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A Masterful Scheme

Symbiotic Nitrogen-Fixing Plants of the Pacific Northwest

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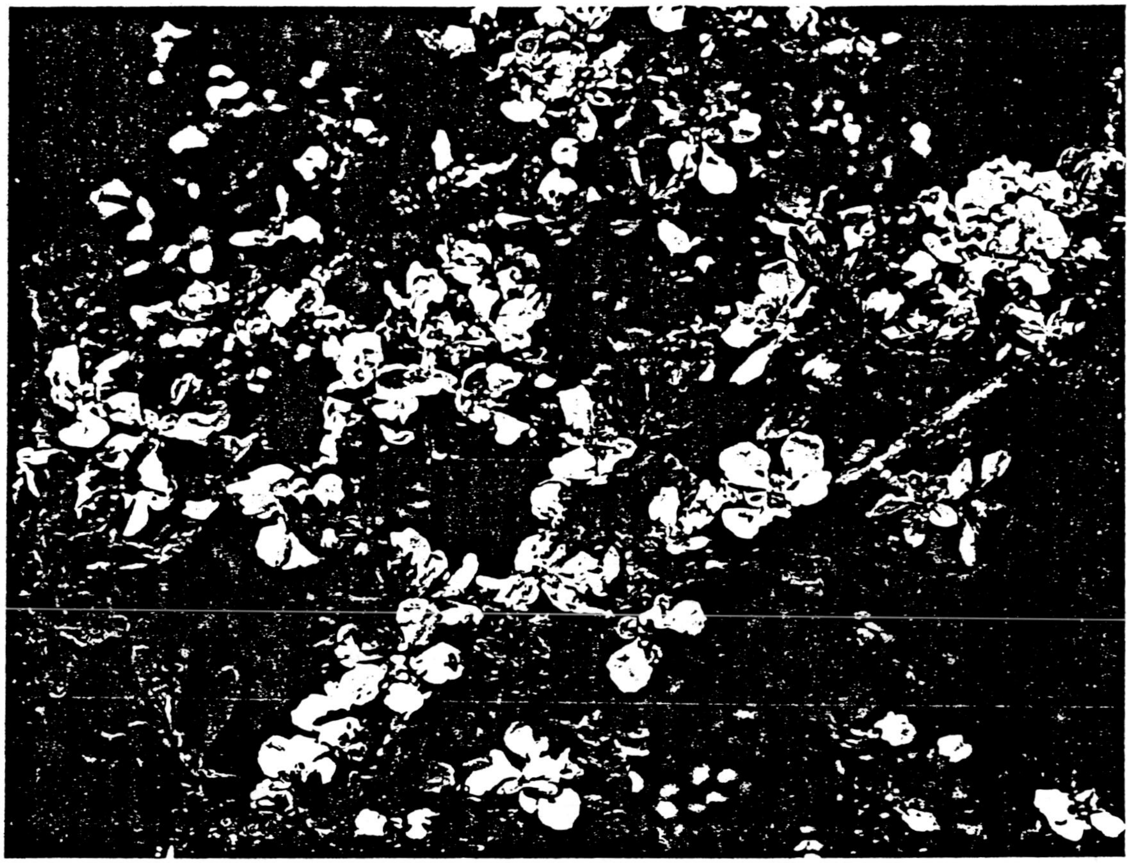
A masterful scheme has evolved in a few higher plants that is a type of symbiosis. In this case, it is a close, mutually beneficial association between higher plants that produce energy, and nitrogen-fixing bacteria. The root hairs of these plants form into nodules when infected by these specific nitrogen-fixing bacteria. Photosynthetic sugars produced in the foliage are transported to the nodules, supplying the energy to support the activity of a bacterial enzyme, which in turn produces nitrogenous compounds useful to the plant and ultimately, to people.

Why is nitrogen fixation important?

Nitrogen is thought to be the most important nutrient element limiting plant growth in the Pacific Northwest. Nitrogen is a major component of all amino acids, proteins, enzymes and chlorophyll. Plant growth slows when the demand for nitrogen exceeds the ability of the soil to supply it. While other nutrients such as phosphorus and potassium can be derived from the breakdown or weathering of rocks and minerals, nitrogen is not derived in significant quantities from this source. Pacific Northwest rain, although usually plentiful, contains only trace amounts of nitrogen (adding only about 0.5-5 kig of nitrogen per hectare every year). To make matters worse, nitrogen is more easily lost than many nutrient elements. Nitrogen in organic matter is released as a gas when combusted; thus intense wildfires and slashburning can greatly deplete nitrogen reserves from a forested area. Further, as plant residues decompose, nitrate (NO_3) can be produced and sometimes lost by leaching below the rooting zone. Nitrates can also be reconverted to nitrogen gas by denitrifying bacteria, such as *Pseudomonas* spp.

