Sustaining multiple production systems
4. Ley pastures in crop-livestock systems in the semi-arid tropics

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Abstract

The search for economically viable ley pastures in the Australian tropics is an attempt to emulate the successful ley farming systems, based on sub-clover and wheat, in regions with Mediterranean and temperate climates in southern Australia.

The paper examines experimental legume ley pastures in the semi-arid tropics from four points of view, viz — initial establishment and re-establishment of the various ley species after a crop; the contribution of biological nitrogen from the ley to the farming system; the control of pasture species during the crop phase; and the feeding value of ley pastures and crop residues to grazing cattle.

Management problems highlighted by the research on experimental ley pastures include: grass dominance in the pasture; the extremely rapid decomposition of legume residues and the resultant leaching of mineral nitrogen beyond the root front of the developing crop; and the lack of sufficient crop and pasture residues in some seasons for successful crop establishment using no-till methods.

The adequacy of existing genetic resources for ley pastures in this region, the biological and economic sustainability of tropical ley systems, and the prospects for commercial use of the experimental results, are also examined.

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Resumen

La búsqueda de la viabilidad económica de la rotación de pasturas con cultivos es un intento por seguir el éxito de los sistemas de rotación de cultivos, basados con trébol subterráneo y trigo, de las regiones con climas mediterráneos y templados en la región sur de Australia.

Los experimentos de pasturas de leguminosas en rotación con cultivos realizados en los trópicos semi-áridos son examinados desde cuatro puntos de vista, los cuales son: establecimiento inicial y re-establecimiento de varias especies en rotación después del cultivo; la contribución de nitrógeno biológico de las especies en rotación al sistema de producción de la granja; el control de las especies de pastura durante la fase de cultivo; y el valor alimenticio de las pasturas en rotación y de los residuos del los cultivos para los animales en pastoreo.

Los problemas de manejo que sobresalieron en la investigación de los experimentos de las pasturas en rotación con cultivos incluyen la dominancia de las gramíneas en la pastura; la descomposición extremádamente rápida de los residuos de las leguminosas con la consiguiente lixiviación del nitrógeno mineral más allá de la zona de las raíces de los cultivos en desarrollo; y la falta, en algunas estaciones, de suficientes residuos de las pasturas y de los cultivos para un éxitoso establecimiento del cultivo sin labranza de la tierra.

Se examinan también la conveniencia de los recursos genéticos existentes para las pasturas alternadas de esta región, el sostenimiento biológico y económico de las pasturas alternadas en los trópicos, y la posibilidad del uso comercial de las resultados.

The concept of tropical ley pastures

Ley pastures have played such an important role in the agricultural systems of the areas of southern Australia with Mediterranean and temperate climates that it was tempting to search for a tropical equivalent. This search was an important component of a major research program by CSIRO and collaborators carried out at the Katherine Research Station from 1978 to 1989 (McCown *et al.* 1985). The Katherine-Darwin region of northern Australia receives an average annual rainfall of 900 mm or more. The major soils are deep sesqui-oxidic red and yellow earths of near neutral pH, and low in N and P and some other nutrients (Jones *et al.* 1985). Despite twelve years of research, however, there are still very few commercial examples of tropical legume-ley pastures in northern Australia. [Lablab (*Lablab purpureus*) is quite widely used as a fodder legume (J.M. Hopkinson, personal communication) but it is not common for it to be used in a deliberate rotation system.] In this paper, we explore why tropical legume leys are uncommon and look at some of the current and foreseeable benefits and problems of systems based on such pastures.

Grass leys are now an accepted part of farming practice on the better watered lands of the Atherton Tableland, north Queensland (J.M. Hopkinson, personal communication). Grass leys are used mainly to restore soil structure after periods of cropping with maize, potatoes, and peanuts (Kilpatrick and Crosthwaite 1978) and may be grazed by cattle, harvested for seed, or cut for hay, or some combination of these. Grass leys using Sabi grass (*Urochloa mosambicensis*) have also been used experimentally in rotation with mung beans at Katherine in the Northern Territory (S. Yates, personal communication). The grass suppresses other species and is then chemically killed before mung beans are planted using no-till methods.

