Fertility Variation across Years in Two Clonal Seed Orchards of Teak and its Impact on Seed Crop.

A. Nicodemus[1*], M. Varghese[1], B. Nagarajan[1] and D. Lindgren[2],
[1]Institute of Forest Genetics and Tree Breeding,
PB 1061, Coimbatore 641 002, Tamil Nadu. India
[2]Department of Forest Genetics and Plant Physiology,
Swedish University of Agricultural Sciences, SE-901 83 Umeå, Sweden.
*email:nicodemus_a@rediffmail.com

Introduction

Teak (*Tectona grandis* L.f.) is a highly valued timber species raised in plantations throughout the tropics. Clonal Seed Orchards (CSO), established through grafts of selected trees are considered to be channels of genetically improved seed and starting point for domestication. India has over 1000 ha of CSOs but seed production from them has been too low to make any impact on the new plantations or advancing the breeding cycle. Genetic improvement of teak has not moved beyond the first generation orchards during the last 50 years.

Reproductive biology of teak and in particular the causes for low seed production in orchards has been intensively studied during the past decade. Teak is a predominantly outcrossing species and insects are the major vectors of pollination. Absence of flowering, clonal variation in flowering phenology and pollinator limitation are reported to be the major reasons for low seed output (Nagarajan *et al*. 1996; Palupi and Owens, 1998; Gunaga and Vasudeva, 2002). The objectives of the present study were to quantify flower and fruit production in two orchards during consecutive years, to estimate fertility variation and its impact on the seed crop and to determine the factors that influence fertility status of orchards.

Orchard Details and Study Methods

Flower and fruit production was estimated during four consecutive years (2003-06) in two orchards located at Topslip (CSO I: 10˚ 25’ N, 76˚ 50’ E; rainfall: 2080 mm) and Walayar (CSO II: 17˚ 40’ N; 81˚ 00’ E; rainfall: 1000 mm). CSO I has 15 clones and CSO II 20 clones and 13 clones are common between them. Both the orchards were established in 1976 in a completely randomized design at a spacing of 5 m. Two thinnings were undertaken in the orchards which resulted in an average spacing of 10 m between trees. During the study period CSO I had 175 trees comprising 6 to 9 ramets each of 15 clones and CSO II had 454 trees represented by 13 to 30 ramets each of 20 clones.

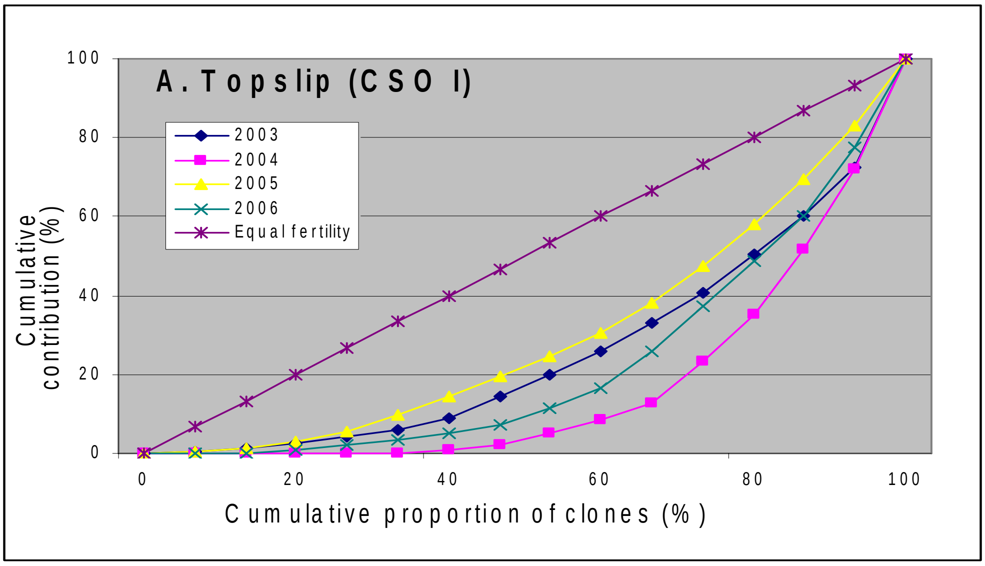
All the flowering ramets were assessed for flower and fruit production following the methods of Bila *et al*. (1999). Diameter was measured for all trees every year while total height and clear bole height were measured only in the last year i.e. 2006. The significance of clonal variation for different traits was determined through analysis of variance. The orchards were divided into four blocks and one random flowering tree in each block was chosen for the analysis. Broad sense heritabilities on individual ramet basis and simple correlations were calculated for all traits studied. Sibling coefficient (Ψ), group coancestry (Θ), status number (*Ns*), relative status number (*Nr*) and gene diversity (GD) were calculated using the methods of Lindgren and Mullin (1998) and Kang and Lindgren (1999).

