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Nutrition Studies on young Sandalwood seedlings in the absence of hosts

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Nutritional requirements for growing *Santalum album* (Indian sandalwood) are poorly understood, partly because of the inherent difficulties of studying root parasites and interpreting the results. Hosts are suggested as the source of Ca and Fe; N and P; K, P and Mg; K, Ca, Mg, Cu and Zn by various researchers. Work on *S. spicatum* (Western Australian sandalwood) and other parasitic plants suggests diverse and variable host contributions.

Research workers in the Mulga Research Centre at Curtin University performed nutrient omission studies to determine the response of unattached (pre-parasitic) *S. album* seedlings to deficiencies of five nutrient elements (N, P, K, S and Ca) in the growing medium. They looked at the effects in terms of morphological attributes, chlorophyll levels and mineral content. Information about seedling development from seed reserves was obtained by withholding all nutrients from one set of seedlings. Fully fertilised seedlings were used as a control. Nut kernels were also analysed. A photographic record was also kept.

The range in measurements of seed (fleshy part removed) used was 5.32±0.42 mm (diameter); 147±19 mg (mass). The average kernel mass was 110 mg. Two hundred and fifty six seedlings were germinated for the trial. The nut was held by the cotyledonous suspensors after germination for between 32.8±12 days with no significant variation between treatments.

The study showed that sandalwood is able to obtain minerals via its own root system, without supplementary nutrition from hosts, and maintain healthy, normal growth for at least three months. Haustorial development and numbers, and therefore capacity to attach to hosts, was promoted by full balance nutrition.

Omission of all nutrients or individual minerals (N, K, P, S, Ca) from the growth medium of the pre-parasitic seedlings produced significant morphological effects. Compared with fully fertilised seedlings, shoot and root length, leaf area, leaf length and width, leaf number, internode length, shoot length/root length ratio, chlorophyll levels, fresh mass and dry mass were all reduced. Leaf thickness increased however (perhaps related to stress tolerance), and stomatal numbers, petiole lengths, root lengths and haustorial numbers showed variable but significant responses.

Mineral specific deficiency symptoms were evident in all omission treatments after three months. Treatments in which N, K or all minerals were omitted had the greatest dwarfing effect and increase in height and leaf number ceased after three months: only seedlings with no added nutrients (dependent on kernel nutrition) were healthy and well-formed, however. The mineral content of no-nutrient seedlings approximated that in the kernels.

Leaf chlorophyll concentration was greatest (and similar) in all-nutrient and no-nutrient leaves. This suggests that when nutrients are balanced, even if in low concentrations, plants can survive and photosynthesise.

The distribution of minerals between plant parts for each treatment was determined. Leaves generally had the highest concentrations, followed by roots then stems. Potassium concentrations and K/Ca ratios were relatively high in leaves of seedlings which received treatments containing K, especially when Ca was absent. A high K/Ca ratio may be inherent in *S. album* seedlings (and larger *S. album* trees) rather than acquired after subsequent host connection. All fully fertilised seedlings developed haustoria within three months suggesting readiness for early host connection. Seedlings in no-nutrient, no-K or no-P treatments had fewer haustoria.

The work has been published in the Annals of Botany journal which is available in most university libraries. This paper also gives references to work mentioned above. The full reference is:

Barrett, DR and Fox JED. 1997. *Santalum album*: Kernel Composition, Morphological and Nutrient Characteristics of Pre-parasitic Seedlings under Various Nutrient Regimes. Annals of Botany **79**:59-66.

A photographic record of seedlings in the treatment is also available in the following journal published in Indonesia:

Barrett, DR and Fox JED. 1993. *Santalum album*: Photographic Record of Nutrient Deficiency Symptoms in Seedlings. Aisuli 6:1-27.

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Host-parasite relations of *Santalum acuminatum* (Quandong)

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Santalum acuminatum (Quandong), one of six *Santalum* species native to Australia, is widespread in drier parts of southern Australia. It is a small tree up to 6 m, but has unscented heartwood and is not exploited for sandalwood production. It grows in rainfall zones between 150–250mm/year and is highly tolerant of both water and salt stress. Mature *S. acuminatum* produce a large endocarp (nut), up to 20 mm diameter containing a large white kernel and has potential as a cultivated nut crop in dry areas. As with all *Santalum* species, *S. acuminatum* is a root hemi-parasite. This article summarises findings from a number of *S. acuminatum* : host pot culture and field experiments.

From our studies it appears *S. acuminatum* has the ability to obtain water from their associated hosts at all times of the day and throughout the year. Anatomical examination of *S. acuminatum* haustoria provide evidence of a direct connection of the water conducting cells between host and *S. acuminatum*. This indicates low resistance to the flow of water and solutes from host to parasite. A glasshouse growth experiment designed to compare the growth of *S. acuminatum* with various hosts and without hosts showed that *S. acuminatum* height, basal stem diameter and shoot dry weight were significantly improved when grown in the presence of a host plant. In particular the host *Myoporum parvifolium* proved to be the most successful host for pot grown *S. acuminatum*.

S. acuminatum leaves contain large amounts of a sugar alcohol known as mannitol which may play a role in protecting the leaves from water stress. The leaves, fruits and roots of all plants contain many different salts, sugars and other compounds.

Experiments to examine the transfer of carbon from host to parasite have been performed. Carbon is made by the plant during photosynthesis and can be found in the plant as simple sugars such as glucose and sucrose or more complex compounds such as mannitol and sorbitol. Photosynthetic rates of *S. acuminatum* and neighbouring plants in the field have been measured and it appears that *S. acuminatum's* daily average photosynthesis is not significantly different from that of neighbouring plants. This suggests that *S. acuminatum* is able to manufacture the majority of its daily carbon requirement.

