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Effect of different forest types and populations on drupe morphometric characters of teak, *Tectona grandis* L f in India

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ABSTRACT

Drupe morphometric characters were studied in different teak forest types, different populations and their interaction where trees were growing. Drupes/fruits were collected from 3 different teak forest types viz very moist teak forest (Kerala), moist teak forest (Gujarat) and dry teak forest (Maharashtra) which represented 2 populations in each forest type. Drupe traits are central components of plant life histories and show seed development potential and seedling establishment. Traits such as drupe length, drupe width, drupe weight, stone length, stone width and stone weight were highly influenced by teak forest types and site quality (populations). Higher values for all drupe traits were obtained from very moist teak forest as compared to moist teak and dry teak forests. In overall Elivaly population performed better than all others and their interactions in which they grew due to light, temperature, water and nutrient availability. Drupe development and fitness were influenced by geo-climatic variables such as latitude and rainfall however longitude and temperature showed non-significant effect. All drupe traits strongly were inter-correlated to one another and showed that healthy seed developed itself completely in all dimensions. Thus drupe development, collection and regeneration of different teak forests in India are directly related to drupe characters. For superior quality seed production within a forest type or between teak forest types, drupe production area should be properly identified and delineated.

Keywords: Teak; drupe traits; forest types; populations

INTRODUCTION

Tectona grandis L f known as King of Timber due to its excellent wood properties is one of the world's most valuable timbers. Its wood is used extensively in India to make ships, railway sleepers, veneers, furniture, buildings etc as it is resistant to termite and insect attacks (Tewari 1992). Teak is a deciduous tropical tree species that grow up to 40 m. It is indigenous to India and southeast Asia and is distributed throughout the India (Tewari 1992). There is huge demand for teak wood in the international as well as Indian markets. In 1997 the gap between demand and supply of industrial timber was 20 million m^3 and is projected to be around 110 million m^3 by 2020 in India (Anon 2007). More than thousand crore rupees worth of raw material is imported every year for meeting the demand of forest-based industries. This can be fulfilled by teak plantation with agroforestry system. But still the low seed yield per tree and extremely low germination rates are significant problems for the teak plantation industry and multiplication of quality seed (Kaosa-ard 1981). Seed related traits such as seed size, seed mass, fruit weight and germination are central components of plant life histories (Thompson 1987). It may highly influence reproduction and seedling establishment (Grime et al 1988).

Seed size, dormancy and dispersal have long been regarded as significant impacts on reproductive biology of plants and creating fitness interaction with changing environment as well as forest types (Venable and Brown 1988). In addition there are many other factors such as rainfall, temperature, latitude, longitude, altitude and genetic plasticity which influence the seed size, yield and quality (Gutterman 2000). Genetic variation among seed traits within and between populations has been documented for economically useful tropical plantation species such as *Gmelina arborea* (Lauridsen 2004, Hodge and Dvorak 2004), *Khaya senegalensis* (Ky-Dembele et al 2014), *Tectona grandis* (Jayasankar et al 1999, Sivakumar et al 2002), *Cordia africana* (Loha et al 2006, Loha et al 2009) and *Faidherbia albida* (lbrahim et al 1997). Therefore the present study was undertaken to evaluate drupe morphometric characters to determine the effect of different forest types and populations within the forest types on drupe morphometric characters, to see the effect of geo-climatic variables on drupe development and to look inter-character correlations for seed quality dimensions.

MATERIAL and METHODS

The present investigations were done at College of Forestry, Navsari Agricultural University, Navsari, Gujarat to study the drupe morphometric characters of teak among populations within a forest type and between different teak forest types. Teak fruits/drupes were collected during April to July 2015 from two different populations within three different teak forest types viz very moist teak forest (Kerala), moist teak forest (Gujarat) and dry teak forest (Maharashtra) (Table 1, Fig 1).

