Comparison of performance of whitewood (*Endospermum medullosum* L. S. Smith) provenances and families in Vanuatu

Ioan Viji N Vutilolo[1], Anand P Tyagi[2], Lex A J Thomson[3], Michael Heads[2]

[1]*Department of Forests, Vanuatu*

[2]*Department of Biology, School of Pure and Applied Sciences, The University of the South Pacific, Suva, Fiji*

[3]*Forestry Section, CSIRO, Canberra, Australia*

tyagi_ap@usp.ac.fj

ABSTRACT

This study reports a comparison of performance of four year-old whitewood (Endospermum medullosum L S Smith) provenances and families trials established by the Department of Forestry of Vanuatu and the South Pacific Regional Programme In Forest Genetic Resources project (SPRIG). Trees in the different open-pollinated, half-sibling families had mean heights ranging from 7.1 m to 10.2 m, dbh from 13.5 cm to 17.8 cm, wood volume from 0.07 to 0.14 m^3 and survival from 54% to 91%. Seedlot GD11 from Shark Bay East Santo showed the superior mean height of 10.2 m followed by seedlot MT29 from Maewo and MS47 from Malel Central East Santo with 9.6 m. The shortest trees were in families JT35 (Forari, Efate) with 7.1 m, MT33 (Maewo) and JT30 (Forari, Efate) with 7.5 m. Trees in seedlots MS44 from Malel Central East Santo and MS32 from Palon East Santo had the biggest diameter increase(mean dbh of 17.8 cm) followed by seedlot GD11 Shark Bay East Santo and MS2 from Sara East Santo with 17.5 cm and MS55 from South East Santo with 17.4 cm. Seedlots with very low diameter increment were MT3 from Maewo and JT35 from Forari (mean dbh of 13.5 cm) followed by MT3 and MT4 from Central Pentecost with a mean dbh of 13.8 cm. Seedlots with superior wood volume production were MS2 from Sara East Santo (with mean of 0.15 m^3 per tree) followed by seedlots MS32 Palon East Santo, GD11 Shark Bay East Santo, MS55 South East Santo with 0.14 m^3 and MS3 Kole East Santo with 0.13 m^3. The slowest growing seedlots were JT35 from Forari Efate and MT32 from Maewo with mean volume of 0.07 m^3. Study reveals that there is a great potential among provenances and families for further improvement and to establish breeding programme to breed whitewood for higher quantity and better timber quality.

1 INTRODUCTION

Whitewood (*Endospermum medullosum* L.S. Smith) is a very important indigenous timber tree and the most important native timber tree in Vanuatu accounting from 40 to 60% of timber harvest (Vanuatu Department of Forests Conservation Strategy Report 2000). Its presence in more accessible areas of native forest is down to a residual of few young trees and a few old poorly formed and senescent trees. The introduction and promotion of small sawmills business has accelerated the logging and extraction of whitewood, thereby reducing the *E. medullosum* stand in Vanuatu (Sam 1997; Thomson and Uwamariya 1998). Large-scale agriculture development programs undertaken in the past to clear the forest to plant coconut and cocoa and rearing livestock have also contributed to reduction of *E. medullosum* populations (Clark and Thaman 1993).

The presence of whitewood on the different islands in Vanuatu and elsewhere, growing in different environments, has the potential to allow genetic diversity to develop, including for the traits of economic importance. Determining genetic diversity in species, and interpreting this diversity in terms of its origin, organization and maintenance, is of fundamental significance for tree breeding work (Young *et al*. 2000).

The native forests of Vanuatu have sometimes been regarded as having limited potential for commercial timber exploitation. As in many tropical hardwood forests, there are hundreds of species, but in Vanuatu only about 12 to 15 species are exploited commercially. In Vanuatu 900,000 ha or 75 percent of the total land area is under forest vegetation but much of it is too steep for commercial forestry. Nearly all the forests have been disturbed by conversion to pasture or cash crop cultivation (Oliver 1999). It is risky and not entirely appropriate concept to rely heavily on natural regeneration (from scattered seeds) of forest resources for a small island country like Vanuatu. Burley and Styles (1976) reported that the considerable effort put into ecological research and attempts at silvicultural manipulation of tropical forests to induce so-called “natural regeneration” have little success.

