Potential Casuarina species and suitable techniques for the GGW

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Abstract

Casuarina tree species belong to the Casuarinaceae family, which includes 4 genera and 96 species. Casuarina trees are native from Australia, Southeast Asia and Pacific archipelagoes. Casuarinas develop symbiotic associations with Frankia, ectomycorrhizal and endomycorrhizal fungi. They have been introduced into tropical and subtropical zones in the world. Casuarinas are economically and ecologically important. They are multipurpose tree species providing a wide range of goods and services, such as windbreaks, sand stabilization, agroforestry and general rehabilitation for difficult sites. Casuarinas can be planted as pioneer species in hot-dry river valley, dry sandy soil, rock mountain and around desert. The wood is a main source of fuelwood and charcoal, for general construction, fiber-wood, and other wood-based industries.

In this presentation, the potential of Casuarina species for the GGW will be described, together with sylvicultural techniques and Casuarina uses. A simple propagation technique that has been developed in China to produce a large number of the best Casuarina seedlings will be presented. Following field experiments, we will show that ectomycorrhizal (ECTM) or arbuscular mycorrhizal (AM) fungi or Frankia-tree genotype symbiotic associations play an important role in improved management of Casuarina forest plantations.

Key words

CASUARINA, SPECIES, MYCORRHIZA, *FRANKIA*, DEGRADED LAND

Introduction

The family *Casuarinaceae* is a group of 96 species of multipurpose trees and shrubs that grow naturally in South-East Asia, Malaysia, Australia, and the Melanesian and Polynesian regions of the Pacific. Casuarinas are characterized by a conifer-like appearance due to morphologically distinctive foliage with the leaves reduced to tiny teeth on green, jointed, needle-like branchlets.

Casuarinaceae are tolerant to adverse edaphic and climatic conditions and most species tolerate extreme heat. They grow in a wide range of different environments, from tropical forests to arid woodlands and coastal dunes. They grow in a wide range of different environments, from tropical forests to arid woodlands and coastal dunes. They frequently occur as pioneer vegetation at early stages of plant succession following disturbances such as fire, landslides, volcanic eruption and flooding. (El-Lakany *et al.,* 1990; Midgley *et al*., 1983; Pinyopusarerk and House, 1993). Vast plantings of *C. equisetofolia* have been established in China along the coast fronting the South China Sea. They form a green belt that stretches for 3000 km and varies from 0.5 to 5 km in width.

Uses of Casuarina trees

Taken collectively, Casuarina trees have many uses (Diem and Dommergues, 1990; Diouf *et al*., 2008). They are capable of stabilizing shifting sand dunes, stabilizing eroding hillslopes, and reclaiming marshy soils that are periodically inundated. Because of their resistance to salt-laden winds, many species such as *C. glauca* and *C. equisetifolia* are widely used to stabilize coastal sand dunes (Zhong and Zhang, 2003). They are also planted as windbreaks to protect crops. Casuarina trees have proved to be one of the most effective shelter trees during typhoons and Tsunami in Asia. Some species such as *C. equisetifolia* and its hybrids grow rapidly (a growth rate of 3 m per year has been reported in India) and have an attractive dense crown; consequently, these species are often planted as ornamental plants for urban beautification, parks and seaside resorts, and along roadsides.

Another important use of Casuarina in the tropics is the production of firewood. In comparison to other fuelwood crop species, Casuarina ranks well for calorific value in relation to wood volume (about 5000 $kcal.kg^{-1}$). People in China use the stumps and even litter for fuel. Because Casuarina wood splits on drying, it is difficult to use the wood for lumber and furniture making. However, it can be used in rural construction as poles for house construction, electric poles and the masts of boats. The wood is very hard, with a density of 1000 $kg.m^{3-1}$, and is resistant to decomposition in soil and saltwater. Thus, Casuarina poles are used in Asia for anchoring fishing nets in the mouths of the rivers. In India, the wood of *C. equisetifolia* is also pulped for paper, and in Madagascar, the bark is extensively used for tanning leather (Midgley *et al*., 1983; Pinyopusarerk and House, 1993; Diouf *et al*., 2008).

Potential Casuarina species for GGW

The *Casuarinaceae* family includes four genera, *Allocasuarina* L. Johnson with 59 species, *Casuarina* L. Johnson with 17 species, *Ceuthostoma* L. Johnson with 2 species and *Gymnostoma* L. Johnson with 18 species (Wilson and Johnson, 1989; Turnbull, 1990). *Allocasuarina* is a large group of shrubs and trees, native to Australian and most of them can grow on poor soils. The potential of Casuarinaceae species for the GGW are shown in Table 1.

Casuarina Propagation Techniques

Casuarinas can be propagated by seed, cutting and tissue culture.

