WOODY NON-LEGUME NITROGEN FIXING PLANTS[1]

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Nitrogen is an essential inorganic element for all forms of life and, with the exception of water, is the most frequently encountered limiting factor in crop production. Organisms capable of using atmospheric nitrogen ordinarily require no other source, but those lacking this capability are dependent upon nitrogen from fertilizer or soil reserves. Biological nitrogen fixation of atmospheric nitrogen not only supplies the element to the fixing organism, but is a source of nitrogen for other plants. This occurs through leakage and plant decomposition in a variety of habitats that are important in food production, prevention of erosion and maintenance of ecological balances.

Nitrogen fixation by legumes has long been recognized and has become an important part of modern agriculture. The occurrence of nodules and nitrogen fixation by non-legume angiosperms is less noted but offers many potential uses.

The first occurrence of nodules on nonlegumes was recorded early in the nineteenth century (25). The latest widely-accepted compilation reports 157 species in 13 genera as possessing nodules (8), including *Alnus, Arctostaphylos, Casuarina, Cercocarpus, Coriaria, Discaria, Dryas, Elaeagnus, Hippophae, Myrica, Purshia* and *Shepherdia. Comptonia peregrina* (L.) Coult. var., *asplenifolia* (L.) Fern, reported as a nodulating genus in some earlier lists, has also been called *Myrica asplenifolia* L.

Several changes have appeared in the literature since the compilation of this listing. *Arctostaphylos uva-ursi* was reported to possess *Alnus*-type root nodules apparently solely on external inspection of nodular structures (1). Under microscopic examination the "nodules" were found to be aggregates of latent buds and sprouting was induced.

Farnsworth and Hammond (14) observed nodules on the roots of *Artemisia ludoviciana*, family Compositae, and reported the endophyte to be bacterial. Reduction of acetylene to ethylene, a test of nitrogen-fixing activity, was recorded. Apparently nodulation also occurred on prickly pear cactus (*Opuntia fragilis*, family Cactaceae) (14), but acetylene reduction has not been reported. Nodulation and acetylene reduction by *Datisca cannabina* and *D. glomerata*, family Datiscaceae, has been recorded (12).

Isolation of the nitrogen-fixing organism associated with non-legume plants has been attempted by a number of investigators with varying amounts of success.

Callahan, et al. (9) successfully isolated the actinomycete symbiont from nodules of *Comptonia peregrina* var. *asplenifolia* (Syn.: *M. asplenifolia*) after incubation and enzyme maceration. Reinfection of sterile seedlings was achieved repeatedly and the same actinomycete reisolated from these seedling nodules. The induced nodules actively reduced acetylene to ethylene. The isolate has also successfully induced root nodules with high acetylene reduction activity in seedlings of *M. gale*, *M. cerifera*, *Alnus crispa*, and *A. glutinosa* (14,23). However, attempts to nodulate *Elaeagnus umbellata* were unsuccessful (5).

The taxonomic status of actinomycete root nodule endophytes has not been duly defined (14,23). Becking (2) applied the generic name *Frankenia*, in the single family Frankeniaceae, to the endophytes of nonleguminous nodules and designated specific epithets referable to the host species or to the original designations. With the successful isolation of the organism of *C. peregrina* var. *asplenifolia* and infection by the isolate in other genera, more appropriate scientific designation may be forthcoming.

The ecological importance of actinomycete-nodulated plants as pioneer species is well documented. *Dryas drummondii* and *Shepherdia canadensis* were early colonizers in recently deglaciated areas in Alaska. *Alnus crispa* usually followed and became dominant. Soil analysis under alder thickets estimated an annual accumulation of 62 kg N/ha, resulting chiefly from nodular fixation (7). *Myrica pensylvanica* appears to be a key successional plant on nitrogen impoverished coastal soils and dunes (27) and growth of young pitch pine (*Pinus rigida*) was significantly greater within *M. pensylvanica* stands (34). *Ceanothus veluinus* is one of the first plants to grow back after conifer forests in the Pacific Northwest are burned or logged (39).

Alnus oregona (Syn.: *A. rubra*) is the largest fiber producing species per unit area (17), and accounts for more than 60% of all merchantile hardwoods in the Pacific Northwest (30). *Ceanothus sanguineus*, *Purshia tridentata* and *P. glandulosa* are desirable grazing (30) and browse plants. *Purshia* spp. have a protein digestability coefficient slightly above that for alfalfa (*Medicago sativa*) (30). Silvester (30) reviewed many other direct uses for other nonlegume nitrogen-fixing species.

