NEW ZEALAND PLANTS THAT FIX NITROGEN

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WHY FIX NITROGEN?

Nitrogen fixation is the ability, found only in some bacteria and some blue-green algae, to convert atmospheric nitrogen gas N_2 into ammonia. This process goes on within the micro-organism and the ammonia is very quickly incorporated into amino acids which are the building blocks of proteins. In some ways the process is analagous to photosynthesis whereby carbon dioxide gas is utilised by all green plants to produce carbohydrate. But why is nitrogen fixation so fundamental?

The major nutrient elements required by plants are carbon C, hydrogen H, oxygen O, phosphorus P, potassium K, nitrogen N, sulphur S, calcium Ca, iron Fe, and magnesium Mg. Looking at the origins of each of these elements we see H and O come readily from water H_2O, while P, K, S, Ca, Fe and Mg are normal components of soil minerals and are generally available to plants. This leaves the elements carbon C and nitrogen N which do not have their origins in the soil but in the atmosphere. It is true that most plants utilise nitrate (NO_3) from the soil but the ultimate origin of this supply of nitrogen is the atmosphere. As the supply of soil nitrogen is often limiting plant growth in both native and exotic communities then the process of nitrogen fixation can be seen as a fundamental process controlling the flow of nitrogen through all living things.

WHERE DOES IT OCCUR?

The bacteria and blue-green algae capable of fixing nitrogen may be free living in soils, lakes, oceans or in decaying vegetation. They are in fact ubiquitous, occupying such diverse habitats as the surface of leaves and the human gut, but seldom in large numbers. Of much greater significance are those bacteria (and algae) which enter into a symbiotic relationship with other plants. The best known of these relationships is the legume root nodule but there are a great many other, often bizarre and ill defined, associations of which New Zealand has more than its fair share.

THE NEW ZEALAND SCENE

New Zealand, probably more than any other country, relies on biological nitrogen fixation as a source of revenue. When land was originally cleared from forest much of the residual nitrogen was lost in burning, erosion run-off and leaching and early agriculture quickly learnt the advantage of white clover in pastures. Since those early days this country has become somewhat of a show piece of efficient production of protein products virtually all by way of the introduced legumes, clover and lucerne.

THE NATIVE PLANTS

As a group the distribution of legumes is centred on the tropics, countries more distant from the tropics such as New Zealand and Canada are notably deficient in legumes, while Scandinavian countries like Finland have no native legumes. New Zealand has some fifty odd legume species in eight genera, all are woody, slow growing perennials of the Papilionoideae. None of the Mimosoideae so well represented in Australia are present in New Zealand.

Historically the New Zealand legumes fall into two main groups each of four genera. Canavalia, Swainsona, Clianthus and Sophora have affinities in Australia for the first three and circum-Pacific for Sophora. Of the other genera all are endemic, with Notospartium, Chordospartium and Corallospartium having but four species between them and of very limited South Island distribution and Carmichaelia, with thirty eight species, being widely distributed. All species investigated are nodulated but save for some species of Carmichaelia, e.g. C. grandiflora, the distribution and vigour of the legumes makes it very unlikely that they have contributed significantly to the nitrogen economy of native communities.

THE NON-LEGUMES

At the time, nearly one hundred years ago, when it was proven that legume nodules fix nitrogen, another group of plants was discovered to possess root nodules which were superficially like the legume nodules. It was not until the 1950's that any serious work was done on them and we still know relatively little about their symbioses. The host plants are from very diverse genera, quite unrelated taxonomically, but in all cases the root nodules are formed not by Rhizobium as in the legumes but by an as yet unknown actinomycete bacterium. There are known today some thirteen genera and three hundred and fifty species of non-legume nodule bearing plants and, significantly, all are naturally distributed in temperate to cold temperate latitudes, so it seems likely that this group is the cool latitude equivalent of the legumes. All are woody plants which play little or no part in modern agriculture, and include such genera as Alnus (Alder), Elaeagnus, Hippophae (sea buckthorn), Shepherdia, Myrica, Ceanothus, Casuarina and in New Zealand Discaria and Coriaria.

Discaria (one species only), otherwise known as Wild Irishman or Matagouri, occurs mainly in inland South Island and nodules were first discovered as recently as 1958. The plant is interesting as a spiny, often leafless, shrub up to 4m high, which Cockayne showed responded remarkably to a humid atmosphere by producing a vast array of small leaves. The plants grow on dry scree, or alluvium often as pioneers on poor soils and are able to survive very dry winds and usually prefer free draining soils. The nodules are invariably small and probably do not survive more than one year. There is no doubt that they fix nitrogen and in some arid areas very large areas of matagouri scrub often dominate the landscape. Growth is slow however, and eventually the scrub gives way to grassland in drier regions and forest in wetter areas.

Coriaria (tutu), while possessing a similar type of root nodule, is completely unrelated to Discaria. Coriaria produces perennial root nodules which on C. arborea may reach tennis ball size, grows rapidly and is the most significant nitrogen-fixing plant in the native flora. There are seven species of Coriaria in New Zealand; others occur in such widely disparate places as New Guinea, Himalayas, Japan, Spain and South America. The New Zealand species form a confusing array of hybrids whenever species overlap and when three or more species combine such as at Swampy Hill, "it is hopeless trying to disentangle the forms present". Six of the species are rhizomatous and are summer green. All these species tend to occur at higher altitudes, although C. sarmentosa grows at sea level in the south of the North Island. Some of the species have very limited distribution, e.g. C. pottsiana which grows only in the vicinity of Mt. Hikurangi (East Cape). It is interesting that C. pottsiana is more closely related to C. terminalis in the Himalayas than to any New Zealand species.