In the remainder of this paper, however, we will confine our attention to leys containing at least some legume, because of the widespread deficiency of nitrogen for both plant and animal production in northern Australia. Important characteristics of legumes for leys are that they a) are easy to establish initially and to re-establish after a short crop phase; b) contribute appreciable biological N to the system and particularly to subsequent crops; c) are controllable to the extent required during the crop phase; and d) produce high liveweight gains in cattle grazing them.

The performance of experimental ley pastures in the tropics

Research in the semi-arid tropics of northern Australia in the 1960s and early 1970s produced a number of well-adapted biennial and perennial herbaceous legumes which are superior to the naturalized annual Townsville stylo (*Stylosanthes humilis*) (Winter *et al.* 1985; Edye and Cameron 1984). These legumes are capable of producing large quantities of dry matter and protein-N, most of which is presumed to come from N fixation (see Vallis and Gardener 1984, for *Stylosanthes* species). Thus, one of the essential ingredients of a tropical ley system, a highly productive legume, is available. Considerable research was therefore carried out at Katherine using three promising ley legumes — caribbean stylo (*S. Hamata* cv Verano), buffalo clover (*Alysicarpus vaginalis*), and centurion centro (*Centrosema pascuorum* CPI 55697).

The objective was to test whether experimental ley pastures, based on these plants as examples of the types of well-adapted legumes available, could be the basis for a viable cropping industry in northern Australia. Sabi grass and *Cenchrus setiger*, also known to be well adapted to the semi-arid tropics (Fisher 1971; Cameron and Austin 1988), were used as the main grasses for comparison in the experimental system. Some aspects of these experimental leys are considered below.

Establishment and re-establishment of pasture species

Although the three legumes can be successfully established under full cultivation, this practice leaves the land very vulnerable to erosion from high intensity storms during the early stages and is to be avoided if possible.

Successful establishment of the three legumes and the two grasses has also been achieved experimentally at Katherine using a no-till approach, whereby seed is broadcast at 2-5 kg/ha into a native grass pasture sward killed with the herbicide 'Roundup' (a.i. 360 g/l Glyphosate). The smaller-seeded legumes, caribbean stylo and buffalo clover (weighing 1.5-2.0 mg/seed), are relatively easy to establish under these conditions, but the larger-seeded centurion centro (15-20 mg/seed) can be more difficult. Overcast showery weather and at least 3000 kg/ha of surface mulch (crop or pastures residues from the previous season or vegetation recently killed *in situ*) are essential for successful establishment. The method has also been used routinely in the evaluation of grass and legume accessions by Cameron (1989).

Re-establishment of pasture species after a crop phase of one or two seasons is usually successful provided there is an adequate soil seed bank and adequate surface mulch. Fortunately, all three legumes seed prolifically and could be expected to set at least 100 kg/ha of seed each year (Clements *et al.* 1984; Martin and Torssell 1974). Where there are appreciable bare or scald patches, a small amount of tillage, e.g. using narrow tynes at 75 cm spacings, may be necessary before broadcasting the seed, in order to break up the surface crust and enhance water entry. Centurion centro, with its larger seed, makes more rapid initial growth than the other legumes; its twining or scrambling habit also allows it to dominate grasses and weeds more readily and at lower plant populations. Caribbean stylo and buffalo clover are more susceptible to grass and weed competition, and swards may require mid-wet season grazing, mowing, or herbicide application (applying Glyphosate using a rope wick applicator to selectively kill taller weeds and grasses or spraying Fusilade or Sertin at 1 l/ha for grass control (Heiner and Cogle 1991)) to keep the legume content of the pasture ley high.

Contribution of biological nitrogen to the system

Fixation of N by the legume during the pasture ley phase and release of N to a subsequent crop have important biological and economic implications in the temperate and Mediterranean ley farming systems of southern Australia (McCown *et al.* 1988). In the semi-arid tropics, vigorous stands of the three legumes can yield 5-8 t/ha of dry matter and often contain 100 kg/ha more N in the tops at the end of the growing season than do grass stands grown under comparable conditions (Vallis and Gardener 1984). This difference is attributed, quite reasonably, to N fixation.

