International Scholars Journals

Advances in Agriculture and Agricultural Sciences ISSN 2381-3911 Vol. 6 (7), pp. 001-006, July, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Author(s) retain the copyright of this article.

Full Length Research Paper

Actinorhizal plants of Kumaun Himalaya and their ecological significance

Kiran Bargali

Department of Botany, Kumaun University (K.U.) Nainital-263002, Uttarakhand, India. E-mail: kiranbargali@yahoo.co.in

Accepted 21 June, 2020

Actinorhizal plants are important in having symbiotic association with actinomycete Frankia. Nitrogen (N) fixation by actinorhizal plants is a major source of fixed N in diverse and widespread ecosystems including forests, bogs, swamps, coastal dunes, landslides, glacial deposits, shrublands, prairies and deserts. They play important roles in wild land ecosystem function and are used in land reclamation, range management, forestry, agroforestry and horticulture. In this study, 8 actinorhizal plants of Kumaun Himalayan region have been described. Habit, habitat, distribution and possible ecological significance of these plants are also described. These plants are not only important for the restoration of degraded lands, but also provide good source of timber, fuel wood, fodder, food and medicines, etc.

Key words: Actinorhizal, degraded, nitrogen, plantation, reclamation.

INTRODUCTION

Frankia, a filamentous bacterium (actinomycete), forms nodule like symbiotic associations with the roots of several plant species known collectively as "Actinorhizal plant". The actinorhizal symbiosis have been reported in numerous plants all over the word except Antartica (Baker and Schwinterzer, 1990). In any ecosystem, or at the scale of the whole planet, the element nitrogen (N) is an extremely important and often limiting nutrient. Legume-*Rhizobium* and actinorhizal plants-Frankia are two major plant symbiotic nitrogen fixation systems, which offer a low-input and cost effective tools in ecosystem restoration (Norris et al., 1994). Their ability to form nitrogen fixing nodules confers a selective advantage in poor soils.

The Himalayan mountain ranges are amongst the most fragile mountain systems in the world. Extensive deforestation in this region is resulting in soil erosion, floods, drying up of water sources, landslides and barren lands. Reclamation of such sites, thus, requires suitable species. A need was therefore felt to identify plant species that not only hasten the process of recovery in degraded lands, but could also serve significantly in the overall nitrogen economy of the region by replenishing nitrogen-poor habitats. This not only reflects the argu-ment previously produced for the importance of nitrogen fixing species in land reclamation, but also extends it to the subtleties of what may be involve in practice.

In the present study, an attempt has been made to identify the actinorhizal plants growing in Kumaun Himalayan region. The recent application of plant nitrogen fixation in ecosystem is a key step to understand its implications in ecological conservation, and future research direction. The results of present study will form a basis for further study and these plants can be further screened for their suitability and potential for nitrogen enrichment and amelioration of the degraded sites.

Description of the study site

Kumaun Himalaya (28°44' to 33°49' N latitudes and 78° 45' to 81°1' E longitudes), occupies the Central part of the Indian Himalaya, and covers an area of about 21,033 km^2. This region embraces six district viz. Nainital, Almora, Udham Singh Nagar, Bageshwar, Pithoragarh and Champawat (Figure 1).

The dissected topography and landscape with a great range of altitude (from 300 to 7436 m asl) resulted in a very diverse climatic condition. This eco-climatic variation has created several micro/macro habitat types resulting in high species/community diversity. The major climatic zones include the sub tropical, temperate and alpine zones. The rainfall pattern is largely governed by the monsoon and the year is divisible into three main

Figure 1. Location map of Kumaun Himalaya.

seasons viz. summer (April - mid June), rainy (mid June to September) and winter (October - February). The annual rainfall is about 2500 mm in most of the places of which, about 75% occur during rainy season (Singh and Singh, 1992).

METHODS

An extensive survey of Kumaun flora was made and information on actinorhizal plant species was collected. The information on habit, habitat, distribution and uses of these actinorhizal plants was also collected following Singh (1993), Samant et al. (1993, 1998) and Gaur (1999).

RESULTS AND DISCUSSION

Description of the actinorhizal plants

A total of 23 genera and 178 species belonging to phylogenetically divergent families are known to be able to form the actinorhizal symbiosis (Norris et al., 1994). The families containing actinorhizal plant species are Betulaceae, Casuarinaceae, Myricaceae, Rosaceae, Rhamnaceae Elaeagnaceae, Datiscaceae and Coriariaceae. In present study, 8 actinorhizal plant species have been described growing naturally or planted in Kumaun Himalayan region (Table 1).

