Indigenous actinorhizal plants of Australia

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Indigenous species of actinorhizal plants of Casuarinaceae, Elaeagnaceae and Rhamnaceae are found in specific regions of Australia. Most of these plants belong to Casuarinaceae, the dominant actinorhizal family in Australia. Many of them have significant environmental and economical value. The other two families with their indigenous actinorhizal plants have only a minor presence in Australia. Most Australian actinorhizal plants have their native range only in Australia, whereas two of these plants are also found indigenously elsewhere. The nitrogen-fixing ability of these plants varies between species. This ability needs to be investigated in some of these plants. Casuarinas form a distinctive but declining part of the Australian landscape. Their potential has rarely been applied in forestry in Australia despite their well-known uses, which are being judiciously exploited elsewhere. To remedy this oversight, a programme has been proposed for increasing and improving casuarinas that would aid in greening more regions of Australia, increasing the soil fertility and the area of wild life habitat (including endangered species). Whether these improved clones would be productive with local strains of *Frankia* or they need an external inoculum of *Frankia* should be determined and the influence of mycorrhizal fungi on these clones also should be investigated.

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1. Introduction

Actinorhizal plants are a group of dicotyledonous plants (Zhang *et al.* 2012) that enter into a symbiotic relationship with soil diazotrophic actinobacteria belonging to the genus *Frankia*, resulting in the formation of root nodules and nitrogen fixation. Apart from actinorhizal plants, the other main group of dicotyledonous plants entering into a symbiotic relationship with a different nitrogen-fixing bacteria (rhizobia) belongs to the family Fabaceae (legume family). Both actinorhizal plants and legumes belong to the nitrogen-fixing sub–clade within the clade I of Eurosids (Sprent 2008; Soltis *et al.* 2000). The amount of atmospheric nitrogen fixed by some of the actinorhizal plants by their symbiotic association with *Frankia* is equivalent to that fixed by the legumes with their symbiotic association with rhizobia (Santi *et al.* 2013). They also increase nitrogen content in the soil by litter fall and its decomposition. Andrews *et al.* (2011) by measuring the natural abundance of ^{15}N in natural ecosystems concluded that actinorhizal plants may fix greater quantities of atmospheric nitrogen compared to legumes in their natural habitats. Apart from the symbiotic relationship with *Frankia,* actinorhizal plants also enter into symbiotic relationship with mycorrhizal fungi. This tripartite relationship enables the actinorhizal plants to grow and thrive in environments hostile to other species as these plants can obtain fixed nitrogen in nitrogen-poor soils with their symbiosis with actinobacteria, and the mycorrhizal fungi aid these plants in better absorption of essential nutrients (Yamanaka *et al.* 2003) in nutrient-poor soils and may aid in better absorption of water (Rojas *et al.* 2002) in soils with low moisture levels. Actinorhizal plants, thus aided by the beneficial soil bacteria and fungi, are well equipped in becoming the pioneer succession species in areas such as land disturbed due to mining and earthquakes.

Except in Antarctica, actinorhizal plants are distributed all over the world (Bargali 2011) as indigenous as well as introduced and naturalized species. Actinorhizal plants are the main source of fixed nitrogen in the arctic regions because leguminous plants have a scanty presence in these regions. Rhizobia develop symbiotic relationship with most of the plants of Fabaceae and with a single genus (*Parasponia*) of non–

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leguminous Ulmaceae. *Frankia* develops symbiotic relationship with actinorhizal plants belonging to a range of families. Actinorhizal plants are found in approximately 220 species belonging to about 25 genera of eight angiosperm families in three orders (Ribeiro *et al.* 2011; Santi *et al.* 2013). In some of these families, all or almost all plants are actinorhizal, and in others, only one or a few genera or a few species in the genera are actinorhizal. Except for herbaceous plants like *Datisca,* generally actinorhizal plants are woody shrubs or trees. *Casuarina glauca* normally grows as a shrub or as a small tree. Prostrate forms have also been found in this species near Sydney region in New South Wales. *Frankia* strains belonging to three phylogenetic groups (cluster 1, cluster 2 and cluster 3) nodulate different genera of actinorhizal plants.

Australia is one of the oldest land masses of the earth. As the smallest continent, it still has large variations in its climatic zones ranging from tropics to the temperate zones, comprising various ecological niches. This continent separated from the ancient Gondwanaland mass millions of years ago, when the ancestors of casuarinas were present before eucalypts had evolved (Corbett 2006). Being an island continent separated from other land masses by huge distances, it possesses its own unique vegetation (including three families of actinorhizal plants), dominated by eucalypts and acacias. Many of the species of actinorhizal plants found here have a restricted native range specific to a region and some of them are found specifically only in this continent. These plants have diversified to adapt to a range of climatic and environmental conditions found here.