Four hundred drupes of each population in four lots/replications (100 drupes per lot) were measured for analysis of the drupe attributes. Drupe length (mm), drupe width (mm), drupe mass (g), stone length (mm), stone width (mm) and stone mass (g) were recorded and averages were computed. Drupe length and width were measured using digital caliper. Drupe mass was evaluated using electronic weighing balance. The mesocarp was removed manually by rubbing drupes on 20 grit sandpaper sheet and stone length, width and weight were measured for individual stone. These data were subjected to statistical analysis using OPSTAT statistical software online and factorial RBD ANOVA was constructed for studied parameters. Simple correlation coefficients were worked out to know the effect of geo-climatic variables and association among characters as per the method given by Panse and Sukhatme (1978).

RESULTS and DISCUSSION

Effect of different teak forest types and populations on drupe morphometric characters

The data on drupe morphometric characters varied significantly with forest type, population and their interactions except stone width for population of teak (Tables 2, 3).

Average drupe length, width and weight differed significantly from 12.95 mm, 14.91 mm and 0.744 g in Elivaly population to 9.64 mm (Nagalwadi), 10.89 mm (Nagalwadi) and 0.486 g (Bhander) respectively among six populations within different teak forest types. However maximum average drupe length (12.67 mm), width (14.84 mm) and weight (0.708 g) were recorded in very moist teak forest followed by moist teak forest whereas minimum were found in dry teak forest (9.68 mm, 10.96 mm, 0.495 g respectively). Significantly maximum stone length (9.00 mm) and stone weight (0.553 g) were found in Elivaly population while minimum values for stone length (8.04 mm) and stone weight (0.347 g) were recorded in Bhander population among six different populations. Similar results were also found for stone length, width and weight among three teak forest types as drupe length, width and weight. As a whole Elivaly population performed better than all others (Table 3). Thus drupe morphometric characters in teak were significantly affected by different teak forest types. Better fruit traits obtained from moist deciduous forests are in conformity with the studies on *Teminalia alata* in which the trees growing in moist deciduous forests produced fruits with higher weight compared to semi-evergreen and dry deciduous forests (Sivaprasad and Channabasappa 2011). The results are also supported by the work of Brancalion et al (2011) wherein they found the effects of forest types on seed dry mass and seed number per bunch for palmiteiro (*Euterpe edulis*) and queen palm (*Syagrus romanzoffiana*) responsible for seed development and quality production. Because seed development is strongly affected by the influence of light (Copeland and McDonald 2001), photoperiod (Munir et al 2001), temperature (Donohue et al 2008), water (Kebreab and Murdoch 2000) and nutrient availability (Cheplick and Sung 1998) of the site where they grow thus seed yield and quality are determined by the maternal environment (Gutterman 2000). Variation in teak drupe characters was documented by several authors such as Jayasankar et al (1999), Sivakumar et al (2002), Jose and Indira (2010). Jijeesh and Sudhakara (2014) graded teak drupes into three diameter classes of 9-12, 12-15 and 15-18 mm to find out the effect of drupe size on earliness of germination, seedling growth and root growth. Bigger size drupe was found to significantly influence the vigour of seedlings in the initial stage of growth. There are several other tropical tree species where such type

Table 1. Geographic locations and climatic conditions of different forest types with two different populations of *Tectona grandis*

Forest Type	Population	Latitude (N)	Longitude (E)	Annual temperature (°C)	Annual rainfall (mm)
Very moist teak forest	Thalappara	11°04’26.4"	75°53’52.8"	27.3	2952
	Elivaly	09°46’44.4"	76°43’30.0"	27.4	3391
Moist teak forest	Bardipada	20°57’32.4"	73°38’27.6"	25.1	1784
	Dharampur	20°30’50.4"	73°16’01.2"	26.8	2303
Dry teak forest	Nagalwadi	21°07’40.8"	78°57’43.2"	26.9	1092
	Bhander	21°31’51.6"	79°02’42.0"	25.5	1294

