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Sandalwood Research Newsletter

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EDITOR'S NOTE

This edition brings together an article on mass cloning of sandal, a note on the establishment of PNG sandal in Western Australia and another article from Timor Island, this time concentrating on seed resource supply (Page 3). A number of authors over time continue to highlight the decline in native forest resource of Santalum album worldwide, concluding that artificial plantations are needed to ensure conservation and maintain resource supply. In order to establish viable and high yielding plantations, seed supply from known provenances is essential. Setiadi & Komar describe the program that is in effect in West Timor to establish high quality plantations. Such sandal tree improvement programs are progressing in many countries to supply high quality, disease free plantations. India, Indonesia, Sri Lanka and Australia have adopted similar procedures for identifying candidate plus trees from which seed is selected. Provenance trials have been initiated in these and many other localities.

Another alternative is the reproduction of large numbers of sandal with specific attributes through biotechnological approaches such as tissue culture. Somatic embryogenesis is a proven method for rapid micro-propagation of sandal as the article by Dr Dey (Page 1) shows. Somatic embryogenesis is the development of plantlets from embryos created from callus cells. Dr Dey describes the method and advantages of mass cloning of S. album using bioreactors. Any individuals interested in collaborative research on mass cloning of S. album or other Santalum species is invited to contact Dr Dey, details are listed on the back page.

The final article reports on the preliminary findings of an ex situ conservation planting of Santalum macgregorii in north Western Australia, which it is hoped will yield useful information for the conservation and regeneration of this species in its native environment.

Once again, individuals are encouraged to utilise the SRN to expand contacts, seek information and advertise books, conferences and workshops relevant to Santalum conservation and management. On page 6 we have listed details of an important tree and nut crops conference, Acotanc 2001, held at the University of WA, Perth in April. A series of mini-conferences were organised, one concentrating on Quandongs and Sandalwood. Although the conference will be over by the time this newsletter is distributed, we have included the details and encourage individuals to contact David Noel at the Tree Crops Centre for conference proceedings (+61-8-9388-1965, fax: +61-8-9388-1852, website: www.AOI.com.au/acotanc).

Articles for publication, questions, comments and feedback are welcome and should be received for the next edition by July 31st 2001. I hope you enjoy this edition.

Tanya Vernes

Mass cloning of *Santalum album* L. through somatic embryogenesis: scale up in bioreactor.

Dr S. Dey

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Santalum album L., the East Indian Sandalwood, enjoys acceptance worldwide because of the unique fragrance in it's oil and wood. The natural propagation of this important plant faces twin threats – spike disease and poaching. Regeneration by silvicultural methods being insufficient to meet the demand, several biotechnological routes of propagation has been tried. Somatic embryogenesis offers highest clonal propagation efficiency. Scale up in air-lift bioreactor improves embryo quality, saves laboratory space and minimizes incubation time as well as production cost.

Introduction

Santalum album L., the East Indian Sandalwood, is among the oldest known perfumery material and is highly acclaimed worldwide. Its use in toiletries was mentioned in Buddhist Jataka Stories in 7th Century BC (Srinivasan *et al* 1992). It is regarded to be native to Peninsular India and is deeply connected with many events of rich cultural heritage in this country. It is distributed within about 9600 km^2 in India, mainly in two southern states Karnataka and Tamil Nadu.

Owing to its unique persistent sweet and woody fragrance, its heartwood oil is widely used in internationally reputed brands of perfumes. The heartwood is commercially important, its close grains making it high quality wood for carving in fabricating costly handicraft items that are fragrant, elegant and are largely self-protected from termites and wood-borers. The average annual Indian export is about 2000 tonnes of wood and 100 tonnes of oil (Gupta 1998). The demand is ever increasing but the supply is decreasing gradually. This alarming situation has cropped up due to dual factors – loss of significant number of mature plants by spike disease and illegal cutting.

The replenishment by conventional silvicultural methods of vegetative propagation and by seed propagation was not very helpful because the former was slow and the latter resulted in heterozygosity in the population. Biotechnological methods of clonal propagation are thought to be the acceptable alternative. Plant biotechnological studies have been carried out for nearly four decades (Rangaswamy & Rao 1963, Lakshmi Sita 1986, Mujib *et al* 1998).