Clearly, legume leys have the potential to contribute quite large amounts of N to the farming system. Bioassay experiments have been conducted on various legume leys at Katherine, in an attempt to quantify this contribution. The general conclusion is that a good legume stand contributes to a following crop the equivalent of 10-90 kg/ha of fertilizer N (Jones *et al.* 1983; McCown *et al.* 1986). To illustrate this, some data from a bioassay experiment, in which caribbean stylo and *Cenchrus setiger* were grown for varying lengths of time before cropping with sorghum, are shown in Figure 1. By extrapolating the curves back to the x axis to get estimates of N from the soil and plant residues, it would appear that the short ley contributed about 15 kg/ha and the long about 85 kg/ha of N to the sorghum crop.

The potential for losses of N from ley pasture systems, however, is quite high. A major factor in this is the lack of co-incidence of the patterns of N release from decomposing plant residues and N uptake by the crop. In this environment,

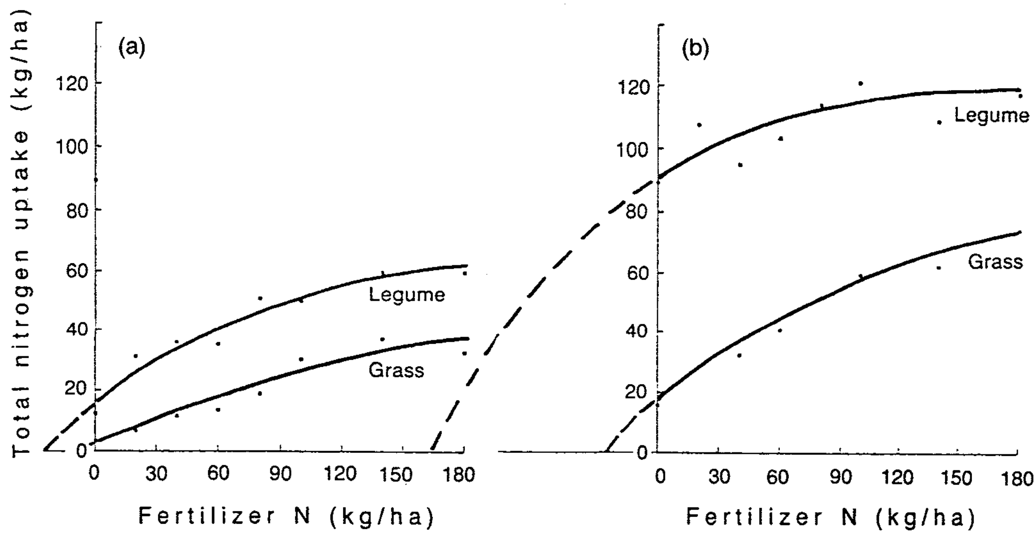

Figure 1. Total N uptake by sorghum when grown after (a) short, and (b) long leys of the legume caribbean stylo or the grass *Cenchrus setiger*. The experiment was conducted on a sandy loam soil near Katherine, NT and a range of rates of fertilizer-N was applied. The data for caribbean stylo are the means of three legume management systems. Leys consisted of a short establishment season plus either one or three subsequent seasons. The curves are drawn by hand.

appreciable rain often falls before the conditions for crop establishment are optimal. Carberry and Abrecht (1991) showed that at Katherine the optimum planting "window" was in the last two weeks of December, by which time an average of 220 mm of rain had fallen. During this pre-planting period, the warm moist conditions are highly favourable for mineralization of both soil organic-N (Wetselaar 1962) and N in plant residues from the previous season (J.P. Dimes, unpublished data). Unfortunately this mineral-N is very susceptible to leaching, particularly on the lighter soils. Cumulative mineral-N profiles taken from the experiment referred to in Figure 1 clearly show (Figure 2) large increases in mineral-N below 100 cm depth, particularly beneath the legume plots. This N at depth would be almost certainly lost to the sorghum crop which had not even been planted at the time of sampling. The loss of N can probably be minimized if a vigorous grass-based pasture is allowed to regenerate on these early rains and is killed chemically just prior to planting the grain crop.