Several non-legume nitrogen-fixing species have been used to increase the growth of forest crops. *Alnus* spp. have been shown to improve fertility and physical properties of soil (35).

The soil fertility beneath a mixed stand of *Alnus oregona* and *Pseudotsuga menziesii* (Douglas fir) was greater than beneath a pure Douglas-fir stand (33). *Alnus oregona* added 200-300 kg N/ha/yr when growing in mixed forest stands and provided nitrogen for associated trees (31). A light understory of *A. oregona* added 200 pounds total nitrogen/A whereas a heavy stand added 780 pounds total nitrogen/A (4). *Alnus oregona* is currently used to improve conifer sites and stands in a rotation or as an interplanted nurse crop (17,32). *Purshia tridentata* is widely distributed in ponderosa pine (*Pinus ponderosa*) forests of the West and makes a significant contribution to the nitrogen economics of the local ecosystem (37). Wollum and Youngberg (38) found seedlings of Monterey pine (*P. radiata*) grown in containers after *Ceanothus velutinus* were comparable to those grown with 35 ppm added nitrogen. The use of *Elaeagnus umbellata* as a nurse crop significantly increased the growth of black walnuts (*Juglans nigra*) (46).

Alnus spp. and other non-legume nitrogen fixers have been widely used for reclamation of disturbed sites and sand dunes in Europe and Japan (21,30,36). The use of *A. glutinosa* for reforestation of disturbed sites in the United States was suggested by Kohnke (22) and its use, especially on strip-mines, has increased in recent years (45). Alder was particularly desirable in such situations because of their ready establishment, rapid growth, abundant leaf litter production and their ability to fix atmospheric nitrogen. The use of other nitrogen-fixing nonlegumes for reclamation is promising (11).

Elaeagnus spp. and other non-legume nitrogen species have been used to develop low maintenance landscapes along several of this nation's roadsides. These plants provide perennial, aesthetically pleasing cover. The need and expense of continuous nitrogen fertilizer application is eliminated in these plantings (10,26).

Both legume and actinomycete-nodulated nitrogen-fixing species offer advantages in more traditional landscape sites. The condition of many sites is little better than those resulting from mining or highway construction. Maintenace may be reduced because of a continuous supply of nitrogen to the entire plant community.

Currently, the intentional use of nitrogen-fixing species in landscape is not common. Information on specific environmental requirements, as well as horticultural descriptions, are somewhat limited. The production and supply of nitrogen-fixing plants is limited and in some cases nonexistent. As more information on potential uses and culture of nitrogen-fixing species increases, potential markets will also increase. Nurserymen should be aware of these potential sales areas.

The following nitrogen-fixing non-legumes are among those with the most immediate use in landscape and reclamation uses. Other genera and species may also provide regional and widespread uses and benefits.

Alders. Several species of alder are common internationally. *Alnus incana* as well as *A. glutinosa* are more common in Europe, although available in the United States. Distribution of other alders useful in the landscape finds: 1. *Alnus rhombifolia* used regularly in California, 2. *Alnus oregona* of major commercial importance in the Pacific Northwest, 3. *A. incana* in coldern northern climates, and 4. *A. maritima* a promising landscape species along the Atlantic Coast.

For the most part, the alders are grown for landscape use in wet areas. This group of plants may possess one of the highest transpiration rates within tree species. Therefore, they have the need and ability to live in wet landscape sites.

Propagation is commonly done by seeds which mature in late fall and are sown in the spring. Seeding techniques can be critical because the seed is fine and lightweight and cannot tolerate deep covering. Best results occur with no covering or a light, airy covering.

Seeds become non-viable without proper storage. Seeds stored in air-tight containers at 1° to 3°C (34° to 37°F) remain viable for one to two years (28). Dried seeds may benefit from cold stratification (13,28). Cultivars are generally propagated by stem cuttings or grafting (29).

Elaeagnus. This plant group includes several species (*Elaeagnus angustifolia, E. commutata, E. pungens* and *E. umbellata*) of landscape value where soils are poor or dry. Thorns and microscopic-sized structural scales are also genus characteristics.