Allocasuarina and *Casuarina* of Casuarinaceae are predominant actinorhizal plants of Australia. They are collectively known as casuarinas and are well known for their water use efficiencies (Kennedy 2012) and other attributes. Although these plants are being exploited for their multiple uses in various parts of the world, especially in tropical and subtropical regions of developing countries, casuarinas have been underutilized in Australia.

In this study we aim to identify and describe some of the significant characteristic of actinorhizal plants of Australia and propose a plan of action for increasing and improving the casuarinas for their uses in farm–forest rotations in Australia, which would have the benefit of not only increasing the declining population of these plants but also utilizing more wasteland regions, increasing the soil fertility of these regions as well as increasing the area of wild life habitat by providing increased amount of food and shelter for native species (including endangered species like *Calyptorhynchus lathami*, or the glossy black cockatoo). Utilization of their woodchips as fuel for electricity generation in place of coal would result in the production of clean green energy. Whether the indigenously available strains of Frankia would be optimal for the growth of these improved super clones of casuarinas or they will need an inoculum of select strains of *Frankia* must be determined. The influence of local mycorrhizal fungi on these clones has to be investigated too.

2. Climatic zones and soil types of Australia

To understand the nature of distribution of various actinorhizal plants in Australia one must have a basic idea about various climatic zones of this continent, which ranges from tropical (in the top northern regions) to temperate zones (in the southeastern regions). But a large part of Australia is desert or semi–arid (figure 1).

Australian soils are geologically old and infertile, underlain by salt and face considerable degradation risks related to processes such as soil carbon decline, acidification and erosion. Only the southern and western corners of Australia have moderately fertile soil. Isolation of Australia from other parts of the world due to its geographical location and its diverse climatic and geological zones has resulted in the creation of various micro- and macro-climatic habitats and resulted in vast diversity of various species of plants and animals of this continent.

3. Actinorhizal plants of Australia

Actinorhizal plants belonging to three families are found indigenously in Australia and grow in various harsh climatic and environmental conditions of this continent. These families are Casuarinaceae, Elaeagnaceae and Rhamnaceae (table 1). Actinorhizal plants belonging to two of the above families, namely Casuarinaceae and Rhamnaceae, have plants whose native range is restricted to Australia. The dominant family of actinorhizal plants in Australia is Casuarinaceae with two of its genera found predominantly in southern parts of Australia, although they are found in other parts of Australia too (figure 2a and b). One of these predominant genera with its entire set of species has its native range restricted to Australia. Most of the indigenous species of another of predominant genus have their native range restricted to Australia. Only a single species in this genus has its native range elsewhere apart from Australia. The third genus has a minor representation in Australia with a single species whose native range is restricted to northeastern region of Queensland (figure 2c). This species is found only in Australia. A single species in a genus belonging to Elaeagnaceae has a broad native range extending into east Queensland's northern and southern regions of Australia