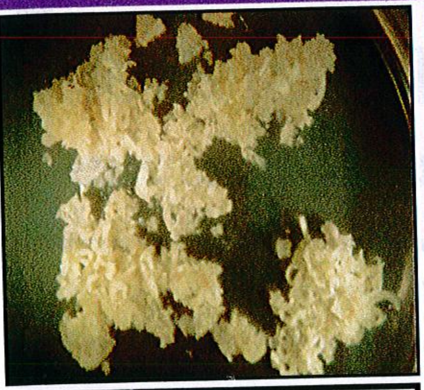

Fig. 1: Embryogenic cell mass

In view of the poor plantlet production efficiency via multiple shoot formation, followed by rooting, somatic embryogenesis is a much more efficient process for mass cloning through somatic seedlng production. Somatic embryogenesis in solid medium displayed the following problems -

- very high asynchrony in somatic embryo development
- frequent developmental abnormalities.
- multiple embryo clumpling
- much lower somatic seedling production potential of embryogenic cell mass.

Somatic embryo production in bioreactor was shown to improve the situation (Bapat *et al* 1990). Our laboratory has been investigating (Das *et al* 1998; Das *et al*, 2001) on this aspect for nearly a decade, with the major objective of scale up of the process of cultivation in bioreactors, for developing sandalwood plantation in non-traditional areas (e.g., West Bengal, Assam). Major part of the work has been done in collaboration with a reputed plantation industry, under a Technology Development Mission Project. A highlight of the methods and results is presented here.

Materials and methods

Embryogenic cell mass (Figure-1) was produced by growing callus in the presence of indole acetic acid (0.5ppm) in MS (Murashige & Skoog 1962) agar medium for about 3 weeks. Somatic embryos were produced in bioreactor (Eyela; 12 litres air-lift type) by inoculating embryogenic cell mass @10gms per litre medium (MS medium with 3% sucrose; 0.5 ppm benzyl adenine), incubated for 4 weeks. Mature somatic embryos, produced in bioreactor, were germinated in Petri plates containing MS solid medium with 3% sucrose, 0.1 ppm gibberellic acid and 0.1 ppm benzyl adenine. These somatic seedlings, after hardening for 2 months in a green house, were transferred to the field.

Results and Discussion

Specific somatic embryo production efficiency (number of morphologically normal mature embryo produced per gram of embryogenic cell mass) improved drastically (8-20 times, depending on culture conditions) as a result of cultivation in bioreactors (Figure-2).

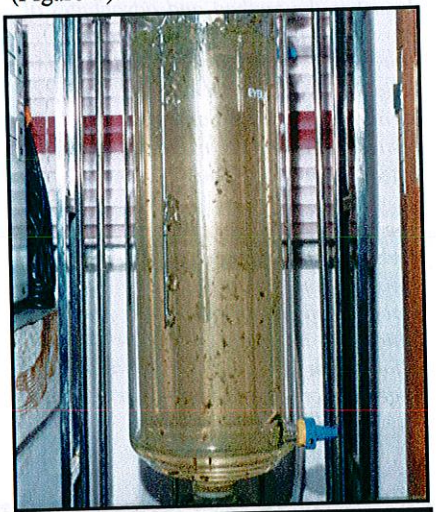

Fig. 2: Somatic embryo production in bioreactor

In every batch a minimum of 2 weeks time was saved. Developing embryos (Figure-3) were more synchronous and minimally clumped (Das *et al* 1999).

Fig. 3: Somatic embryo harvested from bioreactor

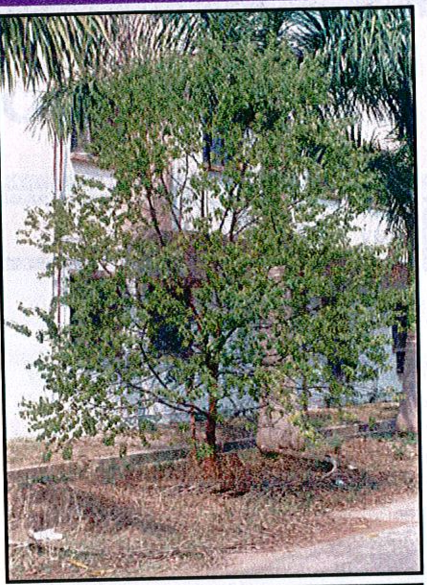

Fig. 4: A five year old plant

This dramatic improvement is due to desirable agitation and uniform access of embryos to the medium. The somatic seedlings are now growing in field conditions in their 5th year (**Figure-4**). The bio-process saves time, minimizes production cost per somatic seedling (one third to one fourth) and requires less space (nearly one–third) during embryo maturation. Certain problems exist due to developmental abnormalities in the somatic seedlings. Subsequently, the survival during green house hardening and field adaptation reduces. The anatomical and molecular biological reasons for such abnormalities are under probe in our laboratory. A solution to such problems will make the process viable for commercial agro-forestry. The process should be applicable to other species of sandalwood. The author proposes collaboration with scientists/industries in other countries for the application of the above bio-process for *in vitro* mass propagation of other species of *Santalum*.