Plants may be propagated by seed, cuttings or layering (29). *Elaeagnus pungens* is noted for several cultivars. These may be propagated by cuttings taken during midsummer and placed under mist or as hardwood cuttings in the fall (29).

Elaeagnus umbellata 'Cardinal' is one of a few woody cultivars that is propagated true from seed. Seed propagation with this species is slow. Germination restriction has been shown to be caused by inhibiting substances in the fruit or seed parts (18). This inhibition can be overcome by the production of germination promoters in the seed or stratification at 1°C (34°F) for 90 days (28). Seed collection must be timely, since plants in this genus are used for wildlife food and cover.

Shepherdia. Buffaloberry (*Shepherdia argentea*) is well adapted to dry, poor locations in the North Central United States (6). Buffaloberry and Russett buffaloberry (*S. canadensis*), which is also adapted to poor sites, have attractive silvery foliage. Yellow and red fruit selections are available.

Seeds of both *S. argentea* and *S. canadensis* are planted in the fall or stratified for 60 to 90 days and planted in the spring (28). Acid scarification of *S. canadensis* may improve germination. Wild plants of *S. argentea* are also collected and marketed.

Sweetfern. Sweetfern (*Comptonia peregrina* var. *asplenifolia*) is a low-growing shrub native to the Atlantic Coast and Northeastern United States. It is best noted for its ability to stabilize sandy soils and do well on otherwise poor sites. While not noted for floral or fruit display, it is distinctive for leaf shape and fragrance (24).

Availability of sweetfern in the nursery trade has been limited because of both propagation problems and poor transplantability. The majority of available plants have been collected and therefore roots have been coarse and few in numbers. The plant does well when produced in containers, and container-grown plants have shown no transplanting problems.

Large-scale propagation has been limited by lack of good seed sources, poor seed germination and lack of rooting with stem cuttings. Propagation has been limited primarily to root cuttings, which means sacrificing of the parent plant. Recent work has indicated root cutting success is improved by relating cutting length to root diameter. Stem cuttings of juvenile growth originating from root cuttings and treated with Hormodin #2 have rooted with excellent success (20).

Bayberry. The blue-gray fruit and fragrance of bayberries (*Myrica californica, M. cerifera, M. gale* and *M. pensylvanica*) make their landscape interest special. These evergreen to semi-evergreen trees and shrubs are dioecious, producing fruit only on pistillate flowering plants. The wax produced on the outer surface of the fruit is used in making bayberry candles.

The most common procedure for propagation is by seed. While in storage, the waxy seed covering should be left intact. The seed will store up to one year. Before stratifying, the waxy coating should be removed mechanically. Stratification ranges from 30 to 90 days depending on species (28). Germination may be enhanced by using gibberellic acid (3,18). Cutting propagation can also be carried out in late summer using half-ripe stem cuttings (29).