How is nitrogen "fixed"?

Paradoxically, nitrogen is abundant in gaseous form; it makes up 79 percent of the air we breathe. But the gas is unavailable to higher plants and most microorganisms because of its great molecular stability. Gaseous dinitrogen (N_2) consists of two nitrogen atoms held very tightly by a strong triple bond. A few microorganisms have developed a very special enzyme, called ***nitrogenase***, that has the ability to break this bond, adding hydrogen to form ammonium (NH_4) that can then be used by plants and microorganisms. This process is called nitrogen fixation. This complicated reaction requires the



Flowers of Purshia tridentata, *Kittitas County*. *photo: B.O. Mulligan*

rare heavy-metal element molybdenum as a catalyst. Thus, molybdenum deficiency can cause an indirect nitrogen deficiency in nitrogen-fixing microorganisms.

Why do these nitrogen-fixing microorganisms not proliferate to the point that nitrogen is no longer limiting? Part of the answer lies with the amount of energy needed to support the process. To fix 1 gram of nitrogen, an estimated 10-100 grams of glucose is required.[1] Most microorganisms rarely have energy resources to produce large amounts of fixed nitrogen. Higher plants can produce excess energy through photosynthesis, but they cannot produce the necessary enzyme.

Which plants fix nitrogen?

Two groups of symbiotic nitrogen-fixing plants are recognized. Many members of the pea or legume family form a symbiotic association with *Rhizobium* spp. bacteria. Several other genera of woody perennials associate with actinomycete bacteria. This second group is known as actinorrhizal plants. Some lichens (for example the common foliose lichen *Lobaria oregana*) are formed through a symbiotic relation between a fungus and a nitrogen-fixing blue-green alga (*Nostoc* spp.). Some of the more important nitrogen-fixing plants in this region are listed in Table 1.

Role of nitrogen-fixing plants in Pacific Northwest ecosystems

Nitrogen-fixing plants have played a key role in developing and maintaining Pacific Northwest ecosystems. Red and Sitka alder (*Alnus rubra* and *A. sinuata*) pollen is found in great abundance in sediments corresponding to a period of early plant development after the Wisconsin glaciers left the Puget Sound area some 12,000 years ago. If we assume that throughout the post-glacial period precipitation was low in nitrogen, as today, and that there

[1] Gutschick, V.P. 1978. Energy and nitrogen fixation. *Bioscience* 28(9):571-575.

were at least a few wildfires, much of the 5,000 + kg of nitrogen per hectare often found on forested sites probably originated through nitrogen fixation by alder. Sediments in Lake Washington have shown a resurgence of alder pollen corresponding with land clearing and logging during the early development of Seattle.[2] Most nitrogen-fixing plants are adapted to disturbance. *Ceanothus* spp. dominates many sites in the Oregon Cascade Range after burning. Many introduced legumes like Scotch broom (*Cytisus scoparius*) come in after soil disturbance from logging or along roadsides. The ability to fix nitrogen gives these plants a competitive advantage on nitrogen-deficient soils, although many also do well on non-nitrogen-deficient soils.

Important uses for nitrogen-fixing plants in agriculture and forestry

Currently, two percent of world fossil-fuel production is used in direct manufacture of nitrogen fertilizer. Increased use of nitrogen-fixing plants in agriculture and forestry could reduce this dependency. Because the cost of fossil-fuel-derived nitrogen fertilizer has decreased in recent years, it is important to find nitrogen-fixers that have economic value in addition to the value of the nitrogen they fix. This will be less important when energy prices increase again.

Agricultural legumes such as soybeans, alfalfa, lentils, and clover require little or no nitrogen fertilizer and provide valuable protein-rich foodstuffs. Rangeland management to pro-

[2] Davis, M.D. 1973. Pollen evidence of changing land-use around the shores of Lake Washington. *Northwest Science* 47(3): 133-148.

