargaon	Maharashtra	India	20° 04' N	80° 17'E
14	Hiwara	Maharashtra	India	21° 31' N	79° 28' E
15	Paoni	Maharashtra	India	20° 30' N	79° 22' E
16	Wimberligunj	Andaman and Nicobar Island	India	11° 45' N	92° 43' E
17	Sampangi	Karnadaka	India	12° 29'N	75° 33'E
18	Mudumalai	Tamil Nadu	India	11° 37' N	76° 34'E
19	Courtrallum	Tamil Nadu	India	8° 55'N	77° 16'E
20	Kalakkad	Tamil Nadu	India	8° 30'N	77° 32' E
21	Siruvani	Tamil Nadu	India	10° 55' N	76° 41' E
22	Topslip	Tamil Nadu	India	10° 27' N	76° 50' E
23	Wadu, Konni,	Kerala	India	9° 13' N	76° 51'E
24	Padam, Konni	Kerala	India	9° 13' N	76° 51'E
25	Kallaley, Konni	Kerala	India	9° 13' N	76° 51'E
26	Karalai, Nilambur	Kerala	India	11° 16' N	76° 13'E
27	Nellikuthu, Nilambur	Kerala	India	11° 16' N	76° 13'E
28	Chatanpura, Nilambur	Kerala	India	11° 16' N	76° 13'E
29	Tholpatty, Wynad	Kerala	India	11° 39N	76° 16'E
30	Parambikulam	Kerala	India	10° 23'N	76° 48'E

Drupe physical characters

Six replications, each with 20 drupes per source, were taken randomly. The measurement of drupe physical characters including 2D surface area (cm^2), diameter (cm), perimeter (cm), roundness and fullness ratio was done using an Image analyzer (Leica Quantimet called QWin 500). The 20 drupes of a replication were arranged upright in a platform and the images were captured using software called QWin using a CCD camera. The images were then calibrated to actual scale. The calibrated images were measured using QWin. The 2D surface area was calculated as the area of a drupe occupied in the calibrated 2D image expressed in cm. Diameter was measured as the average breadth of the drupe in two different perpendicular angles. Perimeter was the total length of boundary of the drupe. Roundness is a shape factor, which gives minimum value of unity for a circle. This is calculated from the formula given below.

$$\text{Roundness} = \frac{(\text{Perimeter})^2}{4 \times \pi \times \text{2D surface area} \times 1.064}$$

An adjustment factor of 1.064 corrects the perimeter for the effect of the corners produced by the digitization of the image. Fullness ratio is also a shape factor, equal to the square root of the ratio of area to circumscribed area as given below.

$$\text{Fullness ratio} = \text{sqrt}\left(\frac{\text{2D surface area}}{\text{Convex area}}\right)$$

Other physical characters

The individual drupes measured using Image analyzer were then used for observing other physical characters such as drupe weight (g), seed weight (g), shell weight (g), mesocarp weight (g), drupe/shell weight (D/S weight) and seed filling percentage. The single drupe weight was taken first with mesocarp after sun drying for two days. Then the mesocarp was removed manually and again weighed. The difference in weight between whole drupe weight and drupe weight without mesocarp was taken as mesocarp weight. Then the drupe without mesocarp was broken to observe the number of chambers and total number of seeds in a drupe. The percentage of number of seeds to number of chambers in a drupe was given as filling percentage. The seed and shell of a drupe were separated and weighed. From the total seed weight, average single seed weight was worked out and given as seed weight. The D/S weight ratio was calculated by dividing the drupe weight by the shell weight of the same drupe. In addition to this, the 1000 drupe weight was estimated taking 100 drupes in 8 replications.

Germination test

Samples of four replications each with 100 drupes were randomly taken for assessing the germinability. The drupes were given pretreatment with alternate wetting (1 day) and drying (1 day) for 6 cycles and finally soaked in cow dung slurry over night. The drupes were sown in open pure sand beds. The beds were watered every morning. Final count for germination percentage was made on the 28^{th} day after sowing, multiple seedlings were considered as single seed.

Maximum possible germination percentage (MPG percentage)

The maximum possible germination percentage (MPG percentage) is a percentage of maximum germination a source can attain. As per ISTA (1993) a tree seed giving rise to multiple seedlings as a result of polyembryony shall be counted as a single seed in the germination test. HEDEGART (1975) defined teak seed viability as "the percentage of fruit containing at least one well developed and sound seed as determined by visual judgment in the cutting test". The drupes having at least one chamber filled are considered as germinable and the percentage of these drupes was given as MPG percentage.