To determine whether *S. acuminatum* can obtain carbon from its host, a radioactive tracer isotope of carbon dioxide was used. A host plant *(M. parvifolium)* was exposed to the radioactive tracer and allowed to photosynthesise, thus taking up the tracer and using it to make its own carbon. Over ten days the *S. acuminatum* leaf tissue was monitored to assess if any of the tracer present in the host was being transferred to the *S. acuminatum*. It was found that carbon in the form of glucose was being transferred from host to quandong in small amounts (between 2-5 per cent of total available radioactive carbon). When *S. acuminatum* was exposed to the radioactive carbon dioxide it was found that the tracer was present in mannitol, suggesting that *S. acuminatum* is able to manufacture its own mannitol yet obtains some glucose from its host plant. It appears that *S. acuminatum* is not dependant on its host for carbon which is what we would expect due to the fact that it contains chlorophyll and can therefore photosynthesise, but it may be obtaining some 'bonus' carbon from its host.

S. acuminatum fruit from trees growing near *Melia azedarach* trees have been observed to have lower rates of insect damage than fruit from trees not near *M. azedarach. M. azedarach* contains many natural insecticides which have antifeedant properties acting on many different types of insect. One of the main chemicals contained in *M. azedarach* is known as azadirachtin and is commonly used in commercial insecticide preparations. This chemical was initially isolated from Neem, a close relative of *M. azedarach*.

Extraction of the *S. acuminatum* fruit from trees near *M. azedarach* showed the presence of an azadirachtin like compound while the fruit from trees not near *M. azedarach* did not contain this compound. This has very interesting implications for integrated pest management in *S. acuminatum* orchards. However, the literature available on the toxicity of azadirachtin like compounds is rather contradictory and whether it is harmful to humans in large quantities is unclear.

A few more experiments, most of which will be conducted in the glasshouse. These will examine more closely the water transfer between quandong and host and also continue the work on azadirachtin transfer.

Source:
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Sandalwood work in the South Pacific Regional Initiative on Forest Genetic Resources Project

Dr Lex Thomson

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Large remnant Santalum austrocaledonicum on Ile des Pins, New Caledonia. Individual trees like this will act as important gene pools for the S. austrocaledonicum seed collection program in 1998.

The South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) aims to strengthen the national capacity of developing countries in the South Pacific in the areas of collection, assessment, improvement and conservation of priority forest genetic resources.

The project is managed by CSIRO Forestry and Forest Products with major funding support being provided by the Australian Agency for International Development (AusAID). The pilot project will run for three years and started in December 1996. The project works principally with the forestry departments of four countries, Vanuatu, Fiji, Tonga and Samoa.

Santalum has been identified as a priority genus by forestry department representatives of South Pacific countries at the first SPRIG meeting held in Nadi, Fiji in December 1996. The focus of SPRIG-supported sandalwood research is on genetic variation in the Pacific *Santalum* species notably *S. austrocaledonicum* in Vanuatu and New Caledonia and *S. yasi* in Fiji and Tonga, but also *S. maacgregorii* from Papua New Guinea. *Santalum album* has performed well in older trials in Fiji and will also be included in field trials. Sandalwood research within SPRIG will be undertaken in close collaboration with CIRAD-Foret in New Caledonia and the Pacific Islands Forest and Trees Support Program (SPC/FAO).

Sandalwood Research

Seed Collections

Comprehensive, well documented seed collections from throughout the native range of each species will provide the basis for the sandalwood research in SPRIG. In the South Pacific sandalwood species flower and fruit somewhat sporadically throughout the year, with the peak fruiting period being January – March and another fruiting period in the middle of the year (July – August). Some seed collections have already been undertaken of

S. austrocaledonicum, *S. yasi* and *S. macgregorii*, with major collection activity scheduled for early 1998. The aim will be to sample all remaining populations of these species (Figure 1).

Research activities

Once comprehensive seed collections have been assembled, field trials will be undertaken in each of the collaborating South Pacific countries. The principle objectives of the field trials will be to investigate growth performance and adaptability of each of the species and provenances. At a later stage in the trials, e.g. 10 years, it is anticipated that evaluations of heartwood development and oil yield and composition would be undertaken.

An MSc student from the Tonga Ministry of Agriculture and Forestry, Mr Siupelli Ha'angana, has commenced an investigation of genetic variation in *Santalum yasi* at the University of the South Pacific. Mr Ha'angana's research program will include field studies, genetic analyses (morphological and RAPD studies) and possibly heartwood oil investigations. One output of the research will be the development of a strategy to conserve and manage the genetic resources in *S. yasi*. The Forest Conservation Unit, within the Vanuatu Forestry Department, has begun to develop a similar strategy for *S. austrocaledonicum*.

Another major research focus is on vegetative propagation of *Santalum* species. This work is being jointly undertaken by the Queensland Forest Research Institute, which manages the vegetative propagation component of SPRIG, and the Fiji Forestry Department (for *S. yasi* and *S. album*) and Vanuatu Forestry Department (for *S. austrocaledonicum*). Preliminary research undertaken in Fiji by the Silviculture Research Section indicates that *S. yasi* seedlings can be successfully propagated by vegetative cuttings.

A South Pacific Regional Database of Forest Genetic Resources is being developed within the SPRIG, and this database will include comprehensive information on each of the sandalwood species naturally occurring or cultivated in the South Pacific.

Articles on a range of *Santalum* species research and management issues are welcomed by the Sandalwood Research newsletter. If you wish to contribute an article to the SRN or wish to be included on the SRN mailing list please write to the Editor stating your name, organisation and postal address.

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