RESEARCH

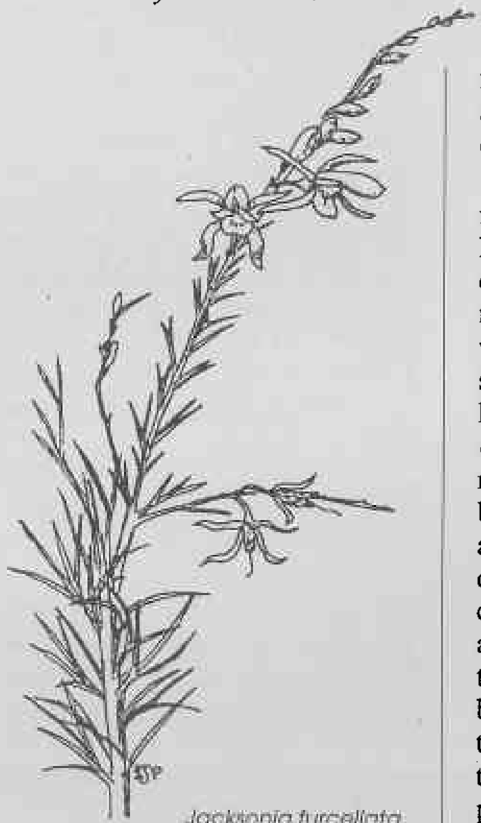
LEGUMES IN NATIVE BUSH AND AGRICULTURE: POTENTIAL ROLES IN FIXATION AND CYCLING OF NITROGEN?

by John S. Pate

WHENEVER one sees a prolific crop of lupins, peas, faba beans or chickpeas, or a pasture rich in clover or serradella, one immediately thinks of bacterial-induced root nodules and their capacity to supply legumes with fixed atmospheric nitrogen. Indeed, without inputs from such crop and pasture legumes, broadacre farming in most regions of Australia would be disastrously unprofitable, since it is uneconomical for most farmers to replace the free source of nitrogen from legumes with expensive nitrogen fertilisers.

Nevertheless, it must be remembered that our agricultural systems operate successfully only through continued application of superphosphate and, in certain circumstances, any of a number of other potentially limiting nutrients such as potassium, sulphur, copper, zinc, manganese, molybdenum and cobalt. By correcting such deficiencies, a situation is created in which legumes flourish and compete successfully with non-fixing species in low nitrogen soils. Additionally, where a cereal follows a previous legume crop or pasture, the yield of the cereal is noticeably benefited by nitrogen released in decomposition of residues of the legumes concerned.

But what about nitrogen fixation in the original bushlands from which our artificial agrosystems have been created? In virtually all cases legumes are present in significant amount in terms of numbers of species and the collective biomass which they represent. In fact in some cases, such as mulga and certain heathland systems, legumes such as wattles (*Acacia* spp) may comprise major components of vegetation. Yet, is there evidence that such legumes are nodulated and, if so, do they fix nitrogen as effectively as in our ameliorated agricultural systems?



Jacksonia furcellata

As a further issue, are there other classes of plant in native vegetation which are able to engage in symbiotic nitrogen fixation in a manner akin to legumes? The remainder of this short article will attempt to answer these and other questions, mostly using information which the author and his colleagues have gathered from a range of ecosystems in south west WA over the past years.

Is it correct to assume that all legumes are capable of forming nodules and therefore fixing nitrogen? Legumes comprise three groups, the pea family (Fabaceae), the acacias and their allies (Mimosaceae) and the cassias and their allies (Caesalpiniaceae). Members of the first two groups can form nodules in the presence of appropriate bacteria, while members of the third group cannot.

