Sandal and Its Products

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Descriptions of some Sandal Tree Populations in the South West Pacific: Consequences for the Silviculture of these Species and Provenances

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Abstract

Many of the islands of the South West Pacific that bear sandal have been visited and the stands described. Mostly the population is depleted, but some stands still exist. Depending on the status of the existing population, several possible management strategies are feasible. The aim is to rebuild stands which are as diverse as possible which will be able to be managed sustainably in a few decades. Some are presently managed with the objective of regular annual heartwood production with an increase of the stock. The observations reported here, especially those regarding shade intensity, can be used to improve the silviculture of the various provenances which differ markedly. Even aspects of seed storage differ, and this demands further investigation. New techniques, which differ significantly from those previously identified for the Ile des Pins provenance, are proposed.

THE DISTRIBUTION OF sandal species in the South Pacific is particular. They are located in two 'poles', separated by a large 'hole'—the Central Pacific—where sandal has never been found. In the east, one widespread species, *Santalum insulare*, still remains; it is spread from the Gambier and Austral Islands to the Marquesses Islands in French Polynesia. In the west side of the ocean, two species are described, *S. austrocaledonicum* located in the Melanesian islands (Vanuatu and New Caledonia), and *S. yasi* on the Polynesian islands of Tonga and Fiji. The latitudinal extent of each species is pertinent:

- *S. insulare*—12–23°S,
- *S. austrocaledonicum*—15–22°S,
- *S. yasi*—16–22°S.

In the frame of South Pacific Forestry Development Project, with the financial support of the French Fond Regional de Cooperation, several consultancies consisting of training workshops for sandal seed technology, nursery practices and first silviculture, as well as stand visits and descriptions, were carried out in 1996 and 1997. These observations are reported here.

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Description of the Stands

Two main species are described in that part of the Pacific Ocean covered by this study. We shall not comment on the botanical description of the species, since that can be easily found elsewhere (e.g. Barrett and Fox 1995). The species are *Santalum austrocaledonicum* and *S. yasi*.

S. austrocaledonicum

This species occurs in south Melanesia, New Caledonia (NC) and Vanuatu (V). It is common on the Loyalty Islands (NC), Ile des Pins (NC), Aniwa (V), Erromango (V) and Espiritu Santo. It is scattered on Tanna (V). It has been seen on all the TAFEA group

islands (South of Efate). The other islands of Vanuatu have not been recently surveyed, but Sandal is known on Malekula as well as at least one location on Efate. Its latitudinal range is 15°S (Espiritu Santo) to 22°20'S (Ile des Pins).

There are substantial, botanically consistent stands on Ile des Pins, Loyalty Islands, and Aniwa, and scattered ones on the Grande Terre, Tanna, and Erromango.

Habitat

S. austrocaledonicum grows on soils developed from several bases:

- coralline rock—either very shallow (Aniwa), or quite deep (Ile des Pins);
- volcanic ash with influence of coralline rock (Loyalty islands);
- mixed volcanic and coralline sedimentary substrate (Erromango); and
- metamorphic rocks, schists, and phtanites (NC, main islands).

It grows mainly in secondary forests and agricultural fallow or clear dry forests with *Acacia spirorbis* on non-coralline soils. A few big or tall trees can be found along the edge of the dense forest or scattered in it, where they were able to grow in a temporary opening following the fall of a big old tree. In Aniwa, the vegetation is more bushy and sparse, not higher than six metres on the upper terrace.

Habit

S. austrocaledonicum has quite different habits depending on the provenance; for example, on Ile des Pins (NC), the provenance is light-demanding and many trees are found isolated in good sanitary conditions. The seedlings grow quickly, with one straight leader and thin perpendicular branches in open areas which are not too dry or windy. However, the best conditions are a lateral shade and protection, and a full vertical opening over the seedling. This is because if conditions are too shady, the seedlings grow very weak and thin. The tall, straight trees found in closed secondary forests—or rarely in dense forests—are isolated because they have grown in a cleared area, mainly due to old agricultural clearings or damage following the fall of a big tree which has been blown down; therefore they are very scattered. The behaviour of the variety in the south of the main island of New Caledonia, *S. austrocaledonicum* var. *pilosulum*, is similar.