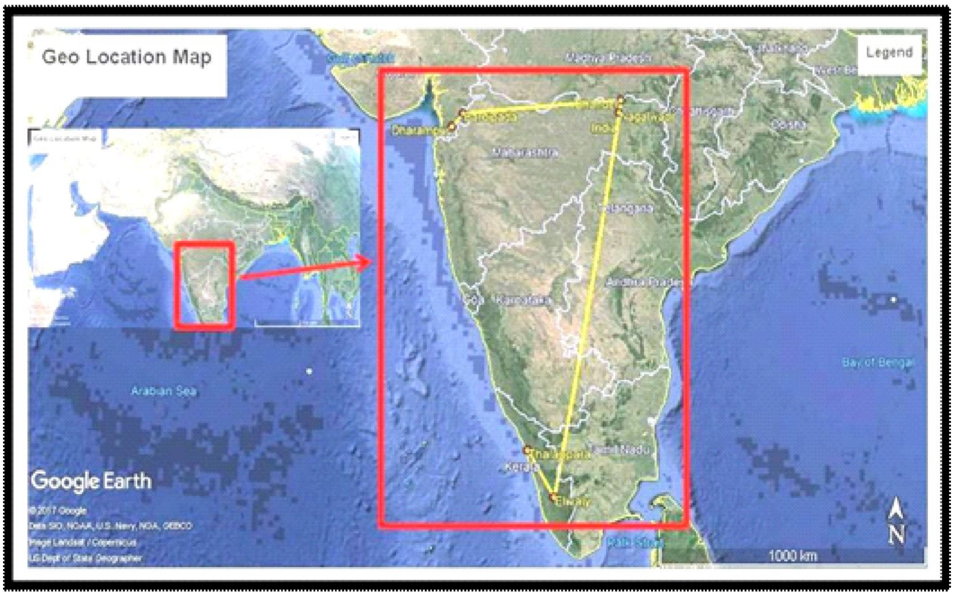

Fig 1. Geographic locations of different populations of *T grandis* represented in the research study

Table 2. Analysis of variance (ANOVA) for drupe morphometric characters of *T grandis*

Source of variation	DF	Mean sum of square (MSS)					
		Drupe length	Drupe width	Drupe weight	Stone length	Stone width	Stone weight
Forest type	2	18.124**	30.236**	0.092**	1.281**	2.541**	0.054**
Population	1	1.360**	0.037**	0.001*	0.078**	0.000^{NS}	0.001**
Forest type x Population	2	0.273**	0.022**	0.008**	0.121**	0.122**	0.009**

*Significant at P <0.05, **Significant at P <0.01, NS= Non-significant, DF= Degrees of freedom

seed-related variations were found to be useful for tree improvement such as *Gmelina arborea* (Lauridsen 2004, Hodge and Dvorak 2004), *Khaya senegalensis* (Ky-Dembele et al 2014), *Faidherbia albida* (lbrahim et al 1997), *Cordia africana* (Loha et al 2006, Loha et al 2009) and *Millettia ferruinea* (Loha et al 2008). Therefore drupe development, collection and regeneration of different teak forests in India are directly related to drupe as well as stone size and mass.

Effect of geo-climatic parameters on drupe development and seed quality

Geographic variables such as latitude showed strong negative correlation with stone length (r= -0.960,

Table 3. Average mean values of drupe morphometric characters for populations and forest types of *T grandis*

Forest type	Population	Drupe length (mm)	Drupe width (mm)	Drupe weight (g)	Stone length (mm)	Stone width (mm)	Stone weight (g)
Very moist	Thalappara	12.40	14.77	0.671	8.83	10.39	0.485
teak forest	Elivaly	12.95	14.91	0.744	9.00	10.67	0.553
	Mean	12.67	14.84	0.708	8.91	10.53	0.519
Moist teak	Bardipada	11.04	13.12	0.604	8.41	9.75	0.480
forest	Dharampur	11.85	13.07	0.558	8.15	9.69	0.414
	Mean	11.45	13.10	0.581	8.28	9.72	0.447
Dry teak	Nagalwadi	9.64	10.89	0.504	8.30	9.55	0.363
forest	Bhander	9.72	11.03	0.486	8.04	9.35	0.347
	Mean	9.68	10.96	0.495	8.17	9.45	0.355
$CD_{0.05}$							
Forest type		0.047**	0.064**	0.003**	0.043**	0.052**	0.003**
Population		0.038**	0.052**	0.003*	0.035**	0.001^{NS}	0.003**
Forest type x Population		0.066**	0.091**	0.005**	0.061**	0.073**	0.004**