LITERATURE CITED

1. Allen, E.K., O. Allen and L. Klebesandel. 1964. An insight into nitrogen-fixing plant associations in Alaska. *In: Science in Alaska.* G. Dahgren (Ed.) Proc. 14th Alaskan Sci. Conf., Ankorage. p. 54-63.
2. Becking, J.H. 1979. *Frankiaceae* Fam. Nov. (Actinomycetales) with one new combination and six new species of the genus *Frankia. Intl. J. Syst. Bacteriol.* 20:201-220.
3. Benson, D.R. 1978. Rutgers University, personal communication.
4. Berg, A. and A. Doerksen. 1975. Natural fertilization of a heavily thinned Douglas-fir stand by understory of red alder. Rsh. Note No. 56. Forest Rsh. Lab., Oregon State Univ., Corvallis.
5. Berry, A., D. Callaham, J. Tjepkema and J.G. Torrey. 1978. Isolation and culture of actinomycetes from nodules of Comptonia and other genera. In: Symposium on Nitrogen Fixation in Actinomycete-nodulated plants. Harvard Forest, Harvard Univ., Petersham, Massachusetts.
6. Bhella, H.S. 1979. Woody Ornamental and Shelter Plants for the North Central Region. U.S.D.A. N.C. Reg. Plant Intro. Stn. Ames, Iowa.
7. Bond, G. 1967. Fixation of nitrogen by higher plants other than legumes. *Ann. Rev. Plant Physiol.* 18:107-126.
8. Bond, G. 1976. The results of the IBP survey of root nodule formation in non-leguminous angiosperms. *In: Symbiotic Nitrogen in Plants.* P.S. Nutman (Ed.) Cambridge Univ. Press, Cambridge. pp. 442-476.
9. Callahan, D., J.G. Torrey and R. Del Tredici. 1978. Isolation and cultivation *in vitro* of the Actinomycete causing root nodulation in *Comptonia. Science* 199:899-902.
10. Carpener, P. and D. Hensley, 1977. Factors influencing nitrogen fixation by several woody shrubs and trees. *In: Development of Techniques for Plant Establishment on the Roadside.* JHRP-76-35. Purdue University, W. Lafayette, IN. p. 7-12.
11. Carpenter, P.L. and D.L. Hensley, 1979. Utilizing N_2-fixing woody plant species for distressed soils. *Bot. Gaz.* 1405:76-81.
12. Chaudhary, A.H. 1979. Nitrogen-fixing root nodules in *Datisca Cannabina* L. *Plant Soil.* 51:163-165.
13. Dirr, M.A. 1977. Manual of Woody Landscape Plants: *Their Identification, Ornamental Characteristics, Culture, Propagation and Uses.* Stipes Publishing Co., Champaign, IL. 535p.
14. Farnsworth, R.B. and M.W. Hammond. 1968. Root nodules and isolation of endophyte on *Artemesia ludoviciana. Proc. Utah Acad. Sci.* 45:182-188.
15. Funk, D.T. 1973. Growth and development of alder plantings on Ohio strip-mine banks. *In: Ecology and Reclamation of Devastated Land.* Vol. 1. R.J. Hutnik and G. Davis (Eds.). Gordon and Breach, New York. p. 483-491.
16. Funk, D.T. R. Schlesinger and F. Ponder. 1979. Autumn-olive as a nurse crop for black walnut. *Bot. Gaz.* 1405:110-114.
17. Gordon, J.C. and J.O. Dawson, 1979. Potential uses of nitrogen-fixing trees and shrubs in commercial forestry. *Bot. Gaz.* 1405:88-90.
18. Hamilton, D.F. and P.L. Carpenter. 1975. Regulation of seed dormancy in *Elaeagnus umbellata* by endogenous growth substances. *Can. J. Botany* 53(20):2303-2311.
19. Hamilton, D.F. and P.L. Carpenter. 1977. Seed germination of *Myrica pensylvanicum* L. *Hortscience,* 12(6):565-566.

20. Hamilton, W.W. 1974. Container production of sweetfern. *Intnl. Plant Prop. Soc. Proc.* 24:364-366.

21. Hashimoto, N.T., Kokima, M. Ogawa and T. Suzuke. 1973. Effects of alder and acadia on devastated land. *In: Ecology and Reclamation of Devastated Land*. Vol. 1 R.J. Hutnik and G. Davis (Eds.). Gordon and Breach, New York. p. 357-367.

22. Kohnke, H. 1941. The black alder as a pioneer tree in sand dunes and eroded land. *J. For.* 39:333-334.

23. LaLonde, M. 1979. Immunological and ultrastructural demonstration of the nodulation of the European *Alnus glutinosa* (L.) Gaertn. host plant by an actinomycetal isolate of the North American *Comptonia peregrina* (L.) Coult. root nodule. *Bot. Gaz.* 1405:35-43.

24. Lewis, C.E. 1979. *Comptonia peregrina. Am. Nurs.* 150(4):34-36.

25. Meyeh, J. 1829. Uberdas herauswachsen parasitischer gewachse aus den wurzeln anderer pflanzen. *Flora* (Jena) 12:49-63.

26. McNiel, R.E. and P.L. Carpenter. 1972. In: Nitrogen availability to woody plant species as influenced by nitrogen fixation. JHRP 13. Purdue University, W. Lafayette, IN. 47907.

27. Morris, M., D.E. Eveleigh, S.C. Riggs and W.N. Tiffney, Jr. 1974. Nitrogen fixation in the bayberry (*Myrica pensylvanica*) and its role in the coastal succession. *Amer. J. Bot.* 61:867-870.