In order to be sustainable the forest industry in Vanuatu must undertake and/or foster replanting of the major timber species, especially whitewood. Reliance on natural regeneration from the natural forest for a future crop of whitewood is considered to be a highly risky strategy. Casey (1993) identified a pressing need to select a suitable timber species for plantation activities in Vanuatu and recommended that the phenology, propagation and planting of the native timber tree species should be studied to determine their plantation potential. Whitewood had been identified as the most promising timber species with good timber properties, coupled with moderately rapid growth and high cyclone resistance. The latter is an important character for forestry plantations in Vanuatu. Pests and diseases of this species were limited and do not pose great danger. Field trial observations in 1990's showed that whitewood has a reasonably good growth rate relative to other Vanuatu indigenous timber tree species. Therefore the main objective of this study was to compare the growth performance of 97 provenances of Vanuatu whitewood (*Endospermum medullosum*), grown at Shark Bay and use this information in tree improvement programme.

2 MATERIALS AND METHODS

The whitewood family trial was located at the Shark Bay Research Station, East Coast of Santo Island in Vanuatu. The trial was established in December 1998-January 1999. The experimental area was 6.25 hectares including the border rows. Experimental design was a Row Column design with 8 replicates each comprising 100 plots (each representing a single seed-lot). Each replicate consisted of 20 rows, 5 columns with a total of 800 plots. Individual plot area was 0.005 hectares had 1 row of 6 trees with a spacing of 6 m between rows by 2 m within rows. Initial stocking was 833 trees per hectare. A total of 97 families of whitewood with seed-lots collected throughout the islands in Vanuatu established in the trial were assessed. Three seed sources from PNG were excluded from analysis, because they were found to be a different, but very closely related species *Endospermum myrmecophilum*. Seedlots were assigned into their respective provenances that made up 11 groupings. All plants were grown from the different seedlots and were almost of the same age.

2.1 METHODOLOGY

2.1.1 TREE HEIGHT AND dbh

Data were collected in 2003 on tree height, diameter at breast height (dbh) using a measuring and diameter tapes. The data recorded and pattern followed in the assessment forms was related to the layout of the experiment. Thus every tree was measured and checked to ensure that they were in the correct positions in the field as is in the Trial Design Layout as described by Williams *et al.* (2002)

2.1.2 VOLUME ESTIMATE

Estimation of individual tree volume (up to diameter of 5 cm) was made using a volume equation derived from a sample of 34 trees from the trial in 2004. The volume estimate employed the Huber's method. Trees were cut at ground level and following measurement were made: base diameter (d1), top diameter (d2), mid diameter (dm) and log length. The log length was from the base (or bottom) of the log to 5 cm from the top.

2.1.3 HUBER'S FORMULA (PHILIP, 1994):

$$V = \pi L d^2/4$$

Thus d = (d1 + d2)/2. Where d is the average diameter of both ends of the log measured in meters and L is the length of log in meters. This is a direct method involved felling a sample of 34 trees with boles, cutting into workable sizes and measuring (Carron 1968).

2.1.4 SURVIVAL PERCENTAGE

Survival percentage and tree forms were recorded by taking into account original planting and tree shape. Williams *et al.* (2002) noted that survival is often used as a variate for analysis although this trial is not specifically design to test it.

2.2 DATA ANALYSIS

2.2.1 ANALYSIS OF VARIANCE (ANOVA)

The analyses of variance (one way) for all the variables were calculated by the GenStatprogram gen.tx. The GenStat program calculated the ANOVA for height, dbh, volume and survival rate. GenStat was also used to undertake a nested ANOVA for the family and provenance. Residual Maximum Likelihood (REML), (reml.gen) program used to carry out a REML analysis for the mixed-effects model where the incomplete blocking factors were specified as random so that recovery of inter-block treatment information is possible. The REML was used to estimate variance components.

2.2.2 SELECTION PROCEDURE

In the ranking of selections on 34 plants (data not shown), values were assigned for the variables for the GenStat program, including the Weight Coefficient (Cotterill and Dean 1990). The higher the value, the more emphasis is placed on family information rather than individual value in constructing the index.

3 RESULTS AND DISCUSSION

3.1 COMPARISON OF THE PERFORMANCE OF WHITEWOOD FAMILIES AND PROVENANCES

3.1.2 COMPARISON OF FAMILY MEANS

The data collected on height, dbh, volume and survival rate for 97 whitewood families are summarized in the text follows:

3.1.1.1 Mean Height

The mean heights ranged from 7.1 to 10.2 m, dbh from 13.5 to 17.8 cm, wood volume from 0.07 to 0.15 m^3 and survival from 54 to 91 percent within and between family and provenance variation in Whitewood. Family GD11 from Shark Bay (East Santo) MT29 from Maewo and MS47 from Malel (Central East Santo) all three with 9.6 m were the tallest provenances. Studies on trials of tree species growing in their local sites have demonstrated better growth performance than from geographically different locations (Sedgley and Griffin 1989; Namkoong, 1979). With the exception of family MT29, which was from another island (Maewo), superior growth in height performance shown by the families GD11 and MS47 from East Santo. Better growth performance by local provenance sources may be expected given their adaptation to local conditions.