Even then, inspection of roots of native members of Fabaceae and Mimosaceae (peas and wattles) will often fail to show presence of nodules, especially when dealing with relatively old plants. However, stands of seedlings of short-lived legumes (eg *Bossiaea*, *Acacia*, *Gompholobium*, *Sesbania*) recruiting after recent fires would be expected to be well nodulated and can be shown by various chemically-based assays to be currently fixing appreciable amounts of nitrogen. However, as these stands age, nodulation becomes much less prolific or even totally absent. Our interpretation of this phenomenon is that the element phosphorous, normally the principal limiting nutrient in our ecosystems, becomes transiently available after a fire in the form of deposited ash or released from plants killed in the fire. On the other hand, most nitrogen of above-ground biomass is lost to the atmosphere as gaseous ammonia and oxides of nitrogen during the fire, and so under the ensuing nitrogen-limited: phosphorous-sufficient conditions well-nodulated legumes will flourish and compete particularly effectively with non-legumes. The predominance of shrub legumes in many post fire understoreys in our forest and woodland ecosystems attest to this.

Eventually, however, once phosphorous availability declines, both legumes and non-legumes have to invest increasingly in specialised feeding roots and symbiotic associations with mycorrhizal fungi to access insoluble forms of phosphorous. Ability to fix nitrogen

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is then no longer an issue. Indeed, legumes might well be disadvantaged if devoting part of their resource of photosynthetic product to formation of nodules while also supporting energy-demanding mechanisms for acquiring phosphate. Nevertheless, despite their declining activity in fixing nitrogen in later years, it is generally agreed that understorey legumes of the above kind play an important role in replenishing nitrogen resources lost in fire. In some cases populations of such shrub legumes die off more or less synchronously, say 6-10 years after the fire event which prompted their establishment. In such cases transfer of nitrogen to non-leguminous sibling species over the following seasons may be very noticeable.

Gastrolobium bilobum

It is well known that cycads such as our zamia (*Macrozamia riedlei*) fix nitrogen through the agency of specialised coralloid roots harbouring nitrogen-fixing blue green algae (*Cyanophyta*), and sheoaks (*Casuarina, Allocasuarina*) behave similarly using root tubercles containing the actinomycete *Frankia.* Studies suggest these long-lived species carry perennial symbiotic organs providing the host plant more or less continuously with nitrogen. However, at least in zamia, nitrogen fixation becomes particularly active after fire, coinciding with the plant producing a flush of new leaves and engaging in fire-induced reproduction. In the case of the above non-legume species and equivalently long-lived legumes one would expect significant and continuous inputs of fixed N to be made, thus contributing towards maintenance of nitrogen capital within the parent ecosystem between successive fires.

One has to be careful before condemning a legume as non-functional in nitrogen-fixation simply on the basis of not finding nodules in its roots. Nodules on most shallow-rooted legumes are typically short lived and, as far as south west WA conditions are concerned, are typically present and active only for a short winter/spring period when soils are moist and temperatures are not excessively high. So excavations in summer would provide misleading information on nodulating capacity. As a general rule of thumb a legume found to be carrying during the growing season a population of nodules collectively amounting to 3-10% of the mass of the plant would be expected to be providing itself with sufficient fixed nitrogen to support growth. But the nodules concerned would have to be healthy and this is best indicated by presence of red or pink pigmentation in their central bacteria-containing tissues. This indicates presence of haemoglobin-type pigment essential to proper functioning of the nodule in nitrogen fixation.

Unfortunately we still know very little regarding the nodulation status and nitrogen fixing capacities of many of our native legumes, nor indeed of the strains of bacteria which they require to nodulate successfully. Research continues to bring up surprises. For instance, we have recently encountered clusters of large elongated and apparently perennial nodules at 1-4m depth encircling the deeply penetrating tap roots of certain native legumes (eg *Acacia saligna, Jacksonia* spp) and the fodder tree legume tagasaste (*Chamaecytisus proliferus*). Being located in deep, continuously moist parts of the soil profile these nodules are protected from the seasonal drought and high temperature stresses experienced by ephemeral counterparts in near surface layers of the soil.