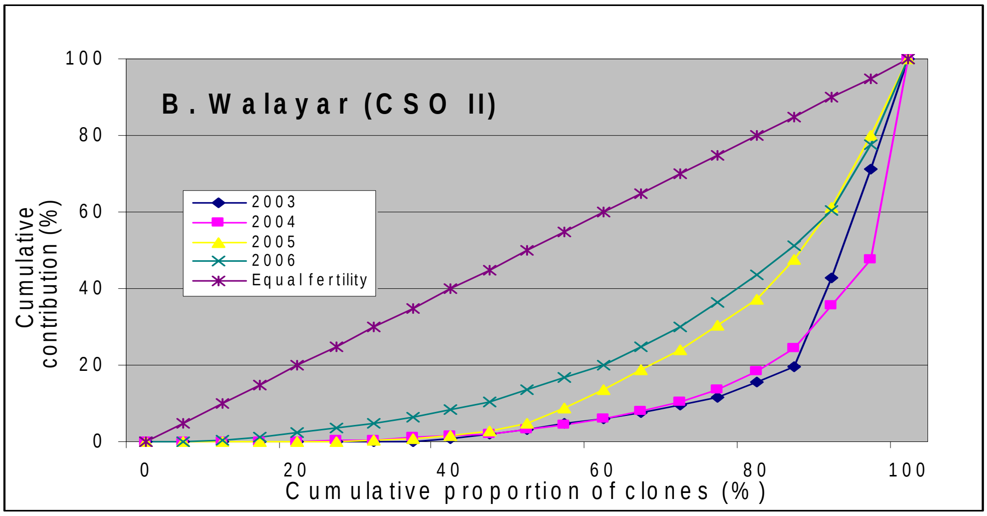
Results and Discussion

Fertility was generally low in both the orchards with the proportion of flowering ramets ranging from 16 to 53%. Each orchard had one abundant flowering year in which CSO I had 53% of ramets flowering while 39% flowered in CSO II. Fruit production per hectare of orchard ranged from 1 to 18 kg in CSO I and 9 to 17 kg in CSO II. Clones and ramets of a clone differed in fertility across years and orchards. Only 60% of the clones flowered in all four years in both the orchards. At individual tree level, only 11% flowered in all years in CSO I and 19.8% in CSO II while 35% and 52% of trees respectively did not flower any of the four years.

Clones significantly differed in flower and fruit production per tree. A few clones contributed more than others and this imbalance was more pronounced in CSO II than CSO I and during low flowering years than abundant years. About 80% of flowers were produced by 50% of clones in CSO I in three of the four years whereas 40% of clones produced 80% of flowers in CSO II even during abundant flowering year (Fig. 1). Broad sense heritability was moderate to high (0.31 to 0.76) for flower production but low (0.07 to 0.35) for fruit production. In general heritability values were higher in low flowering years in both the orchards. Correlation between flower and fruit production was strong and positive in each year and also for the same trait between successive years. Fertility traits showed low and positive correlation with tree diameter but weakly negative relationship with height and clear bole height.

Fig. 1. Cumulative contribution of gametes by teak clones in two orchards during four years





Sibling coefficient (Ψ) and group coancestry (Θ) were higher in low flowering years compared to good years (Table 1). Between the two orchards CSO II showed up to 3 times more fertility variation than CSO I. As a result status number (*Ns*), relative status number (*Nr*) and gene diversity (GD) were generally higher in CSO I than CSO II. However in abundant flowering years the differences in fertility status between the two orchards were greatly reduced and showed comparable sibling coefficient and group coancestry values.

Table 1. Fertility variation (Ψ), group coancestry (Θ), status number (*Ns*), relative status number (*Nr*) and genetic diversity (GD) for four years in two teak CSOs.

	Topslip (CSO I)				Walayar (CSOII)			
	2003	2004	2005	2006	2003	2004	2005	2006
Ψ	1.97	2.64	1.49	2.01	4.45	6.22	2.47	2.26
Θ	0.066	0.088	0.050	0.067	0.111	0.155	0.062	0.057
Ns	7.60	5.68	10.05	7.48	4.50	3.22	8.11	8.84
Nr	0.51	0.38	0.67	0.50	0.22	0.16	0.41	0.44
GD	0.93	0.91	0.95	0.93	0.89	0.84	0.94	0.94

The highest fruit production observed in the present study, 18 kg per ha of orchard would be sufficient to raise only 5 ha of plantations assuming a 30% germination. It could be lower than that if orchard seeds germinate poorly as reported earlier (Indira and Basha, 1999; Mathew and Vasudeva, 2003). The major reason for low fruit production in orchards is a general lack of flowering. Seed production areas of similar age in India have better proportion of fertile trees (58 to 97%) (Varghese *et al*. 2007). Locating orchards in sites suitable for flowering and fruiting like Topslip (CSO I) with high rain fall and deploying clones known to have high fertility in similar sites are expected to increase orchard output.