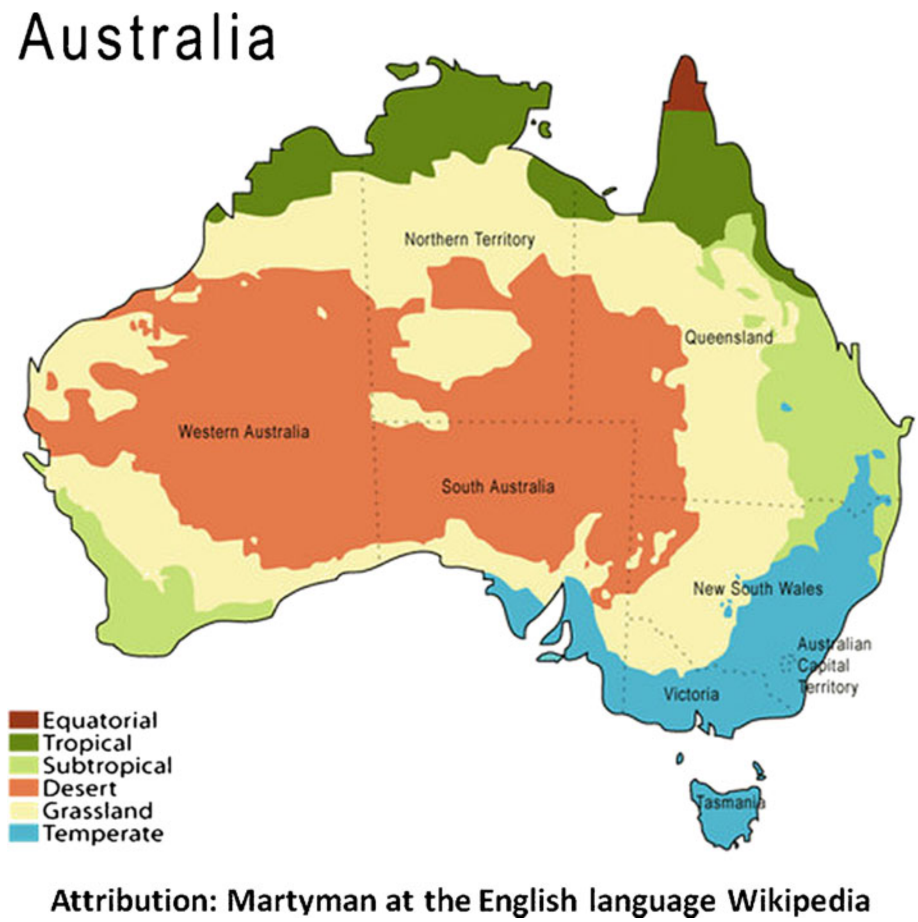

Figure 1. Map of Australia depicting various climatic zones.

(figure 2d). The native range of two species of a genus belonging to Rhamnaceae is restricted to southeastern Australia (figure 2e and f). These two species are found only in Australia.

3.1 *Casuarinaceae (She–oak family)*

Casuarinaceae belongs to the order Fagales. There are four genera in this family. Plants belonging to this family are commonly known as she-oaks or Australian pines. Members of this family have Gondawanic ancestry and their present-day native range is restricted to Australia, Southeast Asian countries and the Pacific Islands although they were more widely distributed in the earlier times. This family is the predominant actinorhizal family in Australia. Plants belonging to this family are very well adapted to the inhospitable environmental conditions prevalent in their natural habitats and display various xeric features. Being switch plants, their leaves are reduced to scales and the photosynthetic function is taken over by their green branchlets.

3.1.1 *Allocasuarina:* All the species belonging to the genus *Allocasuarina* have their native range restricted to Australia (Fennessy 2005). There are about 60 species in this genus, and

Table 1. Actinorhizal plants of Australia

Family	Genera	No. of species in Australia	Native range restricted to Australia
Casuarinaceae	*Allocasuarina*	60	All species
Casuarinaceae	*Casuarina*	6	Five species
Casuarinaceae	*Gymnostoma*	1	Yes
Elaeagnaceae	*Elaeagnus*	1	No
Rhamnaceae	*Discaria*	2	Both species

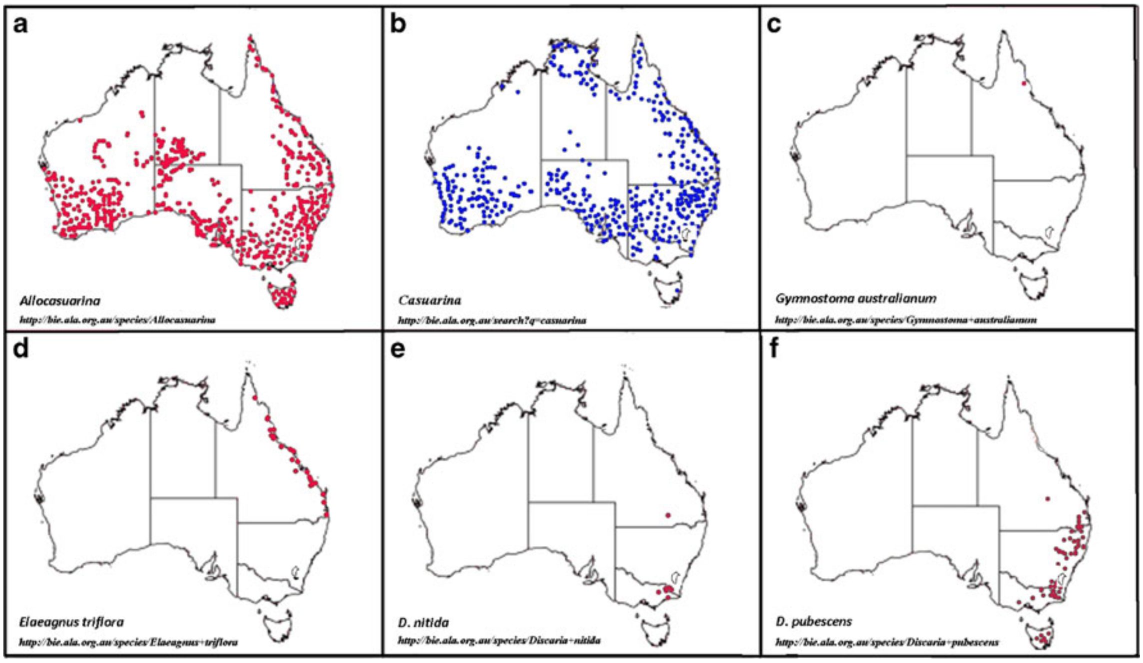

Figure 2. Distribution of actinorhizal plants in Australia. (**a**) *Allocasuarina*, (**b**) *Casuarina*, (**c**) *Gymnostoma*, (**d**) *Elaeagnus*, (**e**) *Discaria nitida* and (**f**) *D. pubescens.*