Table 1. Actinorhizal plants of Kumaun Himalayan region.

Species	Family	Common name	Habit	Elevation (m asl)	Distribution	Uses
Alnus nepalensis D. Don	Betulaceae	Utees	Tree	1200-2500	Near streams forms gregarious patches	Wood used for carpentry and construction, bark used in local medicine; a fast growing tree used as soil binder in landslide area
Casurina equisetifolia J and G	Casuarinaceae	Beefwood	Leafless tree	Up to 800	Cultivated in outer Himalayan ranges	Used as an ornamental plant and fuel wood production; also used for reclamation of land on sandy soil.
Coriaia nepalensis Wall.	Coriariaceae	Makroli/masuri	Large deciduous shrub	1200-2600	On rocky and eroded slopes	Fruits edible, leaf and bark used to intoxicate fishes; baskets are made from the stem; used for plantation in land slide area.
Datisca cannabina Linn.	Datiscaceae	Bujr-bhanga	Erect annual herb	900-1500	In damp marshy places throughout the hills	Roots yield an important yellow dye for colouring cloths, plant juice is given in fever and roots are used in rheumatic pain.
Elaeagnus umbellate Thumb.	Elaeagnaceae	Silver berry	Shrub or small tree	1500-2200	Usually in open forest throughout the hills	Fruits edible and used in cough and bronchitis; wood used as fuel, leaves lopped for fodder and seed powder used as an expectorant
Elaeagnus. latifolia Linn.	Elaeagnaceae		Sub-deciduous shrub	1500-2000	Usually on swampy localities or bordering streams	Leaves lopped for fodder
Hippophae salicifolia D. Don	Elaeagnaceae	Tarwa/seabuckthorn	Tree	1500-3500	Common on river banks and damp places	The wood is useful as fuel and dry branches for hedges; fruit is acidic and made into several preparations, also used in local beverages, flowers used as a source of bee forage.
Myrica esculenta Ham. ex D. Don	Myricaceae	Kaphal	Tree	1500-2200	Common in *Quercus leucotrichophora* and mixed oak forests	Fruits edible and made into refreshing drinks, bark used to intoxicate fishes and yield yellow dye; wood used as fuel and implements.

***Alnus nepalensis* D. Don**

The Himalayan alder (*Alnus nepalensis*) is indigenous to the subtropical and temperate belts of the central and eastern Himalayas. It belongs to the family Betulaceae that is comprised of 6 genera and about 130 species (Mabberely, 1988). This family is characterized by the synapomorphies of male and female compound catkins

and pollen morphology (Chen et al., 1999). *Alnus* is the only actinorhizal member of the family Betulaceae, and all the species of *Alnus* examined so far bear root nodules.

It grows in a wide range of habitats, from glacial hill, sand hills, and bogs to dry volcanic lava, ash alluvium, and water courses (Schwencke and Caru, 2001; Silvester, 1977). *A. nepalensis* is a deciduous tree to 35 m height with dark green or silvery grey bark, and leaves are elliptical or broadly ovate. Flowers are small, appearing before leaves; male catkin is slender, 4 - 20 cm long, green in terminal drooping panicles. Female spikes are small, in axillary racemes forming ovoid, 1.2 to 2 cm long cones.

***Casuarina equisetifolia* J and G**

The *Casuarina eqisetifolia* is a leafless tree in which leaves are reduced to toothed sheaths, surrounding the nodes. The branches terminating in slender, drooping, jointed branchlets. Male spike is cylindrical to 2.5 cm long with one stamen in each flower. Female flowers in globose or ovoid heads almost comb like and become woody when ripe. It comes under family Casuarinaceae represented by four genera (*Gymnostoma* L., *Ceuthostoma* L., *Casuarina* L. and *Allocasuarina* L.) and about 96 species. Of these, *Casuarina* is represented by 17 species with 3 to 4 species naturalised in India. *C. equisetifolia* is supposed to be native of Bangladesh and Myanmar, and extends to Indomalaysia islands and Australia (Gaur, 1999).