The calculation of MPG percentage is done after studying the distribution of number of seeds in a drupe by cutting the drupe and observing the number of seeds in a sample of 20 drupes in each of six replications. The average percentage of number of seeds/drupe has been given in *Table 4*. From the table the MPG percentage can be calculated as given below:

MPG percentage = percentage of drupes with 1 seed + percentage of drupes with 2 seeds + percentage drupes with 3 seeds + percentage of drupes with 4 seeds

Or

MPG percentage = 100 – percentage of empty drupes

Tetrazolium test (Tz)

In each source, drupes were broken and seeds were removed. Samples of four replications each with 25 seeds were taken for Tz test. The seeds were soaked in 1 % of 2,3,5 triphenyl tetrazolium chloride solution for 4 hours in the dark. Then the seeds were observed for staining patterns. Completely stained seeds were counted as viable and expressed in percentage.

Statistical analysis

Variability studies

The characters including 2D surface area, diameter, perimeter, roundness, fullness ratio, drupe weight, seed weight, shell weight, mesocarp weight, D/S weight, filling percentage, germination percentage and viability percentage were subjected to analysis of variance as per GOMEZ and GOMEZ (1984).

Correlation studies

This study was carried out using the individual drupe values and mean source values. The individual drupe characters were analysed to find correlations with filling percentage. The source mean of different drupe characters were analysed to find correlations with germination percentage, MPG percentage and viability percentage. The germination percentage was also studied with the 1000 drupe weight. In addition to this, the percentage of the number of seeds/drupe was analysed with 2D surface area, diameter and germination percentage.

Regression studies

The individual drupe characters including 2D surface area, diameter, perimeter, roundness, fullness ratio, drupe weight, shell weight, mesocarp weight and D/S weight were regressed with filling percentage to find the best variable for predicting filling percentage. The regression equation was derived using GENSTAT.

The mean of source characters including 2D surface area, diameter, perimeter, roundness, fullness ratio, drupe weight, mesocarp weight and D/S weight were regressed against germination percentage using step wise regression method to find the best set of characters for predictions. The non-linear regression models were applied to find out the best fitting regression equation.

Results and Discussion

Variability studies

Significant variation between sources was found with all the drupe characters (*Table 2*). The drupes of Mudumalai seed source were the biggest and the Kariar Road was the smallest among all the seed sources. The Parambikulam drupes were found to be almost round when compared to all other sources. The Parambikulam seed source was heavier with a greater mesocarp weight, but the proportion of D/S weight was higher in Chittakoog sources. The Parambikulam drupes were found to be the heaviest among different sources of the Kerala State (JAYASANKAR *et al.*, 1999).

The filling percentage in Siruvani, all Nilambur sources and Parambikulam sources was higher than other sources. *Table 3* shows the percentage of number of seeds/drupe in each source. The average percentage of empty, one, two, three and four seeded drupes were 37, 43.9, 15.3, 3.4 and 0.5 % respectively.

Table 2. – Variation for drupe physical characters and germination percentages for seeds collected from different locations.