The provenances from the Loyalty islands although considered to be the same botanical variety as that on Ile des Pins, present a very different habit. The seedlings have major leaf and stem morphological differences and look more like *S. yasi*. The shape of light-exposed seedlings is always very branchy, and a leader is hardly found. The branches are inserted in the bole at 40–50°, and tend to curve upward. They are thick and often stronger than the leader which will quickly disappear. Only the trees that have grown inside a shady forest stand (strong lateral and light vertical shade) can show an interesting bole shape. The difference is not only obvious morphologically, but also physiologically. The seed conservation of the Ile des Pins provenance is well known, and the germination rate stays acceptable for 3–4 years. By contrast, the germination rate of the Loyalty provenance stored and treated exactly like the other provenances, decreases very quickly to a rate close to zero after only 18 months storage (Chauvin and Ehrhart 1997). Heartwood rate and oil content rate are also significantly lower than the Ile des Pins provenance.

In Vanuatu, sandal is quite shade-tolerant, and its behaviour is intermediate between the two New Caledonian provenances described above.

On Erromango, the trees are scattered in the clear *Acacia spirorbis* forest where they reach heights of 13 metres, with sometimes eight metres of merchantable bole. These trees are often well shaped with a long and straight clear bole. Unfortunately, presently the high pressure of cattle in these forests stops any regeneration, and there are no saplings.

In the dense forest, beautiful trees are sometimes located but they are very scarce. Trees are more frequent in agricultural areas where they can establish just after the culture periods; but they are small, and often poorly shaped due to the strong light. The few trees seen in the open areas were bushy and crooked.

On Aniwa, the trees are very different. The general shape is bad, mainly small, thin, leaning, and crooked with many branches. The fruits are big, almost twice the volume of the Erromango provenance. A few big trees surrounded by tall bushes were seen on the lower, more fertile terraces of the island. Almost all the trees found on the upper terrace are leaning and crooked. In fact, nearly all of them come from suckers, which has two main consequences. First, since the root system of a sucker stays superficial rather than making a new tap root, the tree does not stand firmly to the wind. Secondly, the sucker does not develop the juvenile form of the seedling or the stump sprout; instead it immediately shows the morphology of a mature tree (broad leaves and no leader dominance), so it is very crooked and does not develop an strong leader.

Even though this species on Aniwa is taxonomically consistent with the description of *S. austrocaledonicum*, its morphological characteristics are quite different from the Ile des Pins provenance. Hence the provenances of *S. austrocaledonicum* should be studied again with a view to separating the species into several varieties. This work is already in process in New Caledonia for the Loyalty provenances.

S. yasi

This species occurs from Eua (20°30' S), South of Tonga to Vanua Levu (16°30' S), North of Fiji. It is very common on EUA (T), rare on Tongatapu, quite rare in the Ha'apai and common in the Vava'u groups (T). In Fiji it has been described on several islands (e.g. the Lau group, Viti Levu, Vanua Levu) but the stands are depleted and have not yet been visited (Bulai 1995).

Habitat

In Tonga the visited stands were growing on soils developed on volcanic ash influenced by the coralline rock below. On Eua the volcanic ash is deep; on Vava'u, less so. On the Ha'apai group, the soils are typical coralline soils developed on raised coral and sand.

S. yasi grows mainly in secondary forests, open areas, and agriculture fallow. Some trees were found in young dense forest in Vava'u (T), but they established themselves when the surrounding trees were smaller and the stand was open for agriculture, notably vanilla. Sandal occurs frequently in the forest covering the small, untouched coralline lime islands of Vava'u; here the forest has many openings due to the severe topographic conditions.

Habit

The shape of *S. yasi* trees and the colour of the leaves are highly dependant on the surrounding vegetation. If the canopy is light, Sandal grows very bushy with many leaders. The lateral branches always take over the previous leader, and so on, giving a strongly ramified crown without a single leader. The foliage is yellowish to yellow. Usually, fruiting is abundant. Such a tree has little economic value due to the small size of the numerous leaders.

In several places in Eua or Ha'apai, consistent sandal stands grow from completely open land to close dense forest through all the intermediate situations: open bushes, close bushes, bushes and trees, and dense tree stands. These areas were old agriculture fallow where trees have slowly taken over the bush and the grass. In open areas, the sandal trees are bushy like the ones described above; but when they grow with the lateral shade of bushes or under the vertical shade of tall trees, their shape improves. Under these conditions, they usually present one single leader, sometimes with big branches that rarely compete with the leader. The foliage is glossy green, and the trees look healthy.