A further example in which unexpected results have been obtained, concerns our recent studies of nitrogen cycling in mulga vegetation of Western and eastern Australia. Here we have failed to find nodules on any of the half dozen or so acacias which dominate this class of vegetation. Using a specialised stable isotope technique to assay the sources of nitrogen which these legumes and cohabiting non-legumes are using, we have confirmed that symbiotic inputs of nitrogen by the acacias are insignificant and that they and other non-fixing species appear to be relying mostly on the large resources of nitrate typically encountered in soil and groundwaters of the ecosystem. It is well known that nodulation and nitrogen fixation of agricultural legumes are strongly inhibited by nitrate and possibly this is what is happening in acacias at our mulga sites. Supporting this contention we have encountered interesting legume populations inhabiting ridges of leached wind-blown sand around a lake in one of the mulga habitats. In this unusual situation the legumes turned out to be well nodulated and were shown by our isotope assay technique to be heavily dependant on fixed nitrogen. Incidentally, despite the general absence of nitrogen fixation by legumes in the major plant components of mulga, fixation inputs were indicated as being made by certain lichen crusts, and possibly more importantly by termite colonies. Worker termites have been shown to have colonies of cellulose-decomposing and nitrogen-fixing bacteria in their guts, with the former micro-organisms providing the latter with energy-yielding sugars to implement nitrogen fixation. Furthermore, one can detect high concentrations of nitrate in the soil below certain termite colonies suggesting that they may have been

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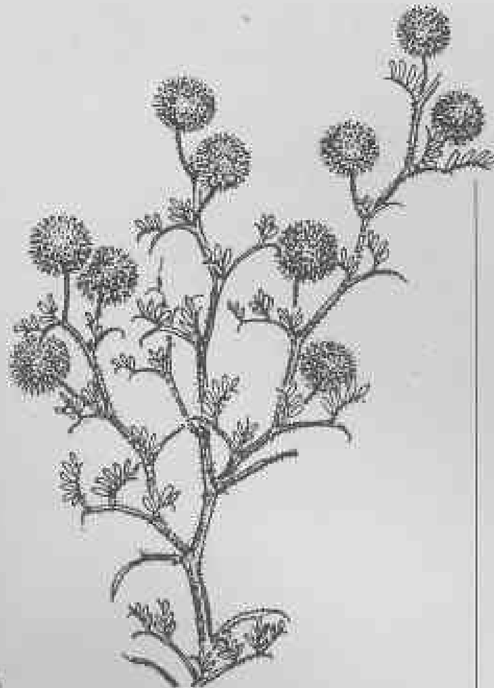

Acacia drewiana

in the past and continue to be responsible for generating the large pools of nitrate now evident in the system.

So we still have much to learn about nitrogen fixation and nitrogen cycling in native and agricultural ecosystems. In view of the important role of nitrogen in plant growth and the dangers which can follow when the element pollutes the environment, research conducted in the future on this topic is clearly necessary and rewarding.

John Pate is Emeritus Professor at the University of Western Australia where he continues research on environmentally-related issues in the Botany Dept. and Centre for Legumes in Mediterranean Agriculture. He can be contacted on (08) 9380 1974 or 9380 2206.

Further Reading

Unkovich MJ, Pate JS, & Sanford P. (1997) Nitrogen fixation by annual legumes in Australian Mediterranean agriculture. *Aust J. of Agric. Res.* **48**: 267-293

Pate JS, Unkovich MJ, Erskine PD & Stewart GR. (1998) Australian mulga ecosystems – 13C and 15N natural abundance of biota components and their ecophysiological significance. *Plant, Cell and Environment* **21**, 1231-1242.

Pate JS & Unkovich MJ (1999) Measuring symbiotic nitrogen fixation: case studies of natural and agricultural ecosystems in a Western Australian setting. IN 'Physiological Plant Ecology' (Eds. MC Press, JD Scholes & MG Barker) pp. 153-173. Blackwell Science, Oxford.