References

Bapat, V.A., Fulzele, D.P., Heble, M. R. & Rao, P.S. (1990). Production of somatic embryos in bioreactors. Current Science, 59: 746-748.

Das, Surajit., Das Susobhan., Mujib, A., Pal, S. & Dey, S. (1998). In fluence of carbon source and pH on rapid mass propagation of *San talum album* by somatic embryo genssis: the application of biotech nology in agro-forestry. *In*: Ra domiljac, A.M., Ananthapadma nabha, H.S., Welbourn, R.M. &

Satyanarayana Rao, K. (Eds). San dal and Its Products. ACIAR pro ceedings No 84, Canberra, pp66-68.

Das Susobhan., Das Surajit., Pal, S., Mujib, A., Sahoo, S. S., Dey, S., Ponde, N. R. & Dasgupta, S. (1999). A novel process for rapid mass propagation of *Santalum al bum* L. in liquid media and biore actors. In: Giberti, G. (Ed) Proc. WOCMAP-2. Acta Hort. 502 (ISHS): 281-288.

Das, Susobhan., Ray, S., Dey, S. & Dasgupta, S. (2001). Optimisation of sucrose, inorganic nitrogen and abscisic acid levels for *Santalum album* L. somatic embryo production in suspension culture. Process Biochemistry (accepted).

Gupta, B.N. (1998). In: Radomiljac, A.M. *et al* (Eds). Sandal and Its Products. ACIAR proceedings No 84, Canberra.

Lakshmi Sita, G. (1986). Sandalwood (*Santalum album* L.) In: Bajaj, Y. P.S. (Ed) Biotechnology in Agriculture & Forestry: Trees I. Springer, Berlin, pp 363-374.

Mujib, A., Pal, S. & Dey, S. (1998). Biotechnological routes of mass propagation of *Santalum album L. In*: Khan, IA & Khan A. (Eds) Role of Biotechnology in Medicinal and Aromatic Plants. Ukaaz Publication, Hyderabad,pp. 83-94.

Murashige, T. & Skoog, F. (1962). A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiol. Plant., 15: 473-497.

Rangaswamy, N. S. & Rao, P.S. (1963). Experimental studies on *Santalum album* L.: Establishment of tissue culture of endosperm. Phytomorphology, 13: 450-454.

Srinivasan, V.V., Sivaramkrishnan, V. R., Rangaswamy C.R., Anantha padmanabha, H.S. & Shankaranarayana, K. H. (1992). Sandal (*Santalum album* L). In dian Council of Forestry Research and Education, Dehra Dun, p.1.

Current Sandalwood Seed Source in Timor Island

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Sandalwood (Santalum album Linn) is one of the native species to East Nusa Tenggara which has high economic value. Effort has been put to increase its productivity, especially through artificial plantation since its natural regeneration success is very low. Artificial regeneration is the only alternative to overcome the shortage of raw material for various wood-base industries as well as for the production of santalol.

Introduction

The reduction of sandalwood population in West Timor and probably in other islands has reached the alarming rate. Based on a recent inventory (1997/1998) conducted by local Forest Service, the reduction has reached 53.96% from the previous inventory (1987/1990) as shown in Table 1.

To promote the success of artificial regeneration program, the availability of the information on seed supply, seed source, germination and seedling growth is very critical. Since the provision of seed and seedling stocks is a primary critical activity in plantation establishment. In this paper we describe the present status of seed source, seed germination and seedling growth of Sandalwood in East Nusa Tenggara, especially in Timor island extracted from recent research results.

Seed Source

There are several types of seed sources available for Sandalwood, each has a different level of silvicultural treatment and management.

1. Seed Production Area

Several Seed Production Areas (SPA) have been determined from four visually selected seed sources in Timor island based on their seed quality (Effendi *at al* 1995). Based on seed quality, the seed source of Leloboko, South Central Timor, produces better quality seeds and higher survival rates at seedling stage (see Table 2). Whereas seeds collected from Biboki Selatan were poor and seeds from Biloto performed the poorest in seedling survival. However, at the present time, seed collection is carried out from those seed sources for various purposes.