However, when the shade becomes too dense, the crown is thin and the leader and branches are weak, even though the leaves are still bright green. This Sandal species has a photosynthetic physiology that is well adapted to shady conditions. The best shade:light ratio is 40–60 per cent. In these conditions, the trees are growing fast in height with a single leader that is quite straight and a crown that is still well developed. However, the crowns are very prone to deformation by branches from the upper-storey trees.

Tree origin also influences shape:

- seedling—a single straight leader in good conditions;
- sucker—crooked and heavily branched, with no leader; and
- stump shoot—often similar to seedlings initially, due to their very fast initial growth.

This observation is the same for *S. austrocaledonicum* (Ile des Pins), except that its seedlings are generally straight with perpendicular branches or—rarely—big branches growing upward and competing with the main stem.

Status of the Stands

The status of *Santalum austrocaledonicum* and *S. yasi* varies considerably from one island to the other. Many different situations are found in the South West Pacific. They can conveniently be considered in four categories:

- Ile des Pins and Loyalty Islands (New Caledonia);
- Eua (Tonga) and Aniwa (Vanuatu);
- Erromango; and
- Tanna (Vanuatu), Ha'apai (Tonga), and Fiji.

Ile des Pins, Loyalty Islands (New Caledonia)

These stands are consistent, well spread over the islands, and continuous. Many beautiful trees are still living. The original sandal stands were strongly depleted, but since the environment has encouraged regeneration and seedling growth, the present population is substantial with a balanced distribution of diameters.

The early felling was done in very short periods, removing the major part of the existing trees. The regeneration and vegetative multiplication were efficient, particularly in open or cleared forests or in agricultural fallow. In these conditions the genetic pool should not have lost much of its variability. A heavy felling allows regeneration to occur and to develop well, and the short period of logging hinders natural selection by regularly removing the best trees, keeping the worst or smaller ones in the stands. However, since the most beautiful trees were located in the densest stands, they were usually not fruiting so few seedlings would have grown after the exploitation. Thus, if the suckers and the stump shoots were not strong enough to survive in the surrounding forest, their genetic information could have been lost.

Management plans with annual yields have been drawn for two of the islands, but since the transition was not properly organised, no felling was done for years. The stock must still increase and the annual yield be maintained at half of the annual volume increment observed during the last inventories. Natural regeneration is important, but plantations should be encouraged too.

Eua (Tonga), Aniwa (Vanuatu)

These stands are continuous and well stocked in number, but depleted in volume since the trees are young and small and often badly shaped. Very few big trees still exist. Even if the valuable stands were completely destroyed, plentiful regeneration and vegetative multiplication have kept a large distribution of the trees on the islands. Genetic diversity should not have decreased too much, even if it is 'hidden' in a general bad shape due to the vegetative origin. The continuity of the stands allows easy gene exchange. However, the cases are not the same and different strategies should be followed on Eua and Aniwa.

On Eua, where many beautiful seedlings are found in the bushy areas, a complete ban on logging should be enforced for at least 20 years in order to allow the present trees to reach maturity. The ways to implement such a ban are many and depending much on local customs The marketable stock will be then consistent and a sustainable management plan can be followed. Natural regeneration is plentiful but often located in open areas where it will not give beautiful trees. Plantations should complement it as soon as possible, and villager awareness be raised in order to protect and improve the shape of existing trees. Seed collection on the best trees of the island is not difficult; these trees should be selected mainly on their shape and registered.

On Aniwa, the present stand will hardly give any merchantable trees because of the poor shape mainly due to their sucker origin. We assume that the genetic stock is not too much depleted owing to the number of trees found and their distribution continuity. Thus, an important improvement of the general shape of the stand is possible by seedling planting. Natural regeneration is rare.

Large-scale plantations would enrich the stand. Since Aniwa sandal seems quite different of that of Tanna and Erromango (e.g. very big fruits), in the absence of reliable information on variability between the islands, only local seeds should be used. Since the present shape of the trees does not reflect their potential shape, seeds should be collected from as many trees as possible without regard to their shape.

Exploitation of dying and damaged sandal in the present stand can be done; but the return will be very low. For example, in 1997, the average heartwood weight per logged tree was 18 kg with a dbh of 12.5 cm (Hook 1997).