Foliage of red alder. *photo: B.O. Mulligan*

Red alder, Alnus rubra

Red alder, Alnus rubra, *can form large nodule clusters, some as large as a baseball.*

Scientific Name	Common Name	Range	Native / Introduced
Leguminous plants			
Cytisus scoparius (L.) Link	Scotch broom	CW	I
Lathyrus latifolius L.		REG	I
Lathyrus nevadensis Wats.		CE	N
Lathyrus polyphyllus Nutt.		REG	N
Lotus crassifolius (Benth.) Greene	Pink trefoil	CW	N
Lotus micranthus Benth.	Slender trefoil	CW	N
Lupinus albicaulis Dougl.	Silky-stemmed lupine	CW	N
Lupinus albifrons Benth.	White-leaved lupine	CW	N
Lupinus latifolius Agardh		REG	N
Lupinus laxiflorus Dougl.	Spurred lupine	CW	N
Lupinus lepidus Dougl.		CW	N
Lupinus micranthus Dougl.	Small lupine	REG	N
Lupinus polyphyllus Lindl.	Large lupine	REG	N
Lupinus rivularis Dougl.	Riverbank lupine	REG	N
Lupinus sulphureus Dougl.	Oregon lupine	CW	N
Medicago hispida Gaertn.	Bur clover	REG	I
Medicago lupulina L.	Black medic	REG	I
Psoralea physodes Dougl.	California tea	REG	N
Trifolium bifidum Gray		REG	N
Trifolium ciliolatum Benth.		CW	N
Trifolium dubium Sibth.	Small hopclover	REG	I
Trifolium eriocephalum Nutt.		REG	N
Trifolium gracilentum T.&G.		CW	N
Trifolium hybridum L.	Alsike clover	REG	I
Trifolium longipes Nutt.		CW	N
Trifolium microcephalum Pursh	Small-headed clover	REG	N
Trifolium microdon H.&A.	Cup clover	CW	N
Trifolium oliganthum Steud.		CW	N
Trifolium pratense L.	Red clover	REG	I
Trifolium procumbens L.	Hop-clover	REG	I
Trifolium repens L.	White clover	REG	I
Trifolium tridentatum Lindl.	3-toothed clover	CW	N
Trifolium variegatum Nutt.		CW	N
Ulex europaeus L.		REG	I
Vicia americana Muhl.	Wild pea	REG	N
Vicia gigantea Hook.	Giant vetch	CW	N
Actinomycete-nodulated (actinorrhizal) plants			
Alnus incana (L.) Moench	Mountain alder	CE	N
Alnus rhombifolia Nutt.	White alder	CE	N
Alnus rubra Bong.	Red alder	CW	N
Alnus sinuata (Regel) Rydb.	Sitka alder	CW	N
Ceanothus cuneatus (Hook.) T.&G.	Common buckbrush	CW	N
Ceanothus integerrimus H.&A.	Deerbrush	CE	N
Ceanothus prostratus Benth.		CE	N
Ceanothus sanguineus Pursh	Buckthorn	REG	N
Ceanothus velutinus Dougl.	Mountain balm	REG	N
Cercocarpus montanus Raf.	Mountain-mahogany	CE	N
Dryas drummondii Richards.	Dryas	REG	N
Dryas octopetala L.		REG	N
Myrica californica Cham.	Pacific wax-myrtle	CW	N
Myrica gale L.	Sweet gale	CW	N
Purshia tridentata (Pursh) DC.	Bitterbrush	CE	N
Shepherdia argentea (Pursh) Nutt.	Thorny buffalo-berry	CE	N
Shepherdia canadensis (L.) Nutt.	Soapberry	REG	N

Ranges are: CW—Cascades westward; CE—Cascades eastward; REG—regional

Table 1.) Common nitrogen-fixing plants of the Pacific Northwest (from Hitchcock, C.L. and A. Cronquist. 1974. *Flora of the Pacific Northwest*).

Mountain balm, Ceanothus velutinus *near Leavenworth, Chelan County.* *photo: B.O. Mulligan*

mote nitrogen-fixers such as bitterbrush (*Purshia tridentata* Pursh) could increase soil fertility and provide protein-rich forage for wildlife and cattle of the Great Basin. Native legumes could be established after logging to improve forage quality for coastal wildlife species. Red alder may become a more important part of forest management on the west side of the Cascade Range because it has one of the highest nitrogen-fixation rates known (50-150 kg/ha annually) and because of the moderately valuable wood it produces.

Summary

Natural sources of nitrogen in rainfall are usually inadequate to meet the demand of growing plants and thus limit their productivity. As a consequence, nitrogen-fixing plants can play a vital role in maintaining the fertility of Pacific Northwest ecosystems. Understanding more about the process of nitrogen fixation and how nitrogen-fixing plants interact with other plants will help to develop sustainable management of forest and agricultural ecosystems.

Editor's Note:
Refer to the Winter, 1987, issue of the *Arboretum Bulletin*, page 4, for more information on nitrogen-fixation in connection with the Leguminosae.