***Coriaria nepalensis* Wall**

Coriaria nepalensis is a common native shrub species of the Central Himalayan region between 1200 to 2500 m elevations. It is predominant in both disturbed and undisturbed forest ecosystems, often present in secondary forest and is a successful coloniser of landslide-affected or freshly exposed rocky and eroded slopes. The genus *Coriaria* has 5 to 20 species depending on the particular classification (Yokoyama et al., 2000) and a remarkable geographic distribution. It is found in the Mediterranean, Southeast Asia, Central and South America, and the Pacific islands of New Zealand and Papua New Guinea (Skog, 1972) . Nodules have been observed on *Coriaria* species from New Zealand (*C. arborea*, *C. plumosa, C. sarmentosa, C. angustissima* and *C. pottsiana*), from Central America (*C. microphylla*), Europe (*C. myrtifolia*) and Central Asia (*C. nepalensis*) (Mirza et al., 1994; Nick et al., 1992; Silvester, 1977). *C. nepalensis* is a deciduous shrub with spreading branches and reddish brown bark. Leaves simple sub sessile ovate or elliptical. Flowers 4 - 5 mm across, greenish yellow, bisexual or polygamous in axillary, solitary or clustered racemes of 3-9 cm long.

***Datisca cannabina* Linn**

Datisca is the monotypic taxon of East Mediterranean and West Asia. Molecular phylogenetic work, places only the genus *Datisca* in the family Datiscaceae with two species. Both *Datisca* species bear root nodules (Swensen et al., 1998, 1994). *Dastica canabina* is erect robust which two species viz. *Elaeagnus parvifolia* and *E. latifolia* grow naturally in Kumaun Himalyan region. *E. parvifolia* is a deciduous, throny shrub to 6 m high, covered with minute silvery scales. Leaves elliptic-oblong, coriaceous acute at both ends, and clothed below with bright silvery scales. Flowers silvery white fragrant, shortly stalked arranged in axillary clusters on short arrested branches.

***Elaeagnus latifolia* Linn**

It is a deciduous shrub scandent, often producing strong adventitious shoots with rusty coloured bark usually armed with straight or recurved throns. Leaves are elliptical, obtuse, base rounded or acute, and densely clothed on both surfaces. Flowers are yellow, in axillary, usually many flowered clusters.

***Hippophae salicifolia* D. Don**

The number of species within *Hippophae* has been in dispute, with numbers ranging from one to seven with numerous sub species (Bartish et al., 2002). *Hippophae* is native to central Asia, distributed from the North Sea to the Black Sea and east to the Himalayas. The plant is deciduous, dioecious, much branched, extends freely through suckers and usually thorny with alternate narrow lanceolate leaves covered with rust coloured scales/hairs and precocious flowers. Leaves oblong-lanceolate stellately pubescent on upper surface and white tomentose on lower surface. Male flowers in axillary clusters, female flowers usually solitary.

***Myrica esculenta* Ham. ex D.Don**

Myrica esculanta is an evergreen tree, 14 m high with brownish-grey, rough, and vertically wrinkled bark. Leaves alternate, crowed at the end of branches, oblanceolate, entire, acute, glossy above, and glaucous dotted below. Flowers are minute, male flowers are 1.2 - 1.5 cm long pale-brown reddish catkins, in branched axillary clusters. Female flowers in erect axillary spikes. Nodulation has been observed on all species of *Myrica*.

***Rubus ellipticus* Smith**

Rubus ellipticus is a common shrub species of Kumaun

Himalayan region. Becking (1984) reported that in *R. ellipticus,* the endosymbiont is located in a circular band near the epidermis. However, no strains of Frankia has been successfully isolated from *R. ellipticus* , although this may also be related to their restricted geographical distribution; therefore, further evidence will be required confirming the nodulation of this genus by Frankia.

Nodulation behaviour of actinorhizal plants

The majority of plants in the eight families that include actinorhizal taxa do not form the symbiotic association. All members are nodulated in the family Coriariaceae, Elaeagnaceae, Datiscaceae and Casuarinaceae whereas only a portion of the genera is nodulated in the family Betulaceae, Myricaceae, Rhamnaceae and the Rosaceae (Mirza et al., 1994; Nick et al., 1992; Silvester, 1977). Actinorhizal nodules appear in a variety of forms in the field. Nodules have a range of colors from light yellow to orange, to various hues of brown and even red. In size, they range from less than a millimeter for very young nodules up to more than 10 cm for older nodules that have developed in loose sandy soil. The larger nodules (more than 1 cm) generally have active nitrogen-fixing tissue on the tip of young nodule lobes. The older portion of the nodule in the interior of the cluster is frequently quite senescent and inactive. Nodules are perennial and can continue to develop from season to season over several years. The position of the nodules on roots varies with the plant and environment in which the plant lives. For example, alder trees growing near water tend to bear nodules quite near the surface such that merely brushing away the leaf litter beneath an alder plant reveals dozens of nodules. By contrast, the *Coriaria* plants that dwell in dry rocky soil tend to have nodules that are quite deep and may be difficult to find in rocky soil.