3.1.1.2 Mean dbh

Family MS44 from Malel (Central East Santo), MS32 from Palon (East Santo) GD11 from Shark Bay (East Santo), MS2 from Sara (East Santo) and MS55 from South East Santo had greatest dbh. As with height superior performances in dbh were observed in most families from East Santo and only in one family from South-East Santo. A difference in dbh by only a few centimetres may appear small but is considerable in wood volume and timber utilization terms when considering the tree improvement for this trait.

Families with low dbh mean such as MT32 from Maewo and JT35 from Forari, MT3 and MT4 from Central Pentecost were mostly from different islands and the poor dbh mean may be due to lack of adaptation to the new environment such as soil type or lack of resistance to cyclone damage and climate. Williams *et al.* (2002) noted that natural patterns of genetic variation in many species have become blurred through human interference.

3.1.1.3 Mean Wood Volume

The families with superior volume means were family MS2 from Sara (East Santo), MS32 Palon (East Santo) and GD11 Shark Bay (East Santo), MS55 (South East Santo) and MS3 from Kole (East Santo). Hodge and William (1999) conducted a study on genetic parameters and provenance variation in *Pinus tecunumanii* in 78 international trials, which revealed that genotype x environment interaction for volume growth, was stronger at the family level than at the provenance level.

Families with good volume production (mean of 0.12 m^3) were: JT42 from Forari, Efate; GD7, GD8, MS17 from Kole East Santo; GD13 and MS10 from Shark Bay, East Santo; MT29 from Maewo; MS1, MS44, MS46 MS47 from Malel Central, East Santo; MS53 and MS62 from South East Santo; JT1 from Teouma, Efate provenance; MT38 from West Ambae provenance and SBC13 from IFP Plantation.

The identification of large group of families with mean volume of 0.12 m^3 was important. Although there was a large difference between 0.12 m^3 and the superior mean volume of 0.15 m^3 but a number of families from different islands had the same volume of 0.12 m^3. This is vital information, which can be used to develop a base population with diverse germplasm of whitewood using the best families on the different islands for tree improvement and / or *ex situ* conservation. From an economic point of view volume is the most important trait. A moderate volume increase has demonstrated the presence of genetic diversity in the families for further utilization in tree improvement programme.

3.1.1.4 Percent Survival

Families with superior survival means were MT39 from West Ambae, MT20 from Central Pentecost, JT41 from Forari, (Efate) and SBC13 from IFP Plantation provenance. Interestingly, when compared, some of the families from the different islands had a higher percentage survival as compared with families from Santo that scored better for height, dbh and volume. Although, fortunately, there was no cyclone during this experiment the trait percent survival of planted trees was quite important for tree breeding and beneficial to farmers especially in Vanuatu, which has an average frequency of 2 -3 cyclones every year (Barrance 1986a,b).

Table 1. Provenance summary of Height, Survival, DBH and individual tree wood volume of whitewood at 4 years of age.

No	Provenance	Height (m)	Survival (%)	DBH (cm)	Volume (M^3)
10	IFP Plantation	9.2	88	16.3	0.12
3	East Coast Santo	8.9	77	16.1	0.11
5	Central East Santo	9.0	72	16.8	0.11
6	South East Santo	8.8	75	16.4	0.11
7	Teouma, Efate	8.5	70	15.6	0.10
8	Uri Wiaru, Malekula	8.6	76	15.1	0.10
9	West Ambae	8.8	82	15.5	0.10
1	Central Pentecost	8.4	74	15.1	0.09
2	Forari, Efate	7.8	76	15.3	0.09
4	Maewo	8.4	70	14.8	0.09

4.2 COMPARISON OF GROWTH TRAITS PERFORMANCE BETWEEN AND WITHIN PROVENANCES.

In the major whitewood family trial there were 10 provenances with numbers of seedlots in each provenance ranging from 1 to 20 seedlots making up the 97 families (Table 1). Provenance means ranged from 7.8 m to 9.2 m for height, dbh from 14.8 cm to 16.8 cm, volume from 0.09 m^3 to 0.12 m^3 and mean survival from 70% to 88%. Australian researchers; Boland *et al*. (1998 Ref not in list) and Williams *et al.* (2002) recommended that 10 or is it 48? trees are sufficient to make up a provenance to evaluate provenances in trials. This is subject to the condition that individual seed trees should be separated from one another by at least 100 m to minimize the extent of common decent (Hodge and William 1999).