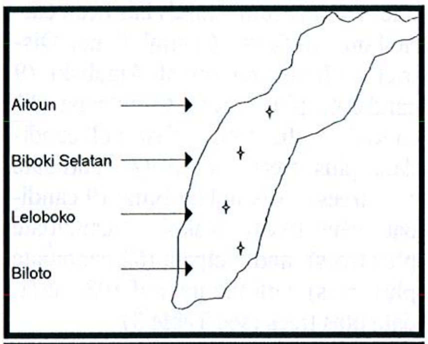

Figure 1: Locations of four identified Seed Production Areas in West Timor

2. Candidate Plus Trees

In order to improve forest productivity through a National tree improvement program, seeds with high genetic quality should be used for plantation establishment.
The tree improvement program for *S. album* has been in the stage of identification and selection of candidate parent (plus) trees to be used for provenance trial and seed orchard establishment. The selection of plus

Table 1: Current Sandalwood population in West Timor Island

No.	Districts of West Timor Island	1987/1990	1997/1998
1.	Kupang	27 590	13 182
2.	South Central Timor (SCT)	234 020	112 710
3.	North Central Timor (NCT)	107 501	34 078
4.	Belu	135 841	90 970
	Total	**504 952**	**250 940**

Source: Laporan inventarisasi Cendana (*S. album*) di Pulau Timor. Dinas kehutanan Prop. NTT. 1998

Table 2: The performance of seeds and seedlings from four seed sources

No	Locations	Germinations (%)	The avg. of height (cm)[1]	The avg. of dia. (mm)[1]	Top-root ratio[1]	Seed Survival
1	Leloboko (SCT)	56,67	22,03 ab	2,93 a	0,45	94,26
2	Aitoum (NCT)	50,33	25,67 a	3,07 a	0,30	82,77
3	Biloto (SCT)	45,33	15,87 b	2,31 b	0,34	72,65
4	Biboki Selatan (NCT)	44,67	24,31 a	2,85 ab	0,27	78,39

Source: Effendi *et al* 1995, evaluated after 6 months.
Similar letter indicates non-significant difference

trees from natural stands has been carried out in South Central Timor District with the region of Ajaubaki (9 candidate plus trees), Oenutnana (11 candidate plus trees), Siso (11 candidate plus trees), Buat (4 candidate plus trees), Amanuban Barat (9 candidate plus trees), Kakoi (3 candidate plus trees), and Netpala (62 candidate plus trees) with the total of 108 candidate plus trees (see Table 3).

The selection for candidate plus trees were carried out based on traits, such as the presence of heartwood, height, diameter at breast height, clear bole, crown and tree free from the incidence of pest and disease. The production of santalol (chemical extracted from the heartwood) is not yet included in the criteria due to some technical difficulties. Seeds from these selected candidate plus trees have been used for progeny trials.

3. Progeny Trials

A progeny trial of first generation from candidate plus trees has been established in Netpala, District of South Central Timor. Results based on the evaluation in 1997 (Effendi *et al* 1997) indicate the average height of 128.75 and 310 cm with diameter of 1.61 – 5.68 cm. At that age (size), most of the trees have been flowering and fruiting. The population of first generation progeny trial could be used as seed source regardless the value of the genetic gain.

Phenology

Study on phenology of sandalwood has been carried out in four different locations representing altitude ranging from 650 m to 1180 m above sea level. Flowering time differs according to altitude (Susila *et al* 1995) with sandalwood growing in low altitudes flowering about one month earlier than those growing in higher altitude (Netpala). This result is in agreement with Hartman & Kester (1975) that the higher the altitude, the slower the flower initiation.

The age of first flowering recorded is after 4 to 5 years, but the viable seeds are obtained after the tree has produced sufficient heart wood

In Timor island sandalwood flowers and fruits from once to twice a year with little variation between populations or individuals. The age of first flowering recorded is after 4 to 5 years, but the viable seeds are obtained after the tree has produced sufficient heart wood. Floral initiation for first season takes place in September – October and the second season (peak season) occurs in November. Fruiting occurs in February through April.

Seed Collection, Extraction and Storage

Seed maturation are mostly indicated by fruit color. Seeds are usually collected when the color of the fruit is brown or nearly black. Fruit are collected directly from the crown by climbing or using long sticks or a bamboo ladder. Seeds collected from the ground with unknown fruit set are mostly poor in quality, especially due to fungal and animal attacks.
Prediction of seed production based on crown dimension reveals that crown size especially length, has positive correlation to fruit production, the larger the crown size the higher the seed production. Height and diameter have negative correlation for which the taller and the bigger the stem diameter the lower seed and fruit production (Susila *et al* –1995).

Seeds are extracted manually by hand and washed directly in fresh water. Immature fruit are not extractable and or produce low quality seeds. After extraction seeds are completely cleaned. Unclean seed could invite fungal attack that causes a decline in seed quality.

After air drying seed moisture content remains relatively high. Prior to storage seeds should be air dried in shade area until the moisture content is approximately 5 – 8 % (fresh weight basis). Direct sun drying should be avoided since the results of observation indicates that direct sun drying causes a significant reduction in seed viability.