Ecological significance of actinorhizal plants

Actinorhizal plants serve numerous functions in forest ecosystems. Nitrogen fixation by these plants is a viable means to replace N lost by perturbation in forests. They can contribute as much nitrogen per hectare as the most productive legumes. The nitrogen fixation rate measured for some alder species is as high as 300 Kg of N_2 $ha^{-1}yr^{-1,}$ close to the highest rate reported in legumes (Zavitovski and Newton, 1968). These N-fixing plants are pioneer, establishing after natural or anthropogenic disturbances and often persist until shaded by over storey trees. Being among the first species to colonize the disturbed environ-ments, actinorhizal plants play a critical role, enriching the soil and enabling the establishment of other species in an ecological succession (Wall, 2000). In addition, different actinorhizal species have ability to grow well under a range of environmental stresses such as high salanity, heavy metal, and extreme pH (Dawson, 1990). Such adaptations make actinorhizal plants useful for fuel wood production, agroforestry and land reclamation (Diem and Dommergues, 1990). *Alnus*, *Coriaria*, *Elaeagnus*, and *Hippophae* are widely planted to prevent soil erosion. Planting plants like *Alnus* for lumber pulp or fuel wood production is the second common use of actinorhizal trees. Some actinorhizal species are used as nurse crops for economically important non-nitrogen fixing plants. The *Hippophae*, one of the few potential resources has been reported to offer hope to give multipurpose benefits to the hill people. It can help to improve the degraded environmental conditions. The executive root system, ability to withstand harsh climatic conditions, salt tolerance, ability to fix atmospheric nitrogen, firewood with high calorific value and higher vitamin C content in fruits make this species very useful for human being (Bhatt et al., 1993). *Casuarina* is the genus extending to tropical areas; its ability to grow under extremely difficult conditions makes it an interesting plant for reforestation programmes as well as production for firewood.

Fruits of *M. esculenta* and others are not only consumed by local people but are also a source of income generation. They are collected and sold in the market by local people and help to generate income to meet their daily needs. In addition, *Myrica spp.* is also useful in traditional medicine system for prevention and cure of flu, cold, etc.

The plants described in present study are of high economic importance to the people (Table 1). They not only solve the problems of fuel wood and fodder for the local people, but could also strengthen their economy. These plant species are also capable of colonising the degraded ecosystems. The low nutritional requirements and an efficient use of the nutrients absorbed make these plants useful not only for restoring the ecological balance in the Himalayas but also for meeting the demands for the local people. These plants should therefore, form basis of eco-development and management of waste and degraded lands in Kumaun Himalayan region in following ways:

(1) They can be planted for timber and pulpwood (*Alnus*, *Casuarina*).
(2) They can be interplanted as nurse plants for other more valuable species (*Alnus*, *Coriaria*).
(3) They can be planted as a component of multipurpose agroforestry plantations (*Alnus*, *Casuarina*).
(4) They can be used for reclamation of degraded lands (*Elaegnus, Alnus, Coriaria, Hippophae*).

ACKNOWLEDGEMENT

Financial support from Department of Science and Technology, New Delhi in form of SERC Fast Track Project is gratefully acknowledged.

REFERENCES

Baker DD, Schwintzer CR (1990). Introduction, In The Biology of *Frankia* and Actinorhizal Plants. (eds) CR Schwintzer and J D Tjepkema. Academic Press, Inc., New York, pp. 3-13.

Bartish V, Jeppsson N, Nybom H, Swenson U (2002). Phylogeny of *Hippophae* (Elaeagnaceae) inferred from Parsimony Analysis of chloroplast DNA and morphology. Syst. Bot., 27: 41-54.

Bhatt AK, Agrawal HO, Pratap T (1993). Seabuckthorn (*Hippophae* L.) and sustainable mountain development: In Himalayan biodiversity (ed) U Dhar. Gyanodaya Prakashan, Nainital, pp. 439-450.