some of them are rare and come under endangered category. Although species of this genus are found in all states and territories of Australia, as coastal and inland species or as both, most of its species are found in southern parts of Australia. About 40% of the species in this genus have their native range in southwestern Australia. Some of the species are found along the eastern Australian coastal belt and some others are found in the arid regions of central Australia. Some species of this genus are found throughout the island state of Tasmania (figure 2a). This genus is named as *Allocasuarina* because of its close resemblance to *Casuarina*, 'allo' meaning 'like'. The species belonging to *Allocasuarina* are capable of growing in less fertile and drier soils compared to the species belonging to *Casuarina*. Root nodules are found in more than 90% of *Allocasuarina* species (Dawson 2008). Frankia strains belonging to the subclade '*Casuarina* strains' of cluster 1 nodulate this genus (Normand *et al.* 2007). The strains of Frankia isolated from this genus are highly salt tolerant (Dawson and Gibson 1987). Nodules are not formed profusely and hence not easy to locate in many of these species. (Lawrie 1982; Dawson *et al.* 1989; Simonet *et al.* 1999).

3.1.2 *Casuarina:* There are 17 species in the genus *Casuarina*. Nodulation has been found in all the species of this genus (Dawson 2008). Six of the species belonging to this genus are found indigenously in Australia (Fennessy 2005). This genus is found in all the states and territories of Australia either as coastal or as inland species or as both. Similar to *Allocasuarina,* most of the species in this genus are found in southern Australia. Some of the species of this genus are found throughout eastern Australian coastal belt and some of the species are found in northernmost regions of Australia. This genus is widely distributed in New South Wales. Very few species of *Casuarina* are found in Victoria, Tasmania and arid central Australia compared to *Allocasuarina* (figure 2b). This genus too, like the genus *Allocasuarina,* is nodulated by *Frankia* strains belonging to the subclade '*Casuarina* strains' from cluster 1 (Normand *et al.* 2007). The strains of *Frankia* isolated from this genus too are tolerant to high concentration of salt (Dawson and Gibson 1987).

Barring *C. equisetifolia,* a typical species of tropical countries (apart from Australia its native range is also found in South east Asian countries, namely Malaysia, Thailand, Myanmar as well as Vietnam and Pacific islands namely Melanesia, Polynesia, New Caledonia and Vanuatu) (Boland *et al.* 2006; Masterson 2007; Davey 2011; Wheeler *et al.* 2011), the other five species, namely *C. cristata, C. cunninghamiana C. glauca, C. obesa* and *C. pauper*, are native to this continent (table 2).

3.1.3 *Gymnostoma:* There are 18 species in the genus *Gymnostoma*. A single rare species, namely *G. australianum*, is found only in Australia. The native range of this species is restricted to northeastern Queensland in the protected heritage

Table 2. Indigenous plants of the genus *Casuarina* in Australia

Species	Native range restricted to Australia
C. cristata	Yes
C. cunninghamiana cunninghamiana	Yes
C. equisetifolia	No
C. glauca	Yes
C. obesa	Yes
C. pauper	Yes

rainforest region (Prider and Chirstophel 2000) (figure 2c). *Frankia* strains belonging to cluster 3 nodulate this plant (Normand 2006). This plant fixes atmospheric nitrogen (Sellstedt 1995).

Other species of this genus are common in New Guinea and Malesia (comprising the Malay Peninsula, Borneo, the Philippines, and the archipelago islands stretching from Sumatra to New Guinea). This genus was more widely distributed in Australia in earlier times (Greenwood and Christophel 2005).

3.2 *Elaeagnaceae (Oleaster family)*

Elaeagnaceae belongs to the order Rosales. Its family history dates back to twenty million years. Plants belonging to this family are adapted to xeric conditions. There are three genera in this family and nodulation is found in all of them. One of the species of the genus *Elaeagnus* namely *E. triflora* has its native range in Australia (figure 2d).