Propagation from seeds

Seed propagation is a common method used for most Casuarina species. The quality of the seedlings depends on the degree of seed maturity, the condition of seed storage and the genetic quality of the mother trees. In China, Casuarinas trees bear seeds from 3 or 4 years of age, and can continue to fruit good quality seeds for many years. The seeds are easily extracted from cones after 3-7 days under shade. Experiments in China have shown that Casuarina seeds do not store well and lose their viability after 1-2 years when stored at room temperature. For long-term storage it is suggested to store seeds at 4-5°C. At CSIRO Australian Tree Seed Centre, seeds of *C. equisetifolia* and *C. junghuhniana* still maintained good germination after 15 years of storage in cool room conditions (4-5°C) (K. Pinyopusarerk, personal communication). Each species has its optimum germination temperature, usually ranging between 20°C and 30°C. Propagation by seed takes advantage of the fact that seeds are easy to obtain, but the disadvantage is the unreliable genetic quality. To obtain seeds of high genetic quality, seed orchards or seed production areas need to be established.

Propagation by cuttings

Water culture is now a common method for the propagation of Casuarina cuttings in China (Liang and Chen, 1982). The vegetative material is the young needle-like branchlet, preferably less than three months old taken from stock plants in hedge orchards. The procedure consists in soaking the bottom part of the 8-10 cm long branchlet in 50-100 ppm of NAA (naphthalene-acetic acid) or IBA (indole-butryic acid) solution for 24 hours. The plant material is then washed and soaked for 7-10 days in water, which is renewed every day, and placed near sunlight. At 25-32°C water temperature, cuttings will root after 7-10 days, and after 15 days, the rooting percentage is over 80%. If the water temperature is lower than 25°C, it may take

15-30 days to root. The rooted branchlets are then transplanted in growth containers filled with standard potting mix. This technique has been extended to county foresters and farmers. At present, private nursery managers can produce Casuarina cuttings using the water culture method, but they have to rely on local forest farms or research organizations to obtain new clonal genetic resources.

Rooting in moist, fine sand, and applying the same hormone treatment than as that previously described above for water culture, is an alternative method. Generally, a sand bed 15-18 cm in depth, 80-100 cm in width and 5-10 m in length, is built with brick. A plastic sheet is placed inside the bed to keep the sand clear from soil, and water pipes are laid at one end to supply water. The sand bed is always kept moist and is covered with clear plastic sheet to increase the temperature in winter. This method is suitable for mass production.

Both water culture and sand culture are used successfully for *C. equisetifolia*, *C. cunninghamiana*, *C. glauca* and *C. junghuhniana*. Other species such as *C. cristata*, *Allocasuarina littoralis* and *A. torulosa* are more difficult to root.

In Vitro Tissue Culture

Since the 1980s, tissue culture methods have been used for Casuarinas by many workers (Duhoux *et al.,* 1990; Abo El-Nil, 1987; Duhoux *et al.,* 1990; Cao *et al.,* 1990; Zhong, 2000; Liu *et al.,* 2003). Tissues include slender branches, young buds, immature male inflorescence spikes, female flower buds and seeds. The success of the approach depends on appropriate disinfection of the plant material, the composition of the nutrient medium, rooting hormone (NAA, 6-BA or IBA), temperature, light, and the biological characteristics of the species. Generally, tissue-cultured material is easier to root than cuttings material. In 2000, Chinese researchers started to work on Casuarina *in vitro*. Up to now, *in vitro* plants of *C. cunninghamiana, C. equisetifolia* and *C. glauca* have been obtained, but there are considerable differences in organogenesis among species (Liu *et al.,* 2003).

Inoculation of Casuarina by Mycorrhizal Fungi and *Frankia*

Mycorrhizal fungi and *Frankia* can improve the growth and biomass production of Casuarina seedlings or saplings. Chinese researchers have been working on the selection of Casuarina symbiotic genotypes (Zhong, 1993; Zhong *et al.,* 2003).

Mycorrhizal fungi tree genotype associations were studied under nursery conditions for *C. equisetifolia* (23 provenances) and under glasshouse conditions for *C. junghuhniana* (10 individual families). The results of *C. equisetifolia* and *C. junghuhniana* showed that inoculation with ectomycorrhizal fungus significantly improved the diameter and height of seedlings. There was also variation among seedlots in response to the inoculation (Zhong *et al.,* 2003).