Chen Z, Manchester SR, Sun H **(**1999). Phylogeny and evolution of the Betulaceae inferred from DNA sequences, morphology, and paleobotany. Am. J. Bot., pp. 1168-1181.

Dawson JO (1990). Interactions among actinorhizal and associated plants species. In: Schwintzer C.R. and Tjepkema J.D. (eds) The Biology of *Frankia* and Actinorhizal plants. Academic Press, New York, pp. 299-316.

Diem HG, Dommergues YD (1990). Current and potential uses and management of casuarinaceae in Tropics and Subtropics. In: Schwintzer C.R. and Tjepkema JD (eds) The Biology of *Frankia* and Actinorhizal plants. Academic Press, New York, pp. 317-342.

Gaur RD (1999). Flora of the district Garhwal north west Himalaya (with ethanobotanical notes. Transmedia publication, Srinagar (Garhwal) UP, India. p. 812.

Mirza MS, Pawlowski K, Hafeez FY, Chaudhary AH, Akkermans ADL (1994). Ultrastructure of the endophyte and localization of *nifH* transcripts in root nodules of *Coriaria nepalensis* Wall. by *in situ* hybridization. New Phytol., 126: 131-136.

Mirza MS, Hameed S, Akkermans ADL (1994). Genetic diversity of *Datisca cannabina*-compatible *Frankia* strains as determined by sequence analysis of the PCR-amplified 16S rRNA gene. Appl. Environ. Microbiol., 60: 2371-2376.

Nick G, Paget E, Simonet P, Moiroud A, Normand P (1992). The nodular endophytes of Coriaria sp. form a distinct lineage within the genus *Frankia*. Mol. Ecol., 1: 175-181.

Norris JR, Read D, Verma AK (1994). Techniques for mycorrhizal research : Methods in microboilogy. Academic Press, Harcourt Brace and Company, Publishers, London, p. 928.

Samant SS, Rawal RS, Dhar U (1993). Botanical hot spots of Kumaun: conservation perspectives for the Himalaya. In Himalayan Biodiversity: Conservation Strategies. (ed) U. Dhar. Gyanodaya Prakashan, Nainital, pp. 377-400.

Samant SS, Dhar U, Palni LMS (1998). Medicinal plants of Indian Himalaya: Diversity, distribution potential values. Gyanodaya Prakashan, Nainital, p. 163.

Schwencke J, Caru M (2001). Advances in actinorhizal symbiosis: Host plant-*Frankia* interactions, biology, and application in arid land reclamation. A review. Arid Land Res. Manage., 15: 285-327.

Silvester WB (1977). Dinitrogen fixation by plant associations excluding legumes:. In A Treatise on Dinitrogen Fixation (eds) R W F Hardy and A H Gibson, John Wiley and Sons, New York, 4: 141-190.

Singh JS, Singh SP (1992). Forest of Himalaya: Structure, function and impact of man. Gyanodaya Prakashan, Nainital, p. 268.

Singh VK (1993). Exploitation and threat to some medicinal plant and folk drugs of Garhwal and Kumaun regions of Uttar Pradesh, India: In Himalayan Biodiversity: Conservation Strategies (ed) U. Dhar. Gyanodaya Prakashan, Nainital, pp. 403-412.

Skog LE (1972). The genus *Coriaria* (Coriariaceae) in the western Hemisphere. Rhodera, 74: 242-253.

Swensen S M, Luthi JN, Rieseberg LH (1998). Datiscaceae revisited: Monophyly and the sequence of breeding system evolution. Syst. Bot., 23: 157-169.

Swensen SM, Mullin BC, Chase MW (1994). Phylogenetic affinities of the Datiscaceae based on an analysis of nucleotide sequences from the plastid *rbcL* gene. Syst. Bot., 19: 157-168.

Wall L (2000). The actinorhizal symbiosis. J. Plant Growth Regul., 19: 167-182.

Yokoyama J, Suzuki M, Iwatsuki K, Hasebe M (2000). Molecular phylogeny of *Coriaria*, with special emphasis on the disjunct distribution. Mol. Phylogen. Evol., 14: 11-19.

Zavitovski J, Newton M (1968). Ecolofical importance of snowbush *Ceanothus velutinusin* the Oregon Cascade. Ecol., 49: 1134-1145.