3.2.1 *Elaegnus:* The genus Eleagnus is a comparatively new genus in its family in terms of geological age. This genus has 45 species. One of its species namely *E. triflora* has its native range extending from Southern Asia to north and northeastern Australia. It is a shrubby vine. *E. triflora* is known as the 'Milla Milla vine' regionally in Queensland. *Frankia* strains belonging to cluster 3 nodulate this genus (Velazquez *et al.* 1998; Igual *et al.* 2003; Chaia *et al.* 2006).This genus fixes atmospheric nitrogen (Sellstedt 1995).

3.3 *Rhamnaceae (Buckthorn family)*

Rhamnaceae belongs to the order Rosales and is closely related to Elaeagnaceae (Richardson *et al.* 2000). This family has a worldwide distribution and has an ancient linage. There are about 50 genera in this family with around 900 species. Plants belonging to this family are adapted to xeric conditions. Six genera of this family are actinorhizal.

3.3.1 *Discaria:* This genus has 15 species native to temperate regions of southern hemisphere. *Discaria* belongs to the tribe Colletieae. Members of this tribe probably had their origins during Gondwanic times. Two out of 15 species of *Discaria* namely: *D. nitida* and *D. pubescens* have their native range restricted to southeastern regions of Australia, closer to the coast. They are popularly known as anchor plants. *D. nitida* is known as leafy/shiny anchor plant. Its native range is found only in south eastern regions of Australia in Eastern Victoria and southeast New South Wales. It also has its range in a small part of southeast Queensland (figure 2e). *D. pubescens* is known as hairy anchor plant. This species too has its native range restricted to eastern Australia. However, it has broader range of distribution extending from southeastern Queensland to Tasmania (figure 2f). Profuse nodulation has been found in *D. nitida* (Menkins 2009) in the field, whereas in *D. pubescens*, no nodules have been found in the field, although the species develops nodules under laboratory conditions (Hall and Parsons 1987; Aagesen 1999) and its nitrogen fixing ability has not been studied. These two species are placed under the category of vulnerable endemics of Australia. Frankia strains belong to cluster 3 nodulate this genus (Chaia *et al.* 2006).

4. Dominant actinorhizal plants of Australia

As stated earlier, casuarinas are the dominant actinorhizal plants of Australia. These plants are capable of growing in marginal soils, because like other actinorhizal plants they form symbiotic associations with beneficial microbes. Moreover, they have various xeric adaptations for tolerating the arid conditions found in most regions of their natural habitats. They also have the inbuilt capacity of withstanding other harsh climatic and environmental conditions and thrive in them. For instance they are capable of growing in difficult habitats like rocky sites (figure 3, photograph 1), in the desert regions of central Australia (figure 3, photograph 2) and survive in periodically flooded areas (figure 3, photograph 3).

4.1 *Uses of casuarinas*

Casuarinas are fast growing plants with many uses (table 3), and have been exploited for this reason in many parts of the world.

4.2 *Forests of casuarinas in Australia*

Although forests of casuarinas are found in all states of Australia, they have rarely been used for commercial purposes. A large number of species of casuarinas especially *Allocasuarin*a are shrubs, and therefore they cannot be