sl no	Name of source	2 D surface area (cm^2)	Diameter (cm)	Perimeter (cm)	Round ness	Fullness Ratio	Drupe weight (g)	Seed weight (g)	Shell weight (g)	Mesocarp weight (g)	Drupe/ shell weight	Filling %	Germination %	Viability % (Tz)
1	Syyabury	1.47	1.36	4.61	1.09	0.983	0.56	0.017	0.40	0.14	1.40	22.48	4.30*	60.71*
2	Chittakoog	1.61*	1.42*	4.83	1.10	0.981	0.59	0.006*	0.39	0.19*	1.51*	12.35*	8.30*	92.86*
3	Lanka	1.65*	1.44*	5.02*	1.16	0.980	0.60	0.008*	0.43	0.16	1.40	14.24*	3.30*	93.75*
4	Tura	1.60*	1.42*	4.84	1.11*	0.983	0.52	0.01	0.43	0.08*	1.21*	22.57	38.5*	77.50
5	Bagafa	1.50	1.38	4.61	1.07	0.983	0.52	0.018	0.39	0.11	1.33	27.76	25.5*	87.50
6	Tarai	1.36	1.31	4.47	1.11	0.981	0.54	0.015	0.38	0.15	1.42	25.56	0.80*	89.71
7	Dehra Dun	1.21*	1.24*	4.12*	1.05*	0.984	0.51*	0.015	0.38	0.12	1.34	24.10	0.30*	85.00
8	Kottiwara	-	-	-	-	-	-	0.008*	0.36	-	-	14.03*	2.00*	85.42
9	Kariar Road, Nuwapada	0.83*	1.02*	3.45*	1.08	0.983	0.50*	0.019	0.35	0.13	1.43	28.76	0.75*	55.00*
10	Jimalgatt	-	-	-	-	-	-	0.012	0.32*	-	-	21.60	8.00*	90.82*
11	Umari	-	-	-	-	-	-	0.015	0.31*	-	-	24.93	10.0	86.54
12	Darekasa	-	-	-	-	-	-	0.015	0.30*	-	-	27.15	9.30	75.10
13	Dongargaon	-	-	-	-	-	-	0.011	0.31*	-	-	20.69	5.50*	81.89
14	Hiwara	-	-	-	-	-	-	0.009	0.27*	-	-	17.50	3.80*	79.32
15	Paoni	-	-	-	-	-	-	0.014	0.30*	-	-	27.22	5.00*	86.64
16	Wimberligunj	1.67*	1.45*	5.45*	1.35*	0.974*	0.67	0.011	0.46*	0.20*	1.46*	15.42*	0.50*	73.21
17	Sampangi	1.54	1.39	4.71	1.09	0.982	0.67	0.013	0.49*	0.17*	1.37	22.57	0.50*	62.50*
18	Mudumalai	1.91*	1.55*	5.59*	1.24*	0.978	0.80*	0.021	0.58*	0.20*	1.38	23.98	2.50*	67.50*
19	Courtrallum	1.37	1.31	4.53	1.14	0.981	0.51	0.013	0.39	0.11	1.31	20.58	16.0	72.50
20	Kalakkad	1.68*	1.46*	4.96*	1.10	0.980	0.58	0.007*	0.44	0.13	1.32	8.694*	13.8	96.67*
21	Siruvani	1.39	1.32	4.89*	1.30*	0.974*	0.64	0.025*	0.46*	0.16	1.39	33.68*	7.00*	64.29*
22	Topslip	1.45	1.35	4.59	1.10	0.982	0.66	0.016	0.49*	0.15	1.35	20.08	2.00*	95.00*
23	Wadu, Konni,	1.03*	1.14*	3.99*	1.17	0.980	0.60	0.018	0.45	0.13	1.33	23.43	28.5*	83.33
24	Padam, Konni	1.43	1.34	4.5	1.08	0.983	0.55	0.015	0.42	0.12	1.31	20.67	20.5*	76.92
25	Kallaley, Konni	1.36	1.31	4.35	1.05*	0.982	0.54	0.018	0.44	0.08*	1.23*	25.76	17.5	65.38*
26	Karalai, Nilambur	1.37	1.31	4.34	1.05*	0.982	0.58	0.020	0.42	0.14	1.38	33.68*	49.0*	80.88
27	Nellikuthu, Nilambur	1.62*	1.43*	4.87*	1.11	0.978	0.60	0.020	0.46*	0.12	1.30*	31.88*	47.0*	79.17
28	Chatanpura, Nilambur	1.08*	1.17*	3.96*	1.10	0.979	0.58	0.020	0.41	0.15	1.41	29.72*	48.3*	85.00
29	Tholpatty, Wynad	1.00*	1.12*	3.83*	1.11	0.983	0.52	0.015	0.37	0.14	1.41	20.08	4.50*	71.43
30	Parambikulam	1.45	1.35	4.46	1.04*	0.986*	0.83*	0.024*	0.56*	0.25*	1.48*	32.43*	3.30*	81.67
	Mean	1.42	1.33	4.56	1.12	0.980	0.60	0.015	0.40	0.14	1.37	23.05	12.88	79.44
	Sed	0.087	0.041	0.145	0.025	0.002	0.041	0.003	0.027	0.02	0.03	3.226	2.40	5.449
	CD(p=0.05)	0.17	0.08	0.29	0.05	0.004	0.08	0.006	0.05	0.04	0.06	6.32	4.77	10.68

* - Significant at 5%

Table 3. – Pattern of seed filling and maximum possible germination percentage (MPG percentage) for different seed sources.