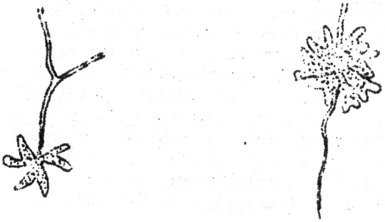
All species bear root nodules, although on the rhizomatous species nodules are often hard to find as they tend to be at ends of secondary roots and are torn off when plants are pulled out.

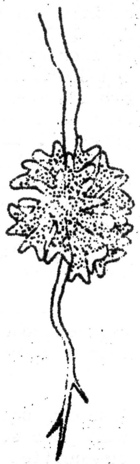
All species are found in damp places, usually on free-draining soils of alluvium, colluvium or ash. They are able to colonise very poor soils and under these conditions they often dominate the communities e.g. along river beds, on shingle slides and eroded surfaces.

By far the most important species, and the most important nitrogen fixing agent in the entire native flora, is C. arborea. Wherever it grows it forms a vigorous cover and on poor soils will form a continuous canopy to the exclusion of all other plants. The root nodules on this plant are perennial and may grow to the size of a man's fist, they are often concentrated on the woody rootstock just below the soil surface as well as being on the smaller secondary roots.

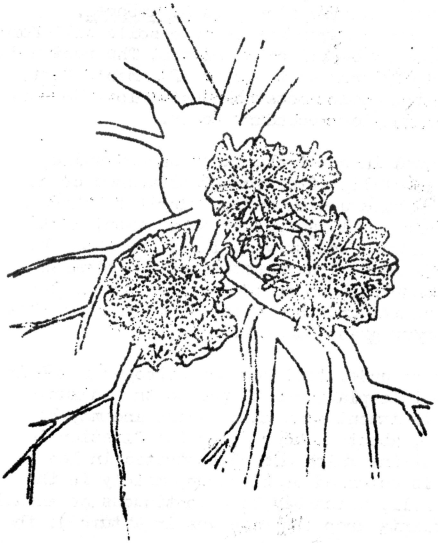
Tutu is often found in great abundance on new soils, e.g. on the central plateau, especially after forest clearance or on eroded surfaces. After the Tarawera eruption and on Rangitoto there is good evidence of tutu dominance of early stages of succession. In the South Island on the West and Kaikoura coasts very large areas can be found along river banks. Near Kaikoura I have estimated, by biomass and soil sampling, that tutu may contribute up to 170lbs of nitrogen per acre per year at early stages of its growth - this is the same as that produced in a good white clover/ryegrass paddock.

It is important to understand how the nitrogen fixed in root nodules is transferred to this plant and thence to the community. Nitrogen is quickly converted to ammonia and amino acids and may be found travelling inside the stem about an hour after its fixation in the nodule. This is used in proteins which are concentrated in leaves (some 3% of all plant leaves is composed of nitrogen, mainly in the form of protein). When leaves fall, which may be a continuous or annual event (in frosty areas tutu plants drop their leaves in autumn), the nitrogen becomes incorporated into leaf litter and thence into soil where decomposition processes liberate nitrate which becomes available for other plants.





ABOVE: STAGES IN THE DEVELOPMENT OF ROOT NODULES ON *CORIARIA ARBOREA*.



LEFT: MATURE NODULES ON *CORIARIA ARBOREA*.

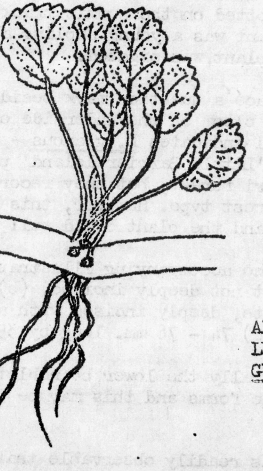
OTHER SYMBIOTIC SYSTEMS

The small water fern Azolla, which often covers farm ponds with a rusty red mantle in autumn and winter, has a nitrogen fixing blue-green alga in its leaves. The alga (Anabaena) allows the plant to grow very rapidly in water where there is no soluble nitrate. A dense cover of Azolla is often followed in summer by an even denser cover of the duckweed Spirodella and one may speculate that the demise of the Azolla may provide nitrogen for the growth of Spirodela.

Some of the primitive liverworts, e.g. Anthoceros have small raised glands on the surface of the thallus which also house nitrogen fixing blue-green algae.

Of much greater interest are the internal algal nodules in the stems of Gunnera. These nodules house Nostoc which is a vigorous nitrogen fixing blue-green alga. Gunnera is a widespread genus and several exotic species are familiar in botanic gardens as enormous (12ft.) rhubarb like herbs. In New Zealand the ten species are all endemic and are very small, creeping, stoloniferous herbs. At the nodes are clustered leaves and roots and in the nodal swelling are concentrated a number of dark internal glands. Cut through a Gunnera node of any species and the very dark green almost black nodules will stand out. Although the structure and organisms are vastly different, these internal nodules function in exactly the same fashion as legume and non-legume root nodules.

Gunnera species are widespread in New Zealand, preferring wet swampy habitats especially alongside rivers where they are able to colonise nitrogen free environments.



ALGAL NODULES AT BASE OF LEAVES ON STOLON OF GUNNERA STRIGOSA.