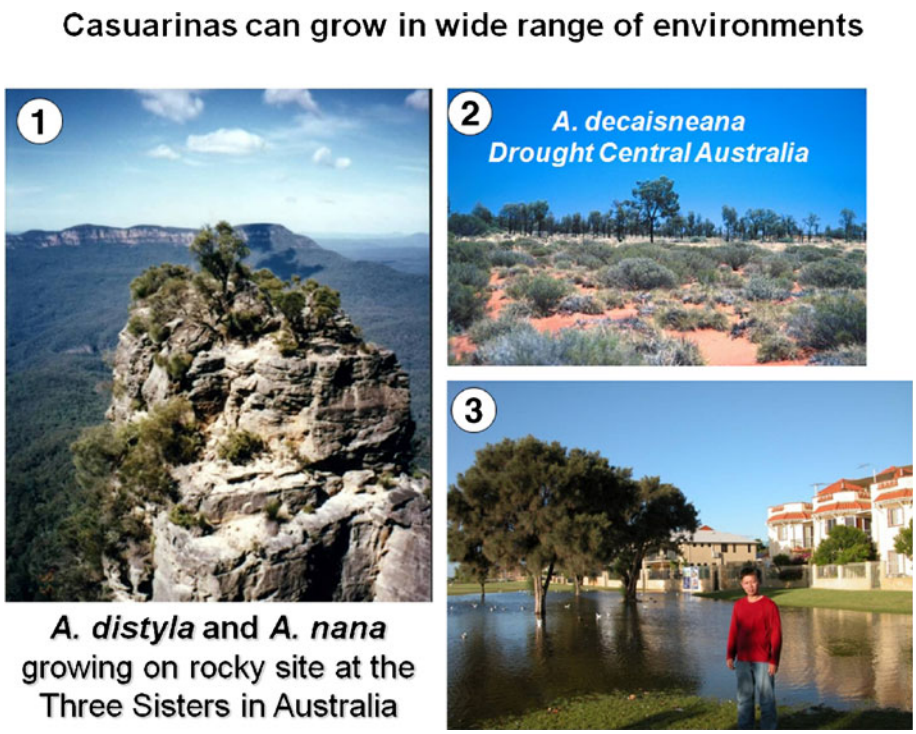

Figure 3. Examples of the various ecological niches where different species of casuarinas have adapted themselves for growth. Photograph 1 shows the shrubby *Allocasuarina* species growing on rocky site of the mountain in New South Wales. Photograph 2 shows the shrubby *Allocasuarina* species growing in drought affected area of Central Australia. Photograph 3 show *Casuarina* species growing in periodically inundated areas (Photograph by Claudine Franche).

classified as forests although a large number of these plants grow in vast areas as pure stands. In other areas casuarinas are too scantily distributed to be classified as forests. In some areas, species like *C. cristata* grow as mixed forest species in forests along with eucalypts and acacias. Only 1–2% of pure stands of casuarina forests are found in Australia. However, a wide variety of casuarinas are found in this continent.

5. Proposal for utilizing the attributes of native casuarinas

Even though it is a fact that in Queensland when land was cleared of Belah (*C. cristata*) and acacias for wheat cultivation, the crop did not need additional nitrogen fertilizer for decades (Kennedy 2012), casuarinas have never been used as biofertilizers. The most popular use of casuarinas at present

Table 3. Uses of casuarinas

Remediation of adverse soil conditions	Shield for strong wind currents	Wood	Miscellaneous
For reducing: alkalinity, acidity, and toxic metals levels as well as high moisture levels	Wind breaks/shelter belts	Timber from hard wood	Production of tannins, resins, indigenous medicines
For growing in soils with low moisture levels		Paper pulp from pulp wood	Ornamentals
Soil reclamation		Fuel	Shade plants
Erosion control			Nurse plants
Increasing soil fertility			Excellent Bonsai subject
			Foliage as fodder during lean times

in Australia is either planting them as roadside trees (figure 4) or using them as electricity poles, cut from native forests.

For exploiting the indigenously available casuarinas and availing the benefits thus obtained a plan of action has been proposed as follows:

- Increasing the population of casuarinas in farm–forestry rotations.

  Benefits: Saving casuarinas from decline and eventual extinction as well as greening more regions of Australia and making the soil in these regions, carbon and more importantly nitrogen rich. The increased population of casuarinas would also result in increase area of wild life habitat and providing food and shelter for native and endangered species like the glossy black cockatoos. The primary food source for these endangered birds is the seeds of casuarinas.
- Improvement of casuarinas from readily available gene pool.

  Benefits: Development of superior clones of casuarinas that grow rapidly and are high yielding in terms of wood and are disease resistant

  Utilities: The wood produced by this practice could be utilized as clean fuel for the production of electricity and has the potential to replace coal to a significant extent in Australia.
- Investigating the effectiveness of local *Frankia* on the superior clones of casuarinas and verifying if inoculum of selected strains of *Frankia* is needed for these clones for their performance.
- Evaluating the effect of local mycorrhizal fungi on the superior clones.

Investigation on the nitrogen fixing efficiency of a locally isolated *Frankia* strain compared to other well-known strains like CcI3 is being carried out in our laboratory.

If the isolated local strain turns out to be a very efficient nitrogen fixer, the need for the inoculation of the superior clones developed with this strain can be investigated.

6. Discussion

There are six genera and seventy species of native actinorhizal plants belonging to three families and two orders of dicotyledonous plants in Australia. The native range of most of these actinorhizal plants is restricted to Australia. Only two members of actinorhizal plants, namely *Casuarina equisetifolia* and *Elaeagnus triflora*, found indigenously in Australia, also have their native range elsewhere in the world. As stated earlier, casuarinas are dominant actinorhizal plants in the Australian scenario and possess excellent attributes typical of the actinorhizal plants. There are about 66 species of casuarinas in Australia and the native range of 65 of these species is restricted to Australia, giving rise to a vast array of readily available gene pool.

Although casuarinas are present in all the regions of Australia, different species have their native range in specific regions and have adaptations to suit their habitats. Majority of casuarinas are found concentrated in various regions of southern Australia including the arid regions (figure 2a and b).