Williams *et al.* (2002) noted that samples (families) of open-pollinated seeds from seed trees in natural populations were commonly assumed to be half sibs. However this may not always be true because there may be some sib mating (Brown *et al.* 1975; Williams *et al.* 2002). Also neighbour inbreeding (i.e. cross-pollination between nearby trees that are closely related (Eldridge *et al.* 1993) and unrelated trees may be represented as male parents in a family. For some female trees with few nearby male trees, there is a high probability that half-sib families will be dominated by just a few pollen parents.

4.2.1 MEAN HEIGHT

The superior provenances for height were from IFP plantation and the Central East Santo. The IFP plantation provenances have the advantage of adaptation on those sites as progeny of the best trees whose mother trees in the native stand were selected from trees with superior phenotype.

Table 2. Ranking of whitewood trees at 4 years of age with economic values of 1 for height and 2 for dbh (only a sample of the best 40 trees).

Replicate	Row	Column	Tree	Family	Provenance	Height (m)	Doh (Cm)	Individual tree Index	Rank
5	1	1	1	ms2	East coast Santo	12.98	30.48	34.9	1
2	18	5	1	ms3	East coast Santo	10.82	29.4	33.19	2
2	7	2	3	ms2	East coast Santo	11.35	26.68	30.54	3
2	4	2	2	ms44	CE Santo	12.77	26.03	30.27	4
4	2	2	3	ms32	East coast Santo	7.22	27.21	29.95	5
4	3	2	6	ms2	East coast Santo	10.37	26.21	29.79	6
8	5	1	3	ms47	CE Santo	11.64	25.64	29.55	7
5	9	5	3	jt39	Forari_efate	10.15	25.99	29.5	8
1	20	4	3	ms32	East coast santo	11.4	25.52	29.36	9
7	8	2	2	ms47	CE Santo	11.82	25.11	29.06	10
5	8	4	5	jt7	Teouma_Efate	8.42	25.74	28.77	11
5	10	5	1	gd8	East coast santo	10.86	24.98	28.66	12
7	8	2	4	ms47	CE Santo	12.31	24.28	28.34	13
8	7	5	6	ms32	East coast Santo	10.88	24.61	28.29	14
2	2	3	2	gd11	East coast Santo	11.87	24.28	28.22	15
8	7	3	1	ms44	CE Santo	9.95	24.7	28.12	16
2	12	3	3	ms53	S& SE Santo	9.71	24.74	28.1	17
3	3	2	3	mt29	Maewo	11.12	24.34	28.07	18
2	4	2	6	ms44	CE Santo	10.27	24.53	28.04	19
2	14	3	5	ms55	S & SE Santo	11.09	24.1	27.82	20
5	20	3	1	ms44	CE Santo	10.68	24.08	27.69	21
6	15	1	4	ms32	East coast Santo	9.91	24.15	27.55	22
4	12	2	3	mt17	Central Pentecost	9.18	24.33	27.53	23
2	16	4	4	ms56	S& SE Santo	10.23	23.89	27.37	24
5	4	1	3	mt6	Central Pentecost	10.51	23.78	27.33	25
3	14	4	4	ms3	East coast Santo	9.44	24.06	27.32	26
3	12	4	4	ms51	S & SE Santo	9.88	23.7	27.08	27
7	12	3	2	mt8	Central Pentecost	10.74	23.45	27.06	28
2	17	4	6	ms5	CE Santo	10.5	23.44	26.98	29
4	11	1	5	ms53	S & SE Santo	10.87	23.33	26.97	30
1	7	4	3	ms17	East coast Santo	9.62	23.61	26.91	31
4	13	1	6	ms55	S & SE Santo	10.75	23.3	26.9	32
4	11	1	3	ms53	S & SE Santo	10.08	23.43	26.85	33
2	7	2	6	ms2	East coast Santo	10.52	23.22	26.76	34
3	9	5	1	gd11	East coast Santo	14.27	22.14	26.68	35
2	4	2	1	ms44	CE Santo	10.87	23.03	26.66	36
1	6	3	5	gd11	East coast Santo	13.74	22.26	26.66	37
5	14	2	6	gd7	East coast Santo	11.8	22.78	26.66	38
8	7	1	4	gd9	East coast Santo	10.11	23.19	26.61	39
5	8	4	2	Jt7	Teouma_Efate	10.12	23.14	26.57	40