Control of pasture species during the crop phase

In the proposed pasture ley system, no-till planting of the crop is considered essential for reducing the risks of soil erosion (particularly in the opening weeks of the wet season) and of high temperature damage to seedlings (Carberry and Abrecht 1991). The plant residues or mulch consist of old crop or pasture material from the previous season, together with new plant material which has grown during the storm period prior to planting and been killed with herbicide sprays one or two weeks before planting. It is important that the interval be short; longer periods allow the legume residues with their low C/N ratios to decompose, leaving a relatively bare soil surface at planting.

Although more work needs to be done on the control of legumes, grasses, and weeds prior to no-till planting of the cereal crop, Roundup applied at 1.5-3 l/ha will control most of the important species. It must be stressed, however, that it should be applied under optimum conditions — viz cool temperatures, high humidity, and when plants have no moisture stress. Buffalo clover and buffel grass (*Cenchrus ciliaris*) may be difficult to control under some conditions, particularly where the plants are past the seedling stage. In this case it may be advantageous to mix other chemicals such as 2,4-D with the Roundup.

Post-emergent control of unwanted plants in the cereal crop is achievable with a mixture of Dual (a.i. 720 g/l Metalochlor) for dicotyledons and Atrazine (500 g/l a.i.) for monocotyledons both at 2.5 l/ha. This gives control for about six weeks which is generally long enough for the crop to achieve canopy closure. The cost of these chemicals is a major limitation to their commer-

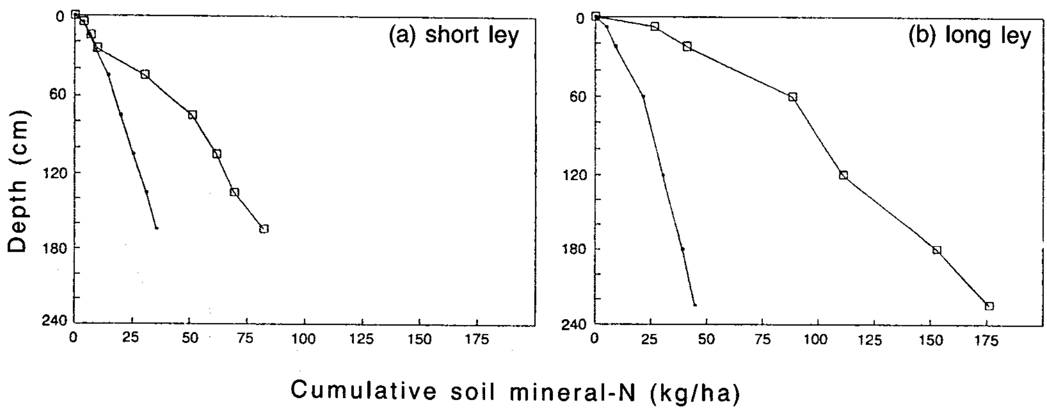

Figure 2. Cumulative amounts of mineral N (nitrate + ammonium) with depth just prior to planting the crops shown in Figure 1 after (a) a short or (b) a long ley. ●—● *Cenchrus setiger* ley pasture, □—□ caribbean stylo ley pasture.

cial use; it could be reduced if grass weeds were eliminated from the prior pasture phase or if a narrower row spacing was used for the cereal crop to give faster canopy closure.

An alternative to controlling the various pasture and weed species during the crop phase is to allow only the ley legumes to grow as an intercrop with the cereal. The advantages of this system (a version of intercropping) are that additional legume seed is set beneath the crop to enhance re-establishment of the pasture in the following year, the value of the residues for animal production is improved, and the cost of herbicides may be reduced. One disadvantage is that the grain yield of the crop may be reduced by competition with the intercrop.

Value of tropical leys to animals

It seems probable that in a ley system the major nutrient limitations to crop growth (other than N) will be removed by fertilizer additions to the crop. Given good agronomy, the productivity of the cereal crop will then be limited only by water and perhaps N. During the pasture phase, therefore, one can expect the pasture species to be well supplied with residual levels of most nutrients. Such pasture will be of high quality for cattle in this region during both the wet and dry seasons.