Allocasuarina is more widely distributed in the central arid zone of Australia compared to Casuarina. One of the species of *Allocasuarina* namely *Allocasuarina decaisneana* grows in the hottest and most arid region of central Australia producing deep roots known as 'sinker' roots to reach deeply situated water tables up to the depth of 10 m. It is the dominant tree of this region. Quite often it is found to be

Figure 4. The photograph shows casuarinas growing as roadside trees on Bussell Highway, Western Australia.

the sole tree species growing in this region. Nodules are located quite deep in the soil (about 5 to 10 m deep) in this species. Both the genera have more or less similar type of distribution compared to *Allocasuarina*; the genus C*asuarina* in spite of having fewer species has a broader range of distribution in Australia and is much more widely distributed in New South Wales. This genus is also found in the northern regions of Northern Territories and western regions of northern Queensland, where *Allocasuarina* is absent or has only a minor presence; however, C*asuarina* has only a minor presence in Tasmania, whereas the genus *Allocasuarina* is distributed throughout this island state. The distribution pattern of *Allocasuarina* and *Casuarina* in various regions of Australia shows their versatile nature in terms of adapting to varied harsh environmental and climatic conditions and that the genus *Allocasuarina* is capable of growing in harsher habitats, indicating that it is probably the most specialized genus among Casuarinaceae (Duhoux *et al.* 1996). The distribution pattern of these two genera opens scope for molecular geneticists to venture into creating various types of hybrids capable of growing in much more varied conditions.

Majority of casuarinas are nitrogen-fixing plants, although the nitrogen fixing efficiency varies from species to species and is governed by the habitat they are located, and the strain of *Frankia* they are infected with. Nodulation has not been found in some of the species of *Allocasuarina.* Although *Frankia* strains belonging to sub-clade 'casuarina strains' of cluster 1 nodulate both the genera (Normand *et al.* 2007), the formation of noduls in *Allocasuarina* is quite sparse compared to *Casuarina* (Lawrie 1982, Dawson *et al.* 1989) due to the comparatively narrow host specificity of *Allocasuarina*-infective *Frankia* strains (Simonet *et al.* 1999). This could be one of the reasons for the difficulties faced in detecting nodules in *Allocasuarina.* Other probable reasons for not obtaining nodules in all the *Allocasuarina* species (considered as *Casuarina* species earlier), especially from the same species in different habitats, could be the influence of the local environment, availability of essential nutrients and the age of the plant (difficult to detect nodulation in big trees) and the presence of infective symbionts (Lawrie 1982). In Victoria, it was found that nodulation was scarce in plants growing about 70 km away from the coastal regions compared to the nodulation of these species in most of the coastal regions (Lawrie 1982). However, this is not the case with all the casuarinas. Nodulation has been found even in inland and arid regions on *A. decaisneana* (Hegazi *et al.* 1993). The other major influences on the formation of nodules are the topography of the habitat and its soil type, aeration, moisture levels, depth of soil and the type and depth of root system produced by the plants (deep rooted plants with very few lateral root systems cause sampling problems) as well as the available *Frankia* strain's sensitivity to various soil types (Dawson *et al.* 1989). One more reason for the difficulty faced for detecting nodulation in this genus could be that in dry locations, where this plant prefers to grow, very few microbes including *Frankia* can survive. It has also been suggested the reason for lower level of detection of nodulation in this genus could be due to the fact that it is on the verge of losing its symbiotic association (Simonet *et al.* 1999). The nitrogen fixing ability of some of the species in *Allocasuarina* has to be determined.

Nodules are formed more profusely in the genus *Casuarina* (Dawson *et al.* 1989) and the infective *Frankia* strains have a wider range of host specificity for *Casurina* (Simonet *et al.* 1999). However, the formation of nodulles in *Casuarina* species is also influenced by similar environmental conditions listed for *Allocasuarina* species. The percentage of nodules formed in *C. cunninghamiana* was found to be three times greater in sandy alluvial soils than in clayey loam red earth soils (Dawson *et al* (1989).

The nitrogen fixing abilities have been studied in many species of *Casuarina*. The lush green growth of casuarinas in regions like Murray Darling basin as well as in many other regions where it is grown as roadside tree (figure 4) suggests that these casuarinas are capable of fixing atmospheric nitrogen, but this observation needs verification (personal observation). *C. cunninghamiana* ssp. *cunninghamiana* is well known for its frost tolerance. *C. obesa* is the most salt-tolerant species of Australia. This species has a peculiar discontinuous distribution pattern. This species is mainly found in south Western Australia. Comparatively few species are also found in far northwest Victoria. *Casuarina glauca*, as mentioned earlier, has a prostrate form in its species apart from shrubs and small trees. Whether some these traits could be selected for the development of superior clones remains to be investigated.