Seeds for the IFP plantation provenance were collected from South Santo provenance, which in the whitewood family trial were averaged to have good height growth performance. The superior height growth in the IFP plantation progeny demonstrated that they are genetically superior for height growth in the provenance. This could be due to these genotypes being similar to their parents and being adapted to environmental condition (Narain 1990). On the other hand poor height may result from poor genetic make up and lack of adaptation to growing conditions (Young *et al.* 2000).

Table 3. Summary of the best family and provenance means of 4 years old whitewood and predicted estimates for various characters.

Sources	Height (m)	DBH (cm)	Volume (m^3)	Stock per Hectare (Trees/ha)	Volume per Hectare (m^3/ha)	Stand Basal Area (m^2/tree/ha)	Mean Annual Increment (m^3/ha/yr)	Prediction10 years (m^3/ha/yr)
Family	10.2	17.8	0.14	833	117	20.5	29.2	292
Provenance	9.2	16.3	0.12	833	100	17.4	25.0	250

4.2.2 MEANS (dbh)

Superior provenances for mean dbh were from the Central East Santo, South South East Santo, IFP Plantation and East Coast Santo. Most of the provenances with superior growth in dbh were from Santo and a narrow range dbh (16.1 - 16.8). Only one superior provenance was from South Santo while the other three provenances with superior dbh were from East Santo (Table 1). Other provenances with mean dbh that showed moderately good potential are Teouma Efate provenance and West Ambae. The lowest mean dbh provenances were from Maewo with 14.8 cm.

4.2.3 MEAN WOOD VOLUME

Superior provenances for the wood volume are the IFP Plantation from East Coast Santo, Central East Santo and South East Santo. Most of the provenances with superior volume growth were from East Santo. Other provenances with good wood volumes were Teouma (Efate), Uri Wiau (Malekula) and West Ambae. (Table 1). Identification of superior provenances of whitewood for wood volume is vital in tree improvement programs for the species (Lantican and Baldwin 1994).

4.2.4 MEAN SURVIVAL

Survival means showed different trend with the IFP Plantation, West Ambae and East Coast Santo provenances exhibiting high survival. Trees of West Ambae origin have performed significantly better in terms of survival percentage. Provenances with mean survival with potential were Forari (Efate) and Uri Wiaru (Malekula), South-East Santo and Central Pentecost (Table 1).

Provenances from Teouma (Efate), Maewo and Central East Santo showed poorest survival. Initial survival within a plantation stand depends on seedling quality, timing of planting to co-inside with high soil moisture, site maintenance and also the capacity of a provenance to stand adverse conditions such as dry periods. Later survival may depend on ability to withstand shading of weeds and vines, disease resistance and withstanding cyclones (Neil 1987; Chaplin 1993).

4.2.5 RANKING OF TREES IN THE TRIAL

An improvement program was undertaken. In the ranking of the whitewood trees an economic weight of 1 was given for height and 2 for dbh. because these are the two most important characteristics for total tree volume in that order. All the individual trees in the trial were ranked, with only the best 40 trees were listed and discussion is based on the best 5 trees. The best 20 trees out of 40 in the ranking originated from the islands of Santo, Efate and Maeow with numbers of trees, 17, 2 and 1 respectively (Table 2). The best 20 ranked trees were from East Coast Santo, Central East Santo and South-East Santo with numbers of trees, 9, 6, and 2 respectively. Other provenances have one tree each from Maewo, Teouma (Efate) and Forari (Efate). The best five trees in the ranking were from families MS2, MS3, MS2, MS44 and MS32 mostly from the East Coast and Central East Santo provenance. The best families have very good height ranging from 7.22 m to 12.98 m and dbh from 26.68 cm to 30.48 cm

Table 3 provides a summary of best families and provenances means at 4 years of age and predicted estimates. Best families and provenances showed relatively greater heights dbh, volume per hectare, mean annual increment and predicted forest product in 10 years (m^3/ha/yr).

Comparative studies on whitewood families and provenances clearly demonstrate that a large genetic variation is present for economic characters in this species. The best performing trees should be used to establish a whitewood improvement programme in Vanuatu. Similar model of study can be followed for other forest species in Vanuatu and other Pacific Island Countries.