Erromango

These stands are located around the villages and settlements or very scattered in forest clearings. The former are depleted but still in significant number, with a poor shape due to the open area where they have grown. The latter are often beautiful, well-shaped and straight, but are under pressure from the villagers. They represent an important genetic resource, but are very difficult to mobilise because of geographical dispersion, their unknown location, the size of trees, the low fruit production, and the high pressure of cattle and pigs that destroy the new seedlings. In this case, the best way—and almost only way—to preserve a large genetic pool is ex-situ conservation.

So far vegetative multiplication by the usual means (e.g. cutting and marcote) has not been successful with this species. Studies of mobilisation techniques are therefore needed.

Ex-situ seed production stands should contain as many mother trees as possible. Fencing of the located stands, thinning of the surrounding trees to give full light to the crown as well as better germination of the fallen seeds, should allow the regeneration to develop. However, any plantation will face wild animal damage, which restricts them to small areas. In this island, villagers are transplanting young wildlings in their fields, and providing that the fencing is well maintained they already have worthwhile experience.

Vava'u in Tonga has some similarities. There is one consistent stand located South West of the main island where the trees are small but well shaped. Few other small and isolated trees were seen elsewhere on this island. It seems that many trees are still growing on the small islands scattered around the main island. Owing to the steep cliffs that surround them, they are often very difficult to reach so some beautiful trees should be found. Routine in-situ seed collection is not possible in these conditions, but a base ex-situ seed production stand could be built up that would provide seeds for large plantations on the main islands.

Tanna (Vanuatu), Ha'apai (Tonga), Fiji

These trees are rare, scattered in the bush on the islands. Sometimes very localised stands can be found (e.g. Ha'apai), but they are mainly young trees and the genetic base is narrow. Reconstitution of new populations from the few existing trees would be risky, so input from other provenances should be planned for wood production.

Supporting this last option for Tonga, the results of a recent analysis of sandalwood oil composition shows that the variation between the provenances of *S. yasi* in Tonga are quite low; and in terms of oil composition, the tested samples are homogeneous (Alpha 1997). Importation of other Tongan provenances on Ha'apai will not lead to disappearance of a particular characteristic that should be kept pure, but further genetic research should clarify this point.

Silvicultural Consequences

Some general rules can be developed from the above observations. They cover matters like shade management, and can be linked to the species and even the provenances inside the species. In fact, at the present stage of knowledge, a distinction can be drawn between two groups:

- *S. yasi* and the *S. austrocaledonicum* provenances of the Loyalty Islands and Vanuatu; and
- the Ile des Pins and Grande Terre provenances of *S. austrocaledonicum.*

Since our usual seed origin in New Caledonia is Ile des Pins, we have specifically worked on it and the proposed silviculture as well as the seed technology were elaborated for it (Ehrhart 1996c; Ehrhart and Nasi 1996a, b; Ehrhart and Fox 1995). In fact, recent observations and studies (Chauvin and Ehrhart 1997) show that we must reconsider our techniques for the Loyalty provenances, and probably for the Vanuatu provenances and the *S. yasi* varieties as well.

Soil

Sandal species are mostly versatile concerning their soil requirements. The general rules are:

- must be well-drained;
- both species grow easily in coralline soils on raised coral or sand;
- heavy clayey soils should be avoided, or trees only planted on slopes;
- temporarily water-logged soil must be avoided; and
- acidic, depleted soils (e.g. fernland) must be avoided.

Climate

Sandal species require a tropical climate. The main characteristics to be taken into account for their silviculture are rainfall and wind. Both are linked since the terminal leaves and bud of sandal are very prone to wilting and can easily be killed; that causes the development of lateral branches and a subsequent bushy shape.

S. austrocaledonicum is drought-resistant, but it prefers a sufficient water supply. We have not enough experience with *S. yasi* for this factor, but it should be less drought-resistant than *S. austrocaledonicum.* This is because *S. yasi* usually grows in well-watered areas, although it is found on the dry side of Viti Levu, Fiji, where precipitation is around 1400 mm/year (Bulai 1995).

The general rules are:

- on well-drained soils there is no major problem, although low precipitation could be detrimental to shape;
- on heavy soils, high precipitation would cause water accumulation; such soils must be avoided particularly on flat areas; and
- during severe drought clay soils are unsuitable sandal, although they could be selected, provided that they present a slope and an existing vegetation provides lateral protection against wind and sun.

Light

This is the major factor to be considered in sandal silviculture. It causes important differences between provenances.