Table 1
Potential Casuarina species for the GGW

No.	Species	Main Characteristics			
		Native Distribution	Rainfall (mm)	Soils	Height (m)
1	*Allocauarina decasisneana*	swales between sand dunes, arid climate, Australia	0-300	Desert sand soils	10-16
2	*A.inophloia*	QLD, Australia	450-800	sandstone or laterite ridges	3-10
3	*A. littoralis*	East Australia	700-2000	sandy and other poor soils	5-15
4	*A.verticillata*	grassy woodland, rocky sea-coasts and dry rocky hill and ridges inland, Australia	150-800	a range of soils	4-10
5	*A.dielsiana*	lateritic hilly country, Australia	200-400	Lateritic soil	4-9
6	*A.helmsii*	WA, northwest Vict., Australia	0-300	a wide range of soils	1-5
7	*A.luehmannii*	QLD, NWS,SA., Australia	700-2000	Non-calcareous soils	5-15
8	*A.torulosa*	oastal hills and ranges as understory in open forest to tall open-forest, Australia	700-1600	A range of soils	5-20
9	*A. huegeliana*	Western Australia	300	Rocky soils from 450 to sea level	4-14
10	*Casuarina pauper*	WA, SA,.NSW, Australia	100-400	red-brown soils with light-texured topsoil and cacareous subsoil	5-15
11	*C.equisetifolia*	North and East of Australia	700-2000	Sandy and rocky sea coasts,	6-35
12	*C.cunninghamiana*	Along fresh water stream, East Australia	800-2000	A range of soils	15-35
13	*C. obesa*	West Australia	200-800	Brackish or saline soils	8-20
14	*C.cristata*	South QLD, NSW, East Australia	800-1600	Clayey grey or brown soils with calcareous nodules	10-20
15	*C.glauca*	East Australia	700-1600	Exposed headlands	8-20
16	*C.junghuhniana*	from 3100 m highland to 100 m above sea level. Native in Indonesia and East Timor	700-1500	A wide range of soils. It is tolerant of a wide pH range, from 2.8 to 8	25-35

In another glasshouse study on *C. junghuhniana, s*eedlings were inoculated with three endomycorrhizal fungi (AMF) and six ectomycorrhizal fungi (ECMF). Seedling height, root length, ground diameter, dry weight underground and above ground and total biomass were measured. The results showed that both fungi significantly improved the growth of *C. junghuhniana* seedlings. The AMF had a more obvious effect in improving drought resistance of *C. junghuhniana* than ECMF according to the nine mycorrhizal fungi used in this experiment. Five isolates were selected from the AMF and ECMF tested, including *Glomus caledonium* 90068, *G. caledonium* 90036, *G. versiform* 9004*, Scleroderma flavidum* 0207 and *Laccaria* sp E439. They could be used as inoculants of *C. junghuhniana* seedlings (Zhang *et al.*, 2006). Since 2001, we have introduced *C. equisetifolia*, *C. glauca*, *C. cunninghamiana*, *C. junghuhniana, C. obesa, C. cristata* and *A. littoralis* in the hot dry river valley in Yuanmou, Yunnan Province, which is characterized by degraded soil, low annual rainfall (634 mm) and high evaporation (3848 mm). The first five species showed potential at some sites. A *Frankia* inoculation experiment on *C. cunninghamiana* was carried out in the hot dry river valley in Yuanmou, Yunnan province. Survival after planting of inoculated seedlings increased by 10.0-20.6% compared with uninoculated seedlings. Tree height after two years differed significantly among *Frankia* treatments. However, not every *Frankia* strain improved tree growth (Yang *et al.,* 2007).

Since 1989, many field inoculation trials have been conducted in Hainan, Guangdong and Yunnan Provinces, China. More than 18 years of experience of applying Casuarina inoculum in China have shown that application of a symbiotic microorganism (*Frankia* and mycorrhizal fungus) can effectively improve survival and biomass productivity of Casuarina plants and is recommended when Casuarina trees are planted at sites where Casuarinas have not previously been planted. In China, pure culture strains or isolate inoculants in liquid form are used to inoculate seedlings in the nursery. In general, seedlings or cuttings that have just developed lateral roots are suitable for inoculation.

Consideration of rehabilitation measurement and strategy for the GGW

Tree improvement

Significant genetic variations of casuarinas trees exist among tree species, provenances, families and/or clones. Selection of appropriate Casuarina genetic resources will undoubtly lead to valuable benefits. In the GGW zones, the first criteria for selection will be trees adapted to environmental conditions, and then economic or social benefits will have to be considered. Casuarinas introduction should take benefit of the wide genetic diversity; in a second stage, casuarina tree productivity will be increased by tree improvement or selection techniques.

Sylvicultural techniques

Water is one of the limiting factors successful to successful tree plantation. Every feasible site management practice to keep runoff water under control should be used. Short raining season is a good time to plant trees. A range of planting models should be assessed for the GGW. On degraded land, a mixed model with grass or shrub-grass or tree-shrub-grass should be tested. In the early stages, it will be very important to plant suitable tree species adapted to degraded lands. They will artificially build successful and convincing forests that will then simulate natural forest population for environmental rehabilitation.

Sustainable management and rehabilitation strategy

The needs of local communities must be balanced with the urgent need to rehabilitate degraded land, through extensive community consultations. It will be necessary to promote technical capabilities of local citizen in all relevant management techniques and practices of vegetative rehabilitation. Another key in the success of the GGW will be to develop successful demonstrations and implement a continual program of extension and education among local communities in order to raise awareness of the importance of vegetative rehabilitation.

Conclusion and suggestion

– Casuarina trees can be easily propagated by seeds or cuttings.

– Casuarina trees are valuable species to improve degraded lands, which can be used as pioneer species, particularly with mycorrhizal fungus or *Frankia*- tree associations.

– Casuarina trees should be considered in the GGW project.

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