*Significant at P <0.05, **Significant at P <0.01, NS= Non-significant

p< 0.01) and stone width (r= -0.956, p< 0.01) and also exhibited a good negative correlation with all other drupe traits. Annual rainfall was positively correlated with all the drupe morphometric characters significantly however longitude and annual temperature were non-significant (Table 4). Seed size (length, width, depth and weight) of natural populations of *Pinus halepensis* were negatively correlated with latitude (Boulli et al 2001) which confirm present results. Among and within perennial Australian *Glycine* species a significant negative relationship emerged between seed size and latitude (Murray et al 2003). Longitude and temperature affects were not found on all drupe characters which is also supported by the work of Mamo et al (2006) in *Juniperus procera*. Thus the geo-climatic parameters have an impact on the drupe development and seed quality in teak.

Inter-character correlations among drupe morphometric characters

All the drupe characters showed a strong significant (p <0.01) positive correlation with one another (Table 5). Similar results were found by Sivakumar et al (2002) that drupe diameter, drupe weight and other drupe parameters were strongly inter-correlated to one another.

Lyngdoh et al (2013) also exhibited positive correlation of drupe diameter with drupe weight. Seed width was positively correlated with seed weight in *Millettia ferruinea* (Loha et al 2008). Seed length, width and weight of *Cordia africana* were shown having strongly positive correlation to one anther (Loha et al 2009). Thus all the drupe morphometric characters were closely related to one another and influenced drupe development and quality seed production.

CONCLUSION

Teak wood is highly demanded tropical wood in the national and international markets which attract the teak growers. But there are two major problems for plantation industries viz low seed production in quality and quantity and germination. In the present

Table 4. Effect of geo-climatic variables on drupe morphometric characters of *T grandis*

Character	Latitude	Longitude	Annual temperature	Annual rainfall
Drupe length	-0.837*	-0.537^{NS}	0.576^{NS}	0.985**
Drupe width	-0.847*	-0.548^{NS}	0.485^{NS}	0.964**
Drupe weight	-0.911*	-0.349^{NS}	0.519^{NS}	0.939**
Stone length	-0.960**	-0.115^{NS}	0.629^{NS}	0.869*
Stone width	-0.956**	-0.192^{NS}	0.632^{NS}	0.924**
Stone weight	-0.813*	-0.454^{NS}	0.365^{NS}	0.883*

*Significant at P <0.05, **Significant at P <0.01, NS= Non-significant

Table 5. Inter-character correlation matrix among drupe morphometric characters of *T grandis*

Character	Drupe length	Drupe width	Drupe weight	Stone length	Stone width	Stone weight
Drupe length	1					
Drupe width	0.974**	1				
Drupe weight	0.915**	0.951**	1			
Stone length	0.783**	0.848**	0.942**	1		
Stone width	0.893**	0.920**	0.972**	0.964**	1	
Stone weight	0.884**	0.930**	0.977**	0.884**	0.908**	1

**Significant at P <0.01, NS= Non-significant, n= 24

study drupe morphometric characters in teak were highly influenced by forest types and site quality (population) and the interactions in which they grew due to light, temperature, water and nutrient availability. Drupe development and fitness were influenced by geo-climatic variables such as latitude and rainfall. Inter-character association showed that healthy seed completely developed itself in all dimensions. So better drupe production area should be properly identified and delineated for superior quality seed production within a forest type and among different teak forest types.

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