Sl No.	Name of the seed source	percentage of number seeds / drupe					MPG%
		0	1	2	3	4	
1	Syyabury	35.0	44.0	18.0	3.0	0.0	65.0
2	Chittakoog	66.4	27.3	6.4	0.0	0.0	33.6
3	Lanka	57.0	29.8	10.7	1.7	0.8	43.0
4	Tura	40.8	40.8	15.8	2.5	0.0	59.2
5	Bagafa	24.3	52.2	16.5	7.0	0.0	75.7
6	Tarai	32.5	44.2	15.0	6.7	1.7	67.5
7	Dehra Dun	27.5	51.7	18.3	1.7	0.8	72.5
8	Kottiwara	60.8	27.5	9.2	2.5	0.0	39.2
9	Kariar Road, Nuwapada	22.5	49.2	20.0	7.5	0.8	77.5
10	Jimalgatt	30.8	54.2	14.2	0.0	0.8	69.2
11	Umari	32.8	42.9	20.2	4.2	0.0	67.2
12	Darekasa	21.7	50.8	25.8	1.7	0.0	78.3
13	Dongargaon	30.0	57.5	12.5	0.0	0.0	70.0
14	Hiwara	44.2	45.0	8.3	2.5	0.0	55.8
15	Paoni	32.5	36.7	23.3	7.5	0.0	67.5
16	Wimberligunj	52.5	40.0	5.0	2.5	0.0	47.5
17	Sampangi	45.8	31.7	16.7	5.0	0.8	54.2
18	Mudumalai	28.8	59.3	11.0	0.8	0.0	71.2
19	Courtrallum	38.3	48.3	10.0	1.7	1.7	61.7
20	Kalakkad	70.8	27.5	0.8	0.8	0.0	29.2
21	Siruvani	25.2	42.0	24.4	6.7	1.7	74.8
22	Topslip	48.0	31.0	18.0	3.0	0.0	52.0
23	Wadu, Konni,	38.3	40.8	16.7	4.2	0.0	61.7
24	Padam, Konni	38.3	48.3	11.7	1.7	0.0	61.7
25	Kallaley, Konni	37.5	45.8	11.7	3.3	1.7	62.5
26	Karalai, Nilambur	19.2	50.8	21.7	6.7	1.7	80.8
27	Nellikuthu, Nilambur	23.3	50.0	20.8	5.0	0.8	76.7
28	Chatanpura, Nilambur	22.5	45.0	30.0	1.7	0.8	77.5
29	Tholpatty, Wynad	39.0	48.0	9.0	4.0	0.0	61.0
30	Chettiwara, Parambikulam	22.2	53.8	16.2	7.7	0.0	77.8
Mean		**37.0**	**43.9**	**15.3**	**3.4**	**0.5**	**63.0**

Table 4. – Correlations between different physical characters of drupe on seed filling and germination percentages.

	2 D surface area	Diameter	Perimeter	Round-ness	Fullness Ratio	Drupe weight	Seed weight	Shell weight	Mesocarp weight	Drupe/ shell weight	Filling %	Germination %	MPG %	Viability % (Tz)
2 D surface area	1.000													
Diameter	0.995**	1.000												
Perimeter	0.941**	0.944**	1.000											
Roundness	0.139**	0.137**	0.454**	1.000										
Fullness ratio	-0.089	-0.089*	-0.280**	-0.598**	1.000									
Drupe weight	0.663**	0.651**	0.630**	0.134	-0.058	1.000								
Seed weight	0.035	0.034	0.028	-0.007	0.001	0.045	1.000							
Shell weight	0.565**	0.558**	0.532**	0.093*	-0.046	0.833**	0.041	1.000						
Mesocarp weight	0.429**	0.415**	0.421**	0.140**	-0.054	0.656**	0.045	0.188**	1.000					
Drupe/shell weight	0.111**	0.105**	0.129**	0.102**	-0.043	0.202**	0.002	-0.27**	0.787**	1.000				
Filling %	0.049	0.048	0.037	-0.018	-0.008	0.213**	0.081*	0.211**	0.003	-0.003	1.000			
d.f	2480	2480	2480	2480	2480	2480	2480	2480	2480	2480	2480			
Germination %	-0.075	-0.080	-0.142	-0.230	-0.050	-0.250	0.265	-0.108	-0.440*	-0.440*	0.395*	1.000		
Max.Possible Ger%	-0.392	-0.388	-0.449*	-0.369	0.262	-0.069	0.689**	-0.098	0.009	-0.041	0.918**	0.309*	1.000	
Viability % (Tz)	-0.252	0.274	0.154	-0.231	0.122	-0.024	-0.420*	-0.166	-0.108	0.100	-0.355*	0.106	-0.355	1.000
d.f	22	22	22	22	22	22	29	29	22	22	29	29	29	29