ACKNOWLEDGEMENTS

Authors wish to thank the Department of Forests, Vanuatu and SPRIG to allowing the use of whitewood trial planted at Shark-Bay in Vanuatu.

REFERENCES

Barrance, A. J. 1986a. Cyclone damage to forest plantation in Vanuatu in January 1985: implications for species and forest management. *Forest Research Report* No. 4/85. Vanuatu Forest Service, Port Vila, Vanuatu, 31 pp.

Barrance, A. J. 1986b. The use of coppicing to regenerate cyclone damaged forest plantations. *Forest Research Report* No. 8/86. Vanuatu Forest Service, 12 pp.

Brown, A. H. D., Matheson, A. C. and Eldridge, K. G. 1975. Estimation of the mating system of Eucalyptus obliqua L'Herit by using allosyme polymorphisms. *Australian Journal of Botany* **23,** 931 - 49.

Burley, J. and Styles, B. T. 1976. Tropical Trees Variation, Breeding and Conservation. Breeding of tropical hardwoods: an evaluation of underlying bases, current status and future prospects. Department of Biology, University of Massachusetts, Boston, Massachusetts, 02125 U.S.A.

Carron, L. T. 1968. An Outline of Forest Mensuration with Special Reference to Australia. Australian National University Press, Canberra, 11 pp.

Casey, J. H. 1993. The Santo Industrial Forest Plantation Project. A Possible Role for Farmars. *Pacific Islands Forest & Trees*. No.1/93. SPC, Suva, 6-8.

Chaplin, G. E. 1993. Silviculture Manual for the Solomon Islands. ODA. Natural Resources Institute, London,U.K.

Clark, W. C. and Thaman, R. R. 1993. *Agroforestry in the Pacific Islands systems for sustainability*. United Nations University Press. Tokyo.

Cotterill, P.P. and Dean, C. A. 1990. *Successful Tree Breeding with Index Selection*. CSIRO Melbourne.

Eldridge, K. G., Davidson, J., Harwood, C. E. and VanWyk, G. 1993. Eucalypt *Domestication and Breeding. Clarendon*, Oxford, UK.

Hodge, G. R. and William, S. D. 1999. *Genetic Parameters and Provenance variation of Pinus tecunumanii in 78 International Trials*. CAMCORE, North Carolina..

Lantican, C. B. and Baldwin, J. A. 1994. Training Notes on Design and Analysis of Forestry and Experiments. For Research Methods Training Course for Pacific Island Countries. RAS/92/361. Field Document No. 4. UNDP/FAO, 140 pp.

Namkoong, G. 1979. Introduction to Quantitative Genetics in Forestry. Technical Bulletin No. 1588, Washington, 1-3.

Narain, P. 1990. *Statistical Genetics*. Wiley Eastern Limited. New Delhi.

Neil, P. E. 1987. Cyclone Uma and damage to southern forests. *Forest Research Report* No. 1/87. Forest Service Vanuatu, 19 pp.

Oliver, W. W. 1999. Update on Plantation Forestry. *Pacific Islands Forest & Trees*. No.3/99. SPC, Suva, 3pp.

Philip, M. S. 1994. *Measuring Trees and Forests*. University Press, Cambridge. UK, 36 - 50.

Sam, C. 1997. Information for the developing a conservation strategy for *Endospermum medullosum*. Forest Conservation Unit, Department of Forests, Vanuatu.

Sedgley, M. and Griffin, A. R. 1989. *Sexual Reproduction of Tree Crops*. Academic Press. London, UK.

SPRIG Report. 2000. Assessment of Whitewood (*Endospermum*) Family Trial in Vanuatu. Pacific Islands Forest & Trees. No.4/01. SPC, Suva, 8-9.

Thomson, L. and Uwamariya, A. 1998. *Endospermum medullosum* L.S.Smith, Notes on taxonomy and Nomenclature. SPRIG MS Access 2000 Database of Pacific Islands Forest and Tree Genetic resources.

Vanuatu Forestry Department Report 2000.

Williams, E. R., Matheson, A. C. and Harwood, C.E. 2002. *Experimental design and Analysis, for tree Improvement*. CSIRO Publishing, Victoria, Australia, 59 pp.

Young, A., Boshier, D., and Boyler T. J. 2000. *Forest Conservation Genetics*. Principles and Practices. CSIRO. Australia.