Air dried seeds must be stored in cold

Table 3: Physical appearance of candidate plus trees

Locations	No. of candidate plus trees	Height (m)	Diam. (cm)	Clear bole (m)	Crown length (m)	Crown diam. (m)	Heartwood diam. (cm)
Ajaubaki	9	14.8	24.8	3.94	8.98	8.04	17.56
Oenutnana	11	12,95	18,83	4,73	6,08	6,11	11,81
Siso	10	10,87	23,06	2,94	5,12	6,56	11,53
Buat	4	13,98	27,44	3,58	5,29	9,96	17,11
Amanuban Barat	9	12,62	33,76	2,52	5,96	7,33	22,94
Koki	3	11,13	30,30	2,47	6,13	9,99	21,63
Netpala	62	10,62	32,66	2,93	4,23	10,49	24,58
Jumlah	108						

Source: Effendi 1993

temperature in refrigerator of about 4 ^{0}C after placing in a plastic bag. Using this method, seeds could be stored for a relatively long period with relatively higher viability . Seed weight of individual seed ranges from 0.120 – 0.179 gram or 5.586 – 8.333 seeds per kilogram (Effendi & Sinaga 1994).

Seed Germination

Several findings on sandalwood seed germination are obtained from research activities in Timor. Physical pretreatment to promote germination has been observed. Seed were uncoated and pin-holed to promote the entry of water to initiate germination. Seed soaking into various water condition (cold, hot) indicates significant results to promote germination (Effendi *et al* 1995). Various germination media have been trialled for which sand was found to be the better medium for germination of sandalwood seeds (Surata 1987).

Seeds collected from Timor island are relatively poor in quality with average viability less than 60 %. The viability is highly variable between individuals observed from 67 individual trees with germination percentage ranging from 9 to 64 % (Effendi & Surata 1993). The variability also exists between populations observed in Timor island that ranges from 20 % to 55 % (Brand 1993, Susila *et al* 1995).

The low viability (low germination %) sandalwood seeds observed in Timor island is suspected to be due to inbreeding depression. This is because, most sandalwood trees growing in Timor island are solitary or form small and scattered populations with limited number of individuals per population. To obtain high quality seed and to minimize the results of inbreeding, seeds should be collected from artificial, compact and determined seed sources with proven quality.

References

Brand. J.E. (1993) Phenotype and genotype variation within *Santalum album* in West Timor. Thesis for degree of master of Science in Biology, Curtin University of Technology (Unpublished)

Effendi. M. dan I. K. Surata. (1993) Uji Keturunan Cendana (*Santalum album*) Variasi dalam benih dan bibit. Santalum 12. 1-10

Effendi. M. dan M. Sinaga. (1994) Pengaruh ukuran benih terhadap pertumbuhan bibit cendana (*Santalum album*). Santalum 15. 15-24

Effendi. M. I., Rachmawati. dan U.R. Fauzi (1995). Identifikasi sumber benih cendana (*Santalum album*) di Nusa Tenggara Timur dan Yogyakarta Santalum 17. 20-27

Effendi. M. dan I. Rachmawati. (1997). Perkembangan penelitian produksi benih unggul cendana (*Santalum album*) di Nusa Tenggara Timur dan permasalahannya Prosiding/Ekspose Hasil-hasil penelitian BPK Kupang

Hartmann. H.T. & D.E. Kester. (1975) Plant Propagation Principles. Prantice-Hall. New Jersey

Surata IK (1992). Perkembangan penelitian pembibitan dan penanaman cendana di Nusa Tenggara Timur. Makalah disampaikan pda seminar Nasional tentang status Silvikultur di Indonesia saat ini. Universitas Gajah Mada, Yogyakarta.

Susila. I. W. M. Effendi dan M. Sinaga. (1995) Studi fenologi dan kualitas benih cendana (*Santalum album*) di Nusa Tenggara Timur. *Santalum* 19. 1-8.

Preliminary results from Santalum macgregorii ex situ conservation planting

Tanya Vernes

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The following reports preliminary results, up to age nine months from a flood irrigated plantation trial of Santalum macgregorii on Cunumurra clay soils near Kununurra. At nine months of age S. macgregorii is exhibiting good survival and growth and although it is less than Santalum album on the same site in a similar plantation design, it is still encouraging.

Introduction

Collecting seed for *ex situ* gene conservation is an increasingly common practice. This approach can complement *in situ* conservation efforts by providing long-term security for a species and its genetic variability in locations removed from threats in their native habitat. Conservation of germplasm of all commercial sandalwood species has been a major concern in many sandalwood growing countries (Thomson & Bosimbi 2000). Over a number of years CALM has established a variety of *Santalum* plantings to ensure conservation of genetic diversity including *Santalum album* from a range of locations in India, Timor and Australia, *Santalum austrocaledonicum* from New Caledonia and *Santalum macgregorii* from Papua New Guinea.