Gymnostoma australianum because of its restricted distribution in wet tropics of northeastern Queensland is a rare species and considered as a habitat specialist. This species is also considered as relictual species (Prider and Chirstophel 2000). Although this plant is capable of growing in nutrient poor soils because of its capability to form symbiosis with *Frankia,* it is not very well adopted to xeric conditions like the casuarinas. The stomata on the foliage of this genus is exposed (suggestive of its name) and does not help in reducing the loss of water as against the other genera where it is hidden on their foliage, showing their adaptation to reduce evaporation. This plant needs plenty of water for its growth and does not tolerate shade. This plant is a slow growing species and assumes a conical shape without any need for pruning and resembles a Chrisms tree, giving opportunity to enterprising nursery dealers to sell it as Australian living 'Christmas Tree'.

Elaegnus triflora is a handsome shrubby vine with bright glossy green leaves on the upper surface and metallic gold to silver colour on the under surface, which gives it ornamental potential for landscape gardening. The fruit of this plant is edible. This species, which grows indigenously in eastern

Queensland, is considered as the outlier of its genus, which has its native range typically in temperate or subtropical regions of Asia.

Discaria nitida and *D. pubescens* grow indigenously in south eastern temperate zones of Australia not more than 300 km from the coastal region, mostly in rocky terrains. *D. pubescens* is also found growing indigenously in the island state of Tasmania. These species, typical to their actinorhizal status, are found in difficult terrains (rocky ridges and steep eroded hill sides). In favourable locations, they are quite common locally. Earlier they were mistaken for an African invasive species, namely *Lycium ferocissimum*, because of their resemblance to this plant, quite a number of them have been eradicated and therefore now they are considered as vulnerable species and are protected by legislation. One of the reasons for not finding nodules in *D. pubescens* could be the inability for the survival of its symbiont in the hostile conditions where this plant grows. However, this speculation needs to be verified.

But for casuarinas the other actinorhizal plants have only a minor presence in Australia and are only of academic interest at present; however, there is scope for investigating nitrogen fixing abilities in some of these species and evaluating and realizing their attributes and increasing the efforts for increasing the number of the endangered and rare actinorhizal plants of Australia instead of merely treating them as curios being sold in nurseries.

Popular Australian species of *Casuarina* that are grown outside their native range for their multiple uses are *C. cunninghamiana*, *C. equisetifolia* and *C. glauca* (Rockwood *et al.* 1990). These plants are capable of adapting and thriving in various climatic and ecological niches. In fact, in many regions these *Casuarina* species have been naturalized after their introduction. In countries like the United States of America, especially in Florida, their population has increased to such an extent that they are being treated as environmental weeds (Wheeler *et al.* 2011). By judiciously managing the plantations of casuarinas, their weedy nature can be systematically controlled.

In various third world countries, apart from growing casuarinas for uses like wind breaks, soil remediation and afforestation, they are also popularly grown for their wood (for fuel), timber and paper pulp production. Wood of casuarinas burns producing least amount of pollutants and has high calorific value, and is therefore considered as the best fuel in the world.

Superior clones of the popularly grown Australian species of *Casuarina* have been developed in the third world countries to suit the local needs, especially in China and India, and have been field-tested for their performance like growth rate, yield, and characteristics like resistance to diseases and tolerance to salinity. Nodulated clones have been shown to be superior performers as compared to clones without nodulation under nursery and field conditions (Karthikeyan *et al.* 2012, 2013).

To date, no serious attempts have been made for improving casuarinas and utilizing them in a farm forestry system in Australia. In southern Queensland, the attempts made for growing casuarinas in farm–forestry system in the last decade did not take off (personal communications). Only in Western Australia, *C. obese*, known as one of the best salt-tolerating species, is being used in some areas for farm–forestry. Only recently the willows that were popularly grown at the expense of native species by farmers are being replaced by native casuarinas in some areas.

It can be concluded that the attributes of casuarinas are clearly underutilized in Australia although a vast variety of these plants are found growing naturally here. With the available genetic variation, superior clones can be developed in this country and potentially cultivated in farm forestry rotational systems for harvesting forest products or the production of paper pulp and the lignocellulose generated could be utilized as feedstock for the chemical industry or as pelletized biofuel for the generation of electricity, even replacing coal to a significant extent (Kennedy 2012). This programme would also be eco–friendly, allowing rehabilitation of degraded lands suffering from acidity or salinity and benefiting wildlife significantly as well as increasing the declining population of casuarinas considerably. The nitrogen fixing ability of local *Frankia* strains and their infective ability and effect on the super-clones as well as any necessity for additional inoculum on these clones has to be evaluated. The effect of local mycorrhizal fungi on these clones also has to be investigated. If the above efforts in the authors' organization are successful, this work can be expanded to the suitable regions of Australia.

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