S. yasi	*S. austrocaledonicum* (Ile des Pins)
	
Needs shade at the young stage.	Tolerates full sun during the first years, but prefers lateral shade with vertical light.
More light-demanding once the crown begins to develop, but always needs lateral shade.	Full light is not detrimental to adult trees, provided that bushes and small trees are surrounding the tree for sufficient parasitism.
Often, the lateral branches take over the previous leader, which causes a very branchy form without a straight and permanent leader stem; this characteristic is invariable in full sun, but far less in shade where usually there is one single leader. Shape pruning of a dense pure stand of branchy trees (fully exposed to sun) has induced the natural death of many small healthy branches; the active crown is now located on the top of the trees, which leads to self-pruning.	The stem is dominant while vertical growth is strong; lateral shade helps to keep this shape. The development of lateral branches as multiple leaders happens when the growth is difficult. This characteristic stresses the importance of fertility and water supply on the tree form; it is exacerbated by wilting due to wind and strong sun during dry periods.
Diameter growth is stronger.	Height growth is better in the first years.
Wind resistant.	Less wind resistant when young (but at the same age the trees are taller, and the stem is more rigid).

Both types present an easy healing of the small wounds caused by pruning. Both are prone to major stem deformation when disturbed by branches from the overstorey trees.

Main Silvicultural Recommendations

Planting on bare land

S. yasi	*S. austrocaledonicum* (Ile des Pins)
(1) Not recommended (except for seed production); or (2) planting of the host first then sandal planting at least one year after (but depending on host's growth). If the host provides a heavy shade, then pure rows of each are recommended. They will be oriented across the prevailing wind. If the host provides only a light shade, alternate planting in the row. The distance between the sandal and the host will then depend on the growth of the host.	(1) Possible with simultaneous planting of sandal and host (provided that the host is fast-growing for the first year, particularly on dry areas); or (2) if large spacing is planned between host and sandal, the host should be planted first.

Both types are strongly prone to deformations when disturbed by lateral or over hanging branches from the host plant. They must be pruned regularly.

Planting inside existing vegetation

Several cases are found. Either the shade is provided by bushes, or it is provided tall trees in which case it must be light (light:shade = 50%).

S. yasi	*S. austrocaledonicum* (Ile des Pins)
Tall trees: very appropriate. All the existing small bushes are kept around the sandal. (Experience has still to be gained additional host planting in this case.)	Tall trees: too heavy; vertical shade is not recommended.
Bushes: rows opened across the prevailing wind, one metre wide.	Bushes: rows opened across the prevailing winds, 1–2 metres wide depending on the bushes' height. If the rows are too wide, they will not provide enough shade to the seedlings, and will not inhibit weeds.
Trees and bushes: in this case the shade ratio from the upper storey trees should not exceed 30%. Rows are opened as above, but the orientation depends less on wind direction.	Trees and bushes: only light shade from the upper storey trees is recommended (*Casuarina* trees gave good results in this design).

Shape management

Wherever the sandal does not grow quickly in height (e.g. low fertility or dry areas), or if the shade ratio is low (e.g. at the beginning of a plantation on clear land), shape pruning is needed.

This removes all the branches that are growing upward and that could take over the leader. The aim is a straight and clear bole 2–4 metres long (depending on the fertility of the soil). This operation is easy to carry out and very fast when it is done early, but becomes longer and more difficult as soon as the trees are taller than about two metres. Also, during an early operation the choice of the branches to cut is easy and does not demand much experience and skill. Therefore, it is recommended that pruning begins in the second year, and is repeated regularly every two years until the stem has reached the targeted length. Above this height, in the best cases, it would eventually happen naturally.

Advantages of planting in existing vegetation

This design has several advantages that recommends it for all the cases where an existent technical structure is not available. In the South Pacific this is almost always the situation. The benefits are:

- low initial investment (seedlings and the opening of the row in the existing bushes);
- tree density can be low by opening the rows at large spacings without the problem of shade ratio;
- only few seedlings are planted (sandal alone, rather than sandal plus hosts);
- further maintainence works are easy to implement (bush trimming in the rows, and pruning of the sandal);
- workers (either hired or on their own land) prefer to work standing and under shade, instead of being bent and exposed to the sun in a new plantation; and
- tree shape will be far better in the event of the plantation not being maintained.

However, it is better to avoid the areas where the existing vegetation is strong and dynamic (strong *Hibiscus tiliaceus* bush, for example), because the sandal could be very quickly eliminated in the absence of maintenanc.e In less vigorous vegetation, like that found in dry forest, the sandal will easily survive and grow even without any maintenance work.