New Guinea Sandalwood

Santalum macgregorii is considered to be scarce in its natural distribution, with existing pressures of wildfire and overexploitation threatening it survival (Paul 1990). *Santalum macgregorii* is endemic to south-western Papua New Guinea, occurring in remote, relatively inaccessible regions in the dry evergreen savannah forest and grassland in a restricted range of its former distribution (Radomiljac & Bosimbi 1999). Some reasonably intact stands still exist in the Central and Gulf provenances, however unless a conservation and management strategy is developed these may be threatened by encroaching development into these otherwise inaccessible regions (Thomson & Bosimbi 2000). Relatively little is known of *Santalum macgregorii* in its native habitats in PNG (Paul 1990). Thomson and Bosimbi (2000) have recently compiled information on the species as part of a CSIRO/PNG Forest Research Institute/ACIAR project "Domestication of Papua New Guinea's Indigenous Forest Species" and as a prelude to development of a conservation strategy for the species.

Collections of *S. macgregorii* were made by the PNG Tree Seed Centre (PNG FRI) as part of a CSIRO/SPRIG project which resulted in the collection of seed from a range of rare and often endangered *Santalum* species of the South Pacific. *S. macgregorii* seed has been distributed for silvicultural trials and *ex situ* conservation in Australia (Queensland and Western Australia) and the Pacific (Thomson & Bosimbi 2000).

A Silvicultural System for New Guinea Sandalwood

A key to the conservation and survival of *Santalum* lies in its potential as a highly valuable plantation species. For this reason, *S. macgregorii* was planted under a flood irrigated system near Kununurra on clay soils to assess growth and yield in a silvicultural system similar to the successful *S. album* plantation design in use in the region (Radomiljac & Vernes 1998).

In early October 1999 2 kg of *Santalum macgregorii* seed obtained from ATSC was germinated at the CALM research nursery, Kununurra. Seed was derived from a bulk collection in 1998 from Iokea Village. Poor germination (2%) yielded 154 germinants which were pricked out into 1.4 litre pots over the 17 week germination period. QRFI experienced a somewhat higher germination rate of 9% (Thomson pers com.) from the same seed batch sowed in mid 1998 (Taylor *et al* 2000).

After a four week hardening off period in the nursery, seedlings were planted in late July 2000 on cracking clay soils under flood irrigation at the Frank Wise Institute of Tropical Agricultural Research, Kununurra. Sandal was planted at a stocking rate of 174 stems/ha, with intermediate hosts at 348 stems/ha (*Sesbania formosa*) and long term hosts at 696 stems/ha (*Acacia auriculiformis, A. crassicarpa, Cathormion umbellatum)* for a total stocking of 1218 stems/ha. The intermediate and long term hosts were chosen for their ability to fix nitrogen (see Radomiljac *et al* 1999, Brand *et al* 2000), and *A. auriculiformis* was chosen as a host as it grows in association with *S. macgregorii* in riparian areas in PNG (Thomson & Bosimbi 2000). As a multispecies plantation with a diversity of products at harvest, the *Acacia* hosts were also chosen for their high value timber qualities.

Immediately after planting the area was oversprayed with pre-emergent herbicide and watered. Watering frequency occurred every 7 days until the wet season (late November 2000) when flood irrigation ceased due to natural rainfall. Watering recommenced on 12th April 2001 and has been undertaken monthly ever since.

Fig.1: Variation in *S. macgregorii* seedlings at time of planting

Table 1. Average growth statistics of *S. macgregorii*

Age*	Height (cm)	Diam. (mm)	Survival (%)
10 months	48.8	4.9	97.4
18 months	85.9	12.3	75.5

The height and diameter of seedlings was assessed at the time of planting (Figure 1) and eight months following field establishment. Table 1 shows the average growth statistics of *S. macgregorii.*

The potential of PNG Sandalwood

To date, *S. macgregorii* has exhibited good early growth and moderately high survival in a flood irrigated system on clay soils in north Western Australia. Although growth is slightly slower than *S. album* on the same site and with similar growing conditions, the potential of *S. macgregorii* is not far behind the much better known species (Figure 2 & 3). Due to the rarity of *S. macgregorii* all seedlings raised in the nursery were planted, however this meant that some were less optimal and subsequently a higher mortality in the field was experienced.