* – Significant at 5 %; ** – Significant at 1 %

The emptiness varied from 19.2 (Karalai, Nilambur) to 70.8% (Kalakkad). Studies carried out on 5 different sources on percentage of fully developed seeds/drupe through x-ray radiography showed the presence of 30.8, 48.4, 16.6, 3.2 and 1.0% of empty, one, two, three and four seeded drupes respectively (KAMRA, 1974).

The Nilambur, Konni, Tura and Bagafa sources exhibited higher germination percentages than other sources. The germination of Nilambur and Konni sources was reported to be high among different sources of Kerala (JAYASANKAR *et al.,* 1999). The sources like Tarai, Dehra Dun, Kariar Road, Wimberligunj and Sampangi had poor germination. The MPG percentage calculated based on number of seeds/drupe for different sources itself showed large variation. The percentage was varying from 29.2 (Kalakkad) to 80.8% (Karalai, Nilambur) (*Table 3*). Variability between different populations within a species in seed characters and germination percentage is due to strong genetic influence (HELLUM, 1976; BAGCHI *et al.,* 1990; VAKSHASYA *et al.,* 1992).

Correlation studies

The correlation studies of individual drupe characters revealed that the drupe weight (r = 0.213) and shell weight (r = 0.211) had significant positive correlation with filling percentage (*Table 4*). The earlier studies showed that the number of seeds per fruit was found to decrease with decreasing fruit size (BANIK, 1977). Studies carried out in Thailand from drupes collected from 5 natural stands showed no significant correlation between drupe size and number of seeds/drupe (BHUMIBHAMON *et al.,* 1983).

The mesocarp weight, drupe/shell weight and filling percentage were found to be correlated with germination percentage. Studies conducted in various seed characters revealed that strong correlation could be established with seed germination (TOON *et al.,* 1990), seedling and tree growth of the progenies (MAHADEVAN *et al.,* 1999). A positive significant correlation of teak fruit size on stump recovery percentage was observed (SURESH *et al.,* 1998).

The drupe weight and shell weight that are positively correlated with filling percentage were not significantly correlated with germination percentage. Similarly the correlation of the 1000 drupe weight on the germination percentage was also found to be non-significant (r = –0.154). While the ratio between the drupe weight and shell weight was found to have significant negative correlation with germination percentage. The ratio of D/S weight will be high when the drupe weight is greater and shell weight is less and the ratio will be low when the difference between the drupe weight and the shell weight is small. In other words, the ratio is low when there is less mesocarp. On the other hand, the direct correlation of mesocarp weight on germination percentage was also found to be negatively correlated. From this it is clear that high mesocarp proportion affects germination. The adverse effect of mesocarp on germination and methods of removing it from drupes for better germination were well documented (BHUMIBHAMON *et al.,* 1983; CHACKO, 1998; BAPAT and PHULARI, 1995).

The maximum possible germination percentage was found to be positively correlated with seed weight, filling percentage and germination percentage and negatively correlated with perimeter. The viability percentage was negatively correlated with seed weight and filling percentage. Earlier studies on relationship of drupe characters and viability in teak indicated that the viability was positively correlated with drupe size (MURTHY, 1974). Correlation studies carried out between percentage of number of seeds/drupe and size of the drupe showed that the size of the drupe was negatively correlated with percentage of two and three seeded drupes (*Table 5*). The study also revealed that the germination percentage was found to be positively correlated with percentage of two seeded drupes.