Improvement of existing natural or artificial stands

Shape pruning is only done on newly planted seedlings and the most beautiful existing sandal. Three categories are discussed.

Natural young trees grown in good shade conditions

The stems are quite straight, there are few branches that have become leaders, the diameter of which is still less than five cm. Pruning of the most disturbing branches (up 60% of the foliage can be removed), in which case, all the plagiotropic branches are kept, even when they are located on the bottom of the stem. If needed, one or two years later, a second pruning will be done in order to remove more leaders and, depending on the size of the crown, to lop the low branches.

This technique should be also used when the trees are poorly shaped but already too big to be treated with the next technique; the objective is to reach a two-metre-clear stem length, whatever the fertility of the soil. Sometimes, in case of too strong pruning and too much lateral light, some shoots come out at the major wounds. They must be removed as soon as possible (within 6–12 months).

Beautiful 6–10 year old stands in Eua have been improved with this technique.

Poorly-shaped young trees from seedlings (up to 5–7 cm of diameter at ground level)

Stems are cut a few cm above the ground. Less than one year later, only the best shoot will be kept and the others removed. Since the shoots are growing fast at the beginning, they always have a straight stem shape.

Very badly shaped older trees from seedlings (diameter >7cm) or from suckers

With the previous techniques, either the size of the stump or the existing root system of a sucker would not allow the future tree to develop a sound and balanced root system, or the trees are too poorly shaped to be improved. The previous operation could be detrimental to the stand value (big wound, difficult recovery). The badly-shaped trees are left growing, and a new plantation of seedlings is established at a large spacing. Only the disturbing badly-shaped sandal are eliminated. The others are kept to be cut at maturity. They will provide oil-grade logs.

Conclusions

Currently, only the New Caledonian populations are able to support regular sustainable logging. Surveys on Ile des Pins and the Loyalty Islands have given information on available sandalwood volume. Successive inventories gave us the annual volume increment of the stand on Ile des Pins and potential annual heartwood yield. They are the basis of long-term manage-

ment aiming to increase the present stock (Ehrhart and Nasi 1996a). For the moment there is no exploitation.

In the other countries, complete protection should be organised in order to stop the present depletion of the rare reserves of immature trees. In the case of some Vanuatu islands (e.g. Erromango and Espiritu Santo), the stands could possibly support sustainable management. However the present ignorance of the exact available stock and its value, and the difficulty of checking whether logging operations comply with annual cut authorisations, demand a long-term ban until the full knowledge of these elements is available. There is still strong logging in Espiritu Santo (more than 100 tonnes were exported in 1997 by Chinese traders) and there is no figure at all of the stands there.

Germplasm banks should be build up in several places (e.g. Erromango, Tanna, and Vavu'u) in order to provide seeds for large-scale planting while keeping genetic diversity as high as possible. Pure provenance-conservation plantations are also an option. In New Caledonia, separate conservation is compulsory because provenances differ markedly. When morphologic differences are not obvious, further studies should be done to identify if separate conservation is appropriate. In Tonga for example, oil composition is similar throughout the country (Alpha 1997). Therefore, separate provenance conservation is not appropriate for this factor; it would be better to gather all the vegetal material in one ex-situ seed production stand to give a larger variability to the pool, instead of working with separate small populations.

In the South Pacific, sandal populations are mostly depleted except on a few islands where the stock is still consistent. In these latter, if the population were surveyed sustainable logging management is possible (e.g. New Caledonia). When no figure is known for the existing resource, sandal should be protected until the knowledge of the stock allows sustainable management (e.g. Vanuatu). In all the other cases, a sound recovery requires complete protection of the last few remaining trees.

Reconstitution of valuable stands would need plantations in many cases. Depending on the sandal status on the considered islands, the seed collection strategy will be different and in many cases, ex-situ seed production stands are recommended.

Observations of natural stands and current plantations have identified several technical itineraries adapted to the variable provenance behaviour depending on light. In particular, *S. yasi* and *S. austrocaledonicum* provenances from Loyalty Islands and Vanuatu need shade (shade:light ratio = 50%) to grow properly and produce high value timber; that conclusion is contrary to previous technical practices adapted to Ile des Pins provenance. Therefore (except for Ile des Pins provenance), the plantation design generally recommended is planting in rows opened in existing vegetation of bushes and trees (clear forests). Plantations on open land must be reserved for seed orchards.

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