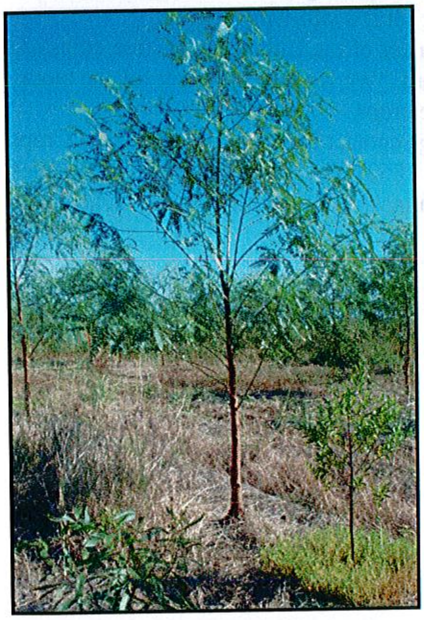

Fig 2: *S. macgregorii* with hosts *Alternanthera nana, Sesbania formosa* and *Acacia auriculaformis* in foreground

S. macgregorii produces a highly valuable aromatic heartwood, its value evident by the overexploitation that has led to the depletion of most natural stands. The quality of oil requires further analysis as the only two tests on oil composition reported in the literature show conflicting results (90% santalol compared to 45%) (Thomson & Bosimbi 2000). The oil yield is reported to be 3-5% (Paul 1990) and requires wider sampling for verification. Even a slightly lower oil yield of 2-3% (such as for Santalum spicatum which attracts a price of AUS$6000/tonne) could produce a substantial export income for local industry. Markets exist for *S. macgregorii* in Hong Kong, Singapore and Japan (Paul 1990) and although prices paid are low, a successful and sustainable marketing strategy could increase prices paid to reflect their true value.

Santalum has a well established market in south-east Asia, the middle east and recently in Australia to which *S. macgregorii* could be added.

Conclusion

Natural regeneration and plantation development in PNG have been recommended for the conservation of *S. macgregorii* whilst simultaneously ensuring a sustainable resource is established for the generation of rural income.

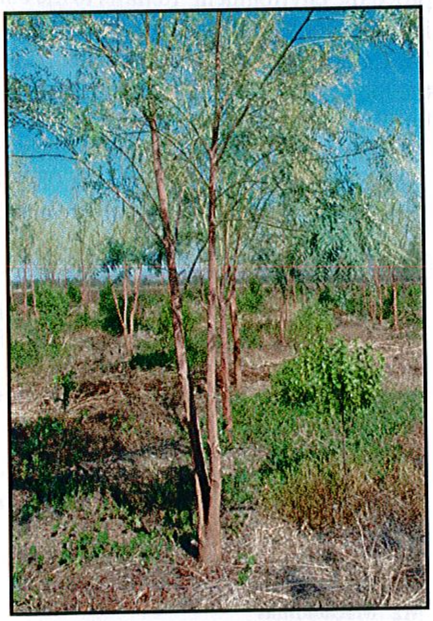

Fig.3: *S.album* with hosts *Alternanthera nana* and *Sesbania formosa* planted at the same time as *S. macgregorii*

Although the data presented here are fairly preliminary, they show encouraging results for the establishment and early growth of *S. macgregorii* on flood irrigated clay soils in a promising multispecies plantation design. This trial adds to information yielded from other *S. macgregorii* silvicultural trials in the Pacific to assist in developing a successful and transferable silvicultural system for *S. macgregorii* plantation development. Long term data on height, growth, survival and oil quality and yield is ongoing and will be collected and published at a later date.

Acknowledgements

Appreciation to Dr. Lex Thomson, Australian Tree Seed Centre, CSIRO, for reviewing the draft paper

References

Bosimbi, D. (1997) Sandalwood development in Papua New Guinea. A progressive report on recent activities. Unpublished report of National Tree Seed Centre, Division of Reforestation and Extension, Papua New Guinea Forest Authority, Bulolo, PNG.

Brand, J. E., Crombie, D. S. Mitchell, M. D. (2000) Establishment and growth of sandalwood (*S. spicatum*) in south-western Australia: the influence of host species. Aust. Forestry 63 (1) 60-65.

Paul, J. H. (1990) The status of sandalwood (*S. macgregorii*) in Papua New Guinea. In: Hamilton, L. & Conrad C. E. (eds.) Proceedings of the symposium on sandalwood in the Pacific, April 9-11, 1990, General Technical report PSW-122, Pacific Research Station, Forest Service, US Department of Agriculture, Honolulu, pp76-78.

Radomiljac, A. M. (1997) Sandalwood nursery and plantation workshop, Port Moresby, Papua New Guinea, November 8-14 1996. Unpublished report, Department of Conservation & Land Management, Kununurra, Western Australia.