We are aware of only one study in the Australian semi-arid tropics (McCown *et al.* 1986, at Katherine, Northern Territory) in which an experimental ley pasture system has been grazed and animal production data recorded. The study compared liveweight gains of beef cattle continuously on native pasture at 15 ha/hd with gains when animals were removed from the native pasture for periods of about 120 days per annum in the dry season (July to October) to graze on ley pasture and crop residues at 0.3 ha/hd (Figure 3).

During the main dry season (about 100 of the above 120 days), animals on ley pasture and crop residues gained an average of 455 g/hd/day compared with losses of 250 g/hd/day at that time on native pasture. In the 20-25 days of the early wet or green season, however, animals which remained on the ley lost more weight than those on native pasture (965 vs 395 g/hd/day). These losses on leys, together with compensatory gains by animals on native pasture during the wet

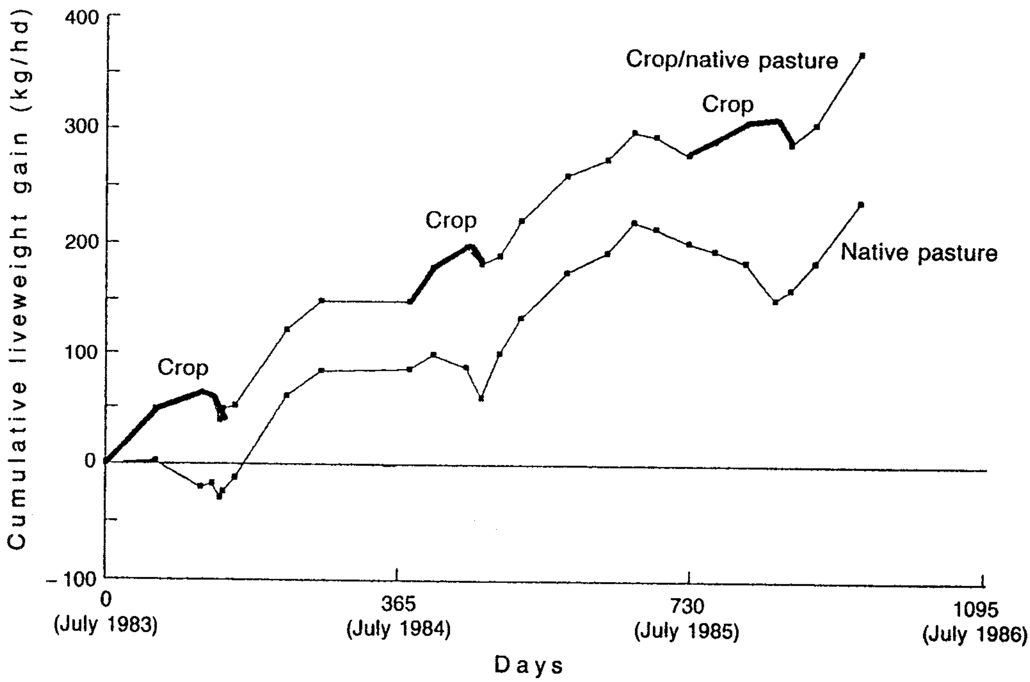

Figure 3. Cumulative liveweight trends for cattle either continuously on native grass pasture (thin lines) or on croplands (thick lines) in the main dry season and on native grass pasture for the rest of the year. (Redrawn from McCown *et al.* 1986.)

season, slightly reduced the overall benefits of the ley system to animal production. However, cattle on leys still gained about 100 kg/hd more than those continuously on native pasture, over the 3 years of the experiment.

In regions where the dry season is reliably dry, one could expect ley pasture (and associated crop residues) to provide a high quality diet for three to four months of the year, and at a high stocking rate. They could be very useful for weaners and female cattle which otherwise would be vulnerable to the usual weight loss and mortality on native pastures.

Management problems and possibilities

Leys consisting of legumes only would seem desirable in order to maximize the N contribution to the systems. However, pure legume leys have several serious disadvantages. Firstly, they are difficult to manage and would require the use of herbicides to kill grasses and weeds, particularly in the second year when soil fertility had improved. Secondly, they decompose too rapidly in the cropping season (J.P. Dimes, unpublished data) and may not provide sufficient mulch for control of soil temperatures and crusting which is so essential for successful crop establishment (Carberry and Abrecht 1991). Associated with this is the rapid mineralization of N which may lead in the short term to the 'nitrate bulge' being out of reach of the crop roots, as in Figure 2, and in the long term to soil acidification. Thirdly, legume residues which have been rained on during the dry season become mouldy and extremely unpalatable to cattle (McCown *et al.* 1981), resulting in rapid liveweight loss (Figure 3 and Staples *et al.* 1983) if animals have no alternative feed.