28. Schopmeyer, C.S. 1974. *Seeds of Woody Plants in the United States*. U.S.D.A. Agricultural Handbook No. 450. 883pp.

29. Sheat, W.G. 1965. *Propagation of Trees, Shrubs and Conifers*. MacMillan & Co., New York. 479pp.

30. Silvester, W.B. 1977. Dinitrogen fixation by plant associations excluding legumes. *In: A Treatise on Dinitrogen Fixation. Section IV. Agronomy and Biology*. R.W.F. Hardy and A.H. Gibson (Eds.). John Wiley and Sons, Inc., New York. p. 141-190.

31. Stewart, W.D.P. 1977. Present-day nitrogen-fixing plants. *Ambio* 6:166-173.

32. Tarrant, R.E. 1972. The role of alder in improving soil fertility and growth of associated trees. *In: Managing Young Forests in the Douglas-fir Region*. A.B. Berg (Ed.). School of Forestry, Oregon State Univ., Corvallis, OR 3:17-34.

33. Tarrant, R.E. and R.E. Miller. 1963. Accumulation of organic matter and soil nitrogen beneath plantation red alder and Douglas-fir. *Proc. Soil Sci. Soc. Amer.* 27:231-234.

34. Tiffney, W.N. Jr. and J.F. Barrera. 1979. Comparative growth of pitch and Japanese black pine in clumps of the nitrogen-fixing shrub, bayberry. *Bot. Gaz.* 1405:108-109.

35. Trappe, J.M., J.F. Franklin, R.E. Tarrant and G.M. Hansen (Eds.). 1968. In: *Biology of Alder*, U.S.D.A. For Ser. Pac. NW. For and Range Exp. Sta., Portland. 292pp.

36. Uemura, S. and T. Sato. 1975. Non-leguminous root nodules in Japan. In: *Nitrogen Fixation and Nitrogen Cycle*. H. Takahashi (Ed.). Univ. of Tokyo Press, Tokyo. p. 102-114.

37. Webster, S.R., C.T. Youngberg and A.G. Wollum, II. 1967. Fixation of nitrogen by bitterbrush (*Purshia tridentata* Pursh. DC). *Nature* 216:392-393.

38. Wollum, A.G. II and C.T. Youngberg. 1967. The influence of nitrogen fixation by nonleguminous woody plants on the growth of pine seedlings. *J. For.* 62:316-321.

39. Wollum, A.G. II, C.T. Youngberg and F.W. Chichester. 1968. Relation of previous timber stand age to nodulation of *Ceanothus velutinus*. *For Sci.* 14:114-118.

QUESTION BOX

The question box session was convened at 4:10 pm with Ralph Shugert and Bruce Briggs serving as moderators.

MODERATOR SHUGERT: Question for Gary Koller. Do you have blight problems with *Aesculus parviflora?* Have you propagated this plant?

GARY KOLLER: We have had no major problem with it. I have seen some leaf scorch in a few areas.

MICHAEL DIRR: It will propagate from root pieces, suckers and seeds.

JOE McDANIEL: *A. parviflora* is susceptible to leaf hopper damage and scorch will set in after an infestation.

RALPH SHUGERT: We can not grow it in Ohio. I think it has a heat problem.

MODERATOR SHUGERT: I have a very hardy *Tilia cordata* from a northern source. Where can I obtain rootstock of comparable hardiness?

DAVE BAKKER: From the federal experimental farm at Mordon, Manatoba.

MODERATOR SHUGERT: I have several superior selections of *Celtis occidentalis*. How can I profitably propagate them?

JOE McDANIEL: I have had success with chip budding in the summer.

MODERATOR BRIGGS: Is anyone using Roundup on nursery shade trees? If so, how often and will it harm established trees?

MIKE LEAN: We have used it at the rate of 1½ oz/gal and have had no problem on limbed-up stock of *Malus*, *Pyrus*, *Crataegus*, *Fraxinus* and *Acer rubrum*. Keep the pressure low with coarse drops for best results.

BEN DAVIS: We are using the same rate but are not taking any chances. We use a shield made from a piece of stove pipe to protect the plants.

MICHAEL SCOTT: It can be used to control suckers on crabapples without any problems.

FRANK GOUIN: Watch out with Roundup; there is a delayed reaction we have noticed on brush control. Early applications on suckers did not show up until the following year. With conifers, application after August gave us no injury.