Table 5. – Correlations of percentage of number of seeds/drupe on germination percentage

Characters	% of one seeded drupes	% of two seeded drupes	% of three seeded drupes	% of four seeded drupes	2D surface area	Diameter	Germination %
% of one seeded drupes	1.000						
% of two seeded drupes	0.285	1.000					
% of three seeded drupes	0.088	0.450*	1.000				
% of four seeded drupes	0.137	0.243	0.264	1.000			
2D surface area	-0.215	-0.437*	-0.367*	-0.220	1.000		
Diameter	-0.229	-0.436*	-0.370*	-0.209	0.995*	1.000	
Germination %	0.180	0.376*	0.098	0.214	-0.075	-0.080	1.000

* - Significant at 5% d.f. = 29

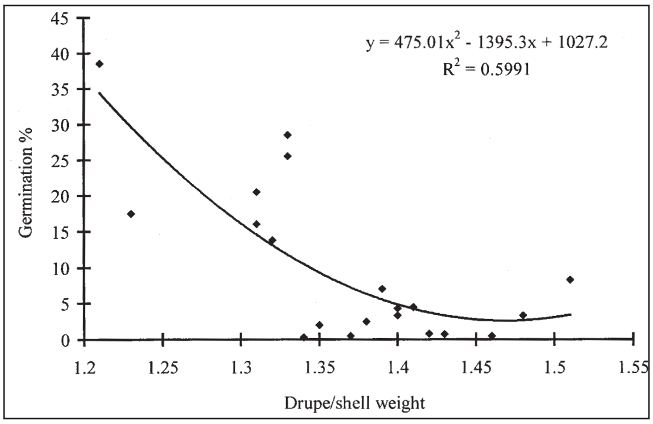

Figure 1. – Polynomial equation for prediction of germination percentage using drupe/shell weight.

Regression studies

Among the different characters the drupe weight was found to establish better regression equation (r^2 = 0.039) for prediction of filling percentage.

Filling percentage = 10.29 + 24.47(Drupe weight in g)

The step wise regression worked out for prediction of germination percentage revealed that the d/s weight as a single character was having functional relationship with germination percentage. The linear regression equation was established with R^2 value 0.497 (SE of estimation = 8.08) is given below.

Germination percentage = –103.25(D/S weight) + 151.26

This equation was further studied for improvement through non-linear regression models. Polynomial regression equation was found to be the best fitting model for prediction of germination percentage through D/S weight with R^2 value 0.599 (SE of estimation = 3.64) (*Figure 1*). The best fit polynomial equation is given below.

$$\text{Germination percentage} = 475.01(D/S\ \text{weight})^2 - 1395.3(D/S\ \text{weight}) + 1027.2$$

A multiple regression model for prediction of teak seed germination percentage was derived using maximum seed width, minimum seed width, seed length and seed weight with R^2 value of 0.366 (JAYASANKAR *et al.,* 1999). In case of *Grewia optiva,* the seed length and the 100 seed weight were found to be the best predictors of germination (TYAGI *et al.,* 1999).

From the above study it is concluded that the drupe and germination characteristics exhibits large variability. The Mudumalai seed source was the biggest and the Parambikulam was the heaviest. The Nilambur source had both high filling and germination percentages. The average percentage of empty, one, two, three and four seeded fruits were 37, 43.9, 15.3, 3.4 and 0.5% respectively. The filling percentage increases with weight of drupe and can be predicted using linear regression equation. The mesocarp and D/S weight plays major role in germination. The germination percentage can be predicated using D/S weight fitting in a polynomial equation. Among one, two, three and four seeded fruits, the germination percentage was observed to increase with increase in percentage of two seeded drupes.

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Pollen Dispersal and its Spatial Distribution in Seed Orchards of *Cunninghamia lanceolata* (LAMB.) Hook

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Abstract

Data from three seed orchards (Chongyang, Zhangle and Laoshan) and Lintian forest of Chinese fir was used to study pollen dispersal and its spatial distribution. The results show that the pollen dispersal has its own release pattern and day-night cycle. Vertical pollen distribution is as a cluster one; Horizontal pollen distribution in seed orchards and in normal forest is a uniform distribution type. Outside seed orchards and normal forest pollen distribution is diffusible. Wind speed is the most important factor for pollen dispersal. The relationship between pollen amount and distance to a seed orchard is linear. Based on the characteristics of pollen dispersal, methods for the management of artificial pollinate during the pollen dispersal season have been developed.

Key words: Cunninghamia lanceolata (LAMB.) Hook/Chinese fir, seed orchard, pollen dispersal, spatial pollen distribution.

A seed orchard is constructed with clones of superior trees in order to produce high quality seeds. To select superior trees