It would seem, therefore, that the presence of some grass in the ley is essential for a stable and sustainable system. Grasses readily invade legume pastures when the level of soil fertility increases, decompose and release their N quite slowly when killed with herbicides (J.P. Dimes, unpublished data), and regrow rapidly at the beginning of the wet season, thus providing high quality animal feed. Grasses have the added advantage of taking up N rapidly on the early rains, thus minimizing leaching loss but releasing it to the crop when killed with herbicide. The spatial distribution of grass within a predominantly legume ley pasture is also important. Grasses which form an intimate mixture with the legume are to be preferred to those which form large pure grass patches. In the latter case, crops grown on the areas formerly occupied by the pure grass are usually poorer because the rate of N release is too slow for the needs of the crop. Grass dominance in the ley can be avoided by judicious grazing in the mid-wet season when cattle prefer grasses to legumes.

Definitive studies on intercropping in northern Australia are as yet incomplete (P.S. Carberry and R.L. McCown, personal communication), but it is clear that an intercrop of forage legume as an understory can compete strongly with the grain crop for scarce resources such as N and water in some seasons and depress grain yields (Chamberlin *et al.* 1986). The development of an intercropping model and an analysis of the probabilities of various outcomes over a range of environments will enable this practice to be realistically assessed. One practical problem associated with the use of centurion centro as an intercrop is its ability to climb up maize and sorghum plants and perhaps interfere with harvesting. An application of 2,4-D prior to harvest may be necessary if this problem is severe.

In grazing the leys during the dry season, it is important to leave sufficient well-distributed mulch on the soil surface for successful re-establishment of either the pasture or the crop. Thus a difficult compromise has to be reached by managers between the needs of the animals and of the plants in the system.

Genetic resources for tropical ley pastures

The genetic resources for pastures which have been evaluated in north-west Australia up to 1983 have been thoroughly reviewed by Winter *et al.* (1985). They pointed out that legume and grass species specifically for ley pasture use had not been sought, and that perennial legumes which could exploit (rather than be disadvantaged by) the rains of the early wet season may be useful. Further testing by Cameron (1989) on the heavier textured Red Earth soils (Tippera series) in the 900-1200 mm rainfall zone of the Northern Territory has brought to light a number of perennial legume accessions from *Centrosema pubescens, C. brasilianum, C. schottii, C. virginianum*, and *Macroptilium atropurpureum* which may have potential to fill this gap.

Considering the small number of farmers in northern Australia with interests in integrated cropping/livestock systems, however, it would appear that there is an adequate range of germplasm available. We consider that further introduction and evaluation of material specifically for pasture leys should await the clearer definition of problems with the current suite of pasture species, under commercial farming conditions.

Prospects for use of ley systems

Prospects for widespread commercial use of ley systems are closely linked with the economic viability of grain cropping in various regions of northern Australia. In the Northern Territory, a number of farmers in the Douglas-Daly region are rotating a sorghum crop with one to two seasons of pasture dominated by centurion centro (cv Cavalcade) (T. Price, personal communication). They may be able to develop a small integrated farming system producing beef, grain, pasture seed and hay for the local market. Wide scale development of ley farming systems, however, must await substantial improvements in the economic viability of cropping. On the widespread sesqui-oxidic soils of this region where leaching of N (and eventual soil acidification) is a problem, a high-value and deep-rooted perennial crop may be the only solution.

In northern Queensland, there appears to be little use by producers of legume ley pasture systems, even around the drier margins of the Atherton Tableland. However, considerable interest is being expressed in systems under test by the Queensland Department of Primary Industries (A.L. Cogle, personal communication).

Despite the many advantages of tropical farming systems based on legume leys, the disadvantages of their requirements for high inputs and quite sophisticated management suggest that any expansion of such systems in northern Australia will be very slow.

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