Radomiljac, A. M., McComb, J. A. & McGrath, J. F. (1999) Intermediate host influences on the root hemi-parasite *Santalum album* L. biomass partitioning. Forest Ecology and Management 113: 143-153.

Radomiljac, A. M. & Bosimbi, D. (1999) *Santalum macgregorii* F. v. Mueller in Papua New Guinea. Sandalwood Research Newsletter, Issue 8, p. 5, Department of Conservation & Land Management, Western Australia.

Radomiljac, A. M. & Vernes, T. (1998) *Santalum album* data sheet. CABI electronic forestry compendium.

Taylor, D., Swift, S. & Collins, S. (2000) Testing growth and survival of four sandalwood species in Queensland. Sandalwood Research Newsletter, Issue 10 pp6-8, Department of Conservation and Land Management, Western Australia.

Thomson, L. & Bosimbi, D. (2000) *Santalum macgregorii* – PNG sandalwood. Unpublished paper prepared for CSIRO/PNG Forest Research Institute/ACIAR project entitled Domestication of papua New Guinea's Indigenous Forest Species. Australian Tree Seed Centre, CSIRO Forestry and Forest Products, Yarralumla, ACT.

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If you would like to contribute an article to the SRN or wish to be included on the SRN mailing list, please send details to the Editor stating your name, title, position, organisation, postal address, telephone, fax and email address.

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Acotanc 2001
More than just a tree crops conference

A big international tree crops conference in Perth this Easter is predicted to be a major watershed for WA and the Australasian region. Acotanc-2001, the Ninth Australasian Conference on Tree and Nut Crops, is being staged at the University of Western Australia from April 13 to 20.

"This is the first time Acotanc has come back to WA since the very first Acotanc, in 1982", said David Noel, the conference coordinator.

"The last 19 years have seen a revolution in land use in WA", he commented. "In 1982, our use of perennial plant crops was very minor. Since then, we have seen a surge in the development of new crops and industries. For example, grapes, avocados and mangos were rare curiosities, and many people had never seen a macadamia or a pecan nut", Mr Noel said. "Now they are part of everyday life."

As well the growth in these new products, Mr Noel said he had been heartened by increasing appreciation of how tree crops can improve the environment and solve land-use problems, and still make money for the land user.

"Our whole landscapes are changing with tree crops ", he said. "Agroforestry has given new hope to farmers struggling with low returns from traditional lines and battling unfavourable weather events."

"For the wider community, these changes make possible a shift out of logging old-growth native forests and the building of land-use industries which actually improve the environment. Returns to the community are greater and the growing stock is stable, robust and unfazed by bad weather. It is a win-win situation".

"In California, the leading agricultural producer of the United States, tree crops are the major player in agriculture", Mr Noel said. "We have been slower off the block, but WA could become a world leader in tree crops.

For information and conference proceedings contact David Noel at the Tree Crops Centre (phone 08-9388 1965, fax 08-9388 1852) or Conference Manager Monica Durcan (08-9291 8249). Details are also available from www.AOI.com.au/acotanc.

Mini-Acs and codes

A2 Almonds
A4 Australian Native Plant Foods ("Bush tucker")
B2 Beverages from Plants (eg green tea, coffee, wine)
C7 Chestnuts
D3 Dry-Country Fruits and Nuts (eg cactus fruits, jujube)
F8 Figs
F3 Forest Products Including Timber
H3 Handling Pests, Diseases, and Weeds (eg Integrated Pest Management)
H6 Harvesting and Post-Harvest in Tree Crops
H I Hazelnuts
I9 Industrial Oils and Plant Essences (eg eucalypt, jojoba)
L5 Land and Environment Improvement
M2 Macadamias
M4 Medicines from Australian Plants
M9 Multi-purpose Tree Crops
N2 Neem
N7 New Approaches to Traditional Fruits (eg stonefruit, citrus, pomefruit)
N3 Non-Timber Forest Products (eg resins, mushrooms, cork, rubbers)
01 Olives and Tree Oils
08 Organic Approaches in Tree Crops
P5 Paulownia
P I Pecans
P2 Permaculture and Tree Crops
P3 Pistachios
P4 Pollination and Tree Crops
P6 Propagation and Tree Crops
Q3 Quandongs and Sandalwood
S8 Site Planning and Management for Tree Crops
S2 Specialist and High-Value Timbers
S9 Salinity and Tree Crops
Tl Tropical Fruits and Nuts
U3 Unusual Temperate Fruits and Nuts (eg blue honeysuckle)
V9 Vetiver, Ground Covers, and Orchard Practices
W5 Walnuts
W9 Water and Tree Crops (water harvesting, irrigation)