Unkovich MJ, Pate JS, Lefroy EC & Arthur DJ. (in press) Inputs of fixed nitrogen by the fodder tree tagasaste at alley and plantation densities on deep sands in southwestern Australia. Aust, J. Plant Physiology.

ABOUT GROUPS

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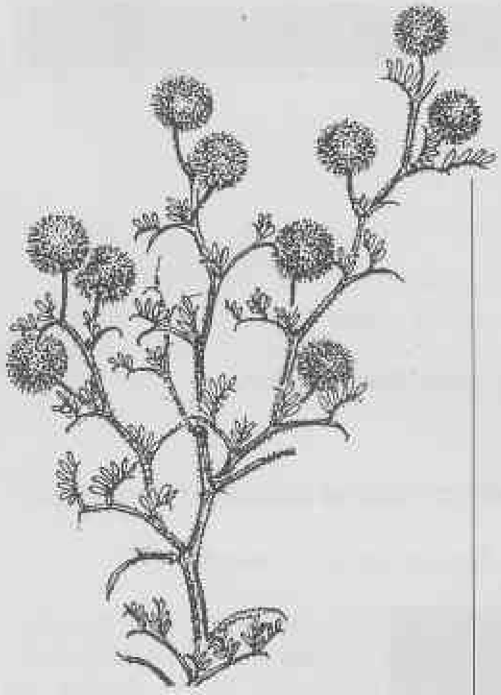

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ABOUT GROUPS

The community group Green Skills has asked that we include information about their employment arm, 'Ecojobs'.

ECOJOBS ENVIRONMENTAL PERSONNEL:
FOR ALL YOUR ENVIRONMENTAL PERSONNEL NEEDS

As we are in the middle of the tree planting season, I would like to remind everyone that Ecojobs offers a wide range of skilled environmental personnel at very affordable rates, starting from $17.50/hr (+ GST). Our rates are all inclusive and we can also provide project coordination and supervision of volunteers.

Ecojobs Environmental Personnel is a project of Green Skills Inc. which has been successfully operating since 1995. Our clients include the Botanical Gardens and Parks Authority, the Water and Rivers Commission, various councils, private consultancies, as well as catchment and landcare groups.

We are looking forward to hearing from you soon.

Jean-Paul Orsini, Ecojobs Coordinator
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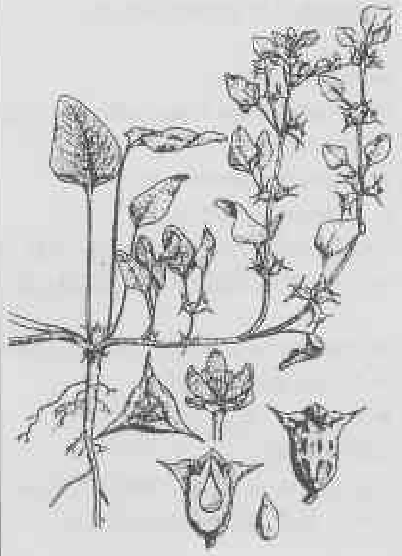
BUSH DETECTIVE ANSWER



They are Doublegee (*Emex australis*) fruits. Early settlers brought the plant from South Africa to use as a salad vegetable, and it is now widespread over the State. Red-tailed Black Cockatoos eat the seed, they are able to crack the fruit with their powerful bills. (Try to crack open the fruit yourself, to see how strong they must be.)

✦ ✦ ✦ ✦

A final comment, from a teenage *LFWer.*

Q: What do you get if you collect up a pile of Doublegee seeds, make holes in them, and thread them on twine to make two ropes?

Ans: A double G-string!

OUCH!!!

WEEKEND GETAWAY!

Many LFW members have facilities for visitors - if you are looking for somewhere to go where people care about bushland -you need the WA LFW Ecotourism Contact List! Ring 9334 0427 for your copy.