Moderate to high heritability for flowers and fruits per tree indicate that reproductive traits are under fairly strong genetic control in teak as reported for dimensions of floral parts and flowering phenology (Vasudeva *et al*. 2004). Tree size (diameter) has low but positive correlation with fertility traits indicating that selecting trees based on size will not result in reduction of reproductive output. But total and clear bole height showed weakly negative correlation with flower and fruit production. It is reported that in teak the first flowering is terminal which results in forking of the main stem. The early flowering trees have shorter clear bole length and are usually ignored while selecting plus trees. Forking of the main stem results in a wide crown with many positions for floral development and thus making the tree more fertile than others. The most fertile clone in CSO II (SBL 1) had the shortest clear bole height.

Since fertility variation and group coancestry are more in low flowering years compared to abundant years, seed collection may be restricted to abundant years only especially if seeds are collected for progeny testing and other breeding purposes. Intentional adjusting of ramet number to balance contribution of clones and mixing of seeds from successive years may also reduce relatedness among orchard progeny. Existing orchards typically with 15 to 30 clones may not achieve the production levels assumed at the time of establishing them (250 kg ha^{-1}; Hedegart, 1976). Seed production areas (SPA) which are rigorously thinned plantations can be regarded as low input breeding options for teak (Lindgren and Wei, 2007). Flowering, seed production and germination are generally reported to be better in SPAs compared to orchards (Indira and Basha, 1999; Varghese *et al*. 2005). The large number of parent trees in SPAs ensures that high level of diversity is maintained in the progeny even if the gains are modest. They can also be a source of seed for developing next generation seedling seed orchards.

Acknowledgements

This study was supported by International Foundation for Science (IFS), Sweden through a research grant to A. Nicodemus (Grant No.D/3384-1) and Swedish Research Council and SIDA by a research grant to Mohan Varghese and Dag Lindgren. Assistance and field support was provided by research wing of Tamil Nadu forest department.

References

Bila, A.D., Lindgren, D., and Mullin, T.J. 1999. Fertility variation and its effect on diversity over generations in a teak plantation (*Tectona grandis* L.f) Silvae Genet. 48: 109-114.

Gunaga, R., and Vasudeva, R. 2002. Genetic variation for fruiting phenology among teak clones of different provenances of Karnataka. Indian J. For. 25:215-220.

Hedegart, T. 1976 Breeding system, variation and genetic improvement of teak (*Tectona grandis* Linn.f.). In: Burley, J. and Styles, B.T. (eds.). Tropical Trees, Linnean Society Symposium Series No.2, Academic Press, London. pp.109-123.

Indira, E.P. and Basha,, S.C. 1999. Effect of seeds from different sources on germiantion and growth in teak (*Tectona grandis* L.f.) nursery. *Annals of Forestry* 7:39-44.

Kang, K.S., and Lindgren, D. 1999. Fertility variation among clones of Korean pine (*Pinus koraiensis*) and its implications on seed orchard management. For. Gen. 6(3): 191-200.

Lindgren D. and Mullin T.J. 1998. Relatedness and status number in seed orchard crops. Can. J. For. Res. 28: 276–283.

Lindgren, D. and Wei R.P. 2007. Low-input tree breeding strategies. In Proceedings of the IUFRO Division 2 Joint Conference: Low Input Breeding and Conservation of Forest Genetic Resources: Antalya, Turkey, 9-13 October 2006. Edited by Fikret Isik. p 124-138.

Mathew, J. and Vasudeva, R. 2003. Clonal variation for seed germination in teak (*Tectona grandis* Linn. f). Current Science, 84:1133-1136.

Nagarajan, B., Mohan Varghese, Nicodemus, A., Sasidharan, K.R., Bennet, S.S.R. and Kannan, C.S., 1996. In: Dieters, M.J., Matheson, A.C., Nikles, D.G., Harwood, C.E. and Walker, S.M. (eds.). Tree Improvement for sustainable tropical forestry. Proceedings of QFRI-IUFRO Conference, Caloundra, Australia. pp.244-248.

Palupi, E.R. and Owens, J.N. 1998. Reproductive phenology and reproductive success in teak (*Tectona grandis* L.f.). Int. J. Plant Sci. 159:833-842.

Varghese, M., Nicodemus, A. and Nagarajan, B. 2005. Fertility variation and dynamics in two clonal seed orchards of teak. In: Bhat, K.M., Nair, K.K.N., Bhat, K.V., Muralidharan, E.M. and Sharma, J.K. (Eds.). Quality Timber Products of Teak from Sustainable Forest Management, Proccedings of the IUFRO International Conference held between 2-5 December 2003 at Peechi, India. Kerala Forest Research Institute, Peechi, Kerala, India and ITTO, Yokohama, Japan. pp.338-346.

Varghese, M., Kamalakkannan, R., Nicodemus, A., and Lindgren. D. 2007. Fertility variation and its impact on seed crop in seed production areas and a natural stand of teak in southern India. Euphytica (in press).

Vasudeva, R, Hanumantha, M. and Gunaga, R.P. 2004. Genetic variation for floral traits among teak (*Tectona grandis* Linn. f.) clones: Implications to seed orchard fertility. Current Science, 87:358-362.