Sustaining productive pastures in the tropics 8. Persistence and productivity of temperate legumes with tropical grasses

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Abstract

This paper discusses the distribution, importance, current status and future research needs of three groups of temperate legumes which grow with tropical grasses in eastern Australia. Lucerne (*Medicago sativa*), is best adapted to more fertile soils in sub-coastal and inland areas. White clover (*Trifolium repens*), other *Trifolium* species and *Lotus* grow mainly in the sub-tropical coastal areas of southern Queensland and northern New South Wales. Annual legumes adapted to drier inland areas include annual medics (*Medicago* spp.) on slightly acid to alkaline loams and clays, sub clover (*T. subterraneum*) on moderately acid sandy and loamy soils and serradella (*Ornithopus* spp.) on moderately to strongly acid sandy soils. The total area where mixed pastures of temperate legumes and tropical grasses are adapted is at least the size of Victoria.

Temperate legumes are invaluable to dairying, beef, sheep and mixed farming (grain and animal production) enterprises and are used to augment native pasture, sown pastures, forage and hay crops and to restore soil fertility for grain forage production.

Resumen

*Se discute la distribución, la importancia, el estado actual y la investigación futura requerida sobre tres grupos de leguminosas templadas, las cuales son cultivadas en asociación con gramíneas tropicales en la región este de Australia. La alfalfa (*Medicago sativa*) se encuentra mejor adaptada a suelos más fertiles de las áreas sub-costeras y de las áreas del interior. El trébol blanco (*Trifolium repens*), otras especies de *Trifolium *y* Lotus *son cultivados principalmente en las áreas costeras sub-tropicales de la región sur de Queensland y en la región norte de New South Wales. Las leguminosas anuales adaptadas a las áreas secas del interior incluyen medics anual (*Medicago *spp.) en la suelos limosos y arcillosos ligeramente ácidos a alcalinos, el trébol subterráneo (*T. subterraneum*) en suelos arenosos y limosos moderadamente ácidos y la serradella (*Ornithopus *spp.) en suelos arenosos moderada a fuertemente ácidos. El área total en donde se encuentran adaptadas las mezclas de leguminosas templadas y las gramíneas tropicales es cuando menos del las dimensiones del estado de Victoria, Australia.*

Las leguminosas templadas son de un gran valor para las empresas de producción de borregos, de leche y carne bovina, y para las granjas de producción mixta (producción animal y de granos). Dichas leguminosas son usadas en asociación con las pasturas nativas, con las pasturas introducidas, con los cultivos para forraje y heno y para restaurar la fertilidad del suelo destinado a la producción de granos y forrajes.

Introduction

This paper discusses the distribution, importance, strengths and weaknesses and future research needs of three groups of temperate legumes which grow with tropical grasses in eastern Australia.

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The most important legumes are lucerne (*Medicago sativa*) (summer-growing temperate perennial), white clover (*Trifolium repens*) and lotus (*Lotus pedunculatus*) (temperate perennials), and annual medics (*Medicago* spp.), sub clover (*T. subterraneum*) and serradella (*Ornithopus* spp.) (temperate annuals).

Distribution and importance of temperate legumes in the sub-tropics

Climate and soil

Frost and low temperatures stop the growth and reduce the quality of tropical grasses in winter. However, mild temperatures combined with significant amounts of winter rain (which provides at least 30% of the annual total in the winter six months in sub-tropical eastern Australia) allow for growth of adapted temperate legumes. The large area (about 230 000 km^2 — at least the size of Victoria) where both sown tropical grasses and temperate legumes are adapted is shaded in the accompanying maps (Figure 1). The inland limit shown for sown tropical grasses is modified from Moore (1970).

The area shown for lucerne is based on Weston *et al.* (1984) and McDonald and Waterhouse (1988). It occurs east of the 450 mm isohyet in the north, and the 350 mm isohyet in southern New South Wales. Lucerne is well adapted to more fertile soils, but not to acid sandy soils. White clover grows on all but the poorest acid soils east of the 800 mm annual rainfall isohyet and north to Gympie (Moore 1970), and on the elevated Atherton Tableland and Eungella Range in north Queensland (not shown in Figure 1). The area shown for annual medics is adapted from Moore (1970), Clarkson (1977) and Weston *et al.* (1984). Medics are well adapted to slightly acid to alkaline loams and clays, but not to more acid sandy soils. In Queensland they grow between the 800 mm and 400 mm isohyets, but in southern New South Wales the lower limit is 250 mm. New cultivars of sub clover, adapted to drier environments, enable the western limit of Moore (1970) to be extended down to the 500 mm isohyet. Sub clover is adapted to moderately acid sandy and loamy soils. The map for serradella is modified from Michalk (1990) by adding a new area in southern Queensland and excluding coastal areas, and represents moderately to strongly acid sandy soils where MAR exceeds 500 mm.

Uses in farming systems

Temperate legumes are invaluable in the dairying, beef, sheep and mixed farming areas because they increase pasture protein levels and sustain pasture and animal productivity. They are used to augment native pastures and are also widely sown with introduced tropical grasses such as kikuyu (*Pennisetum clandestinum*), setaria (*Setaria sphacelata*), rhodes (*Chloris gayana*) and purple pigeon (*Setaria incrassata*) grasses. Lucerne (and to a lesser extent snail medic (*M. scutellata*)) is also used extensively as a grazed forage or hay crop.

Ley pastures of lucerne, annual medics or a mixture of tropical grasses and temperate legumes have an emerging role in restoring soil fertility of arable soils, particularly vertisols used for grain production. Ley pastures improve the grain yield and protein content of wheat (Lloyd *et al.* 1991; Dalal *et al.* 1991).

Strengths and weaknesses of different species

Lucerne

Lucerne has been widely grown in Australia at least since the 1860s (Cameron 1973), but until the 1960s Hunter River was the main cultivar. New cultivars introduced before 1977 were intended to raise yields, especially in winter (Oram 1990). Because most of the seed was produced in the south, there was no opportunity for natural selection to develop specific adaptation to the subtropics (Cameron 1977).

By 1977, recognition of the importance of the diseases *Colletotrichum* crown rot and *Phytophthora* root rot in the persistence of lucerne in the sub-tropics (Irwin 1977; Gramshaw 1978) and the appearance of the devastating bluegreen aphid (*Acrythosiphon kondoi*) and spotted alfalfa aphid (*Therioaphis trifolii* f. *maculata*) in that year led to the introduction of new genetic material from the USA (Brownlee *et al.* 1984; Lloyd *et al.* 1985). Subsequent breeding programmes by CSIRO, QDPI and NSW Agriculture & Fisheries have improved the productivity and persistence of lucerne in the subtropics (Clements *et al.* 1983; Lowe *et al.* 1987) partly because of well-coordinated testing (Lloyd *et al.* 1985). The important new cultivars, Trifecta and Sequel (Qld) and Aurora (NSW) (Oram 1990), have substantial resistance to the above pests and diseases and are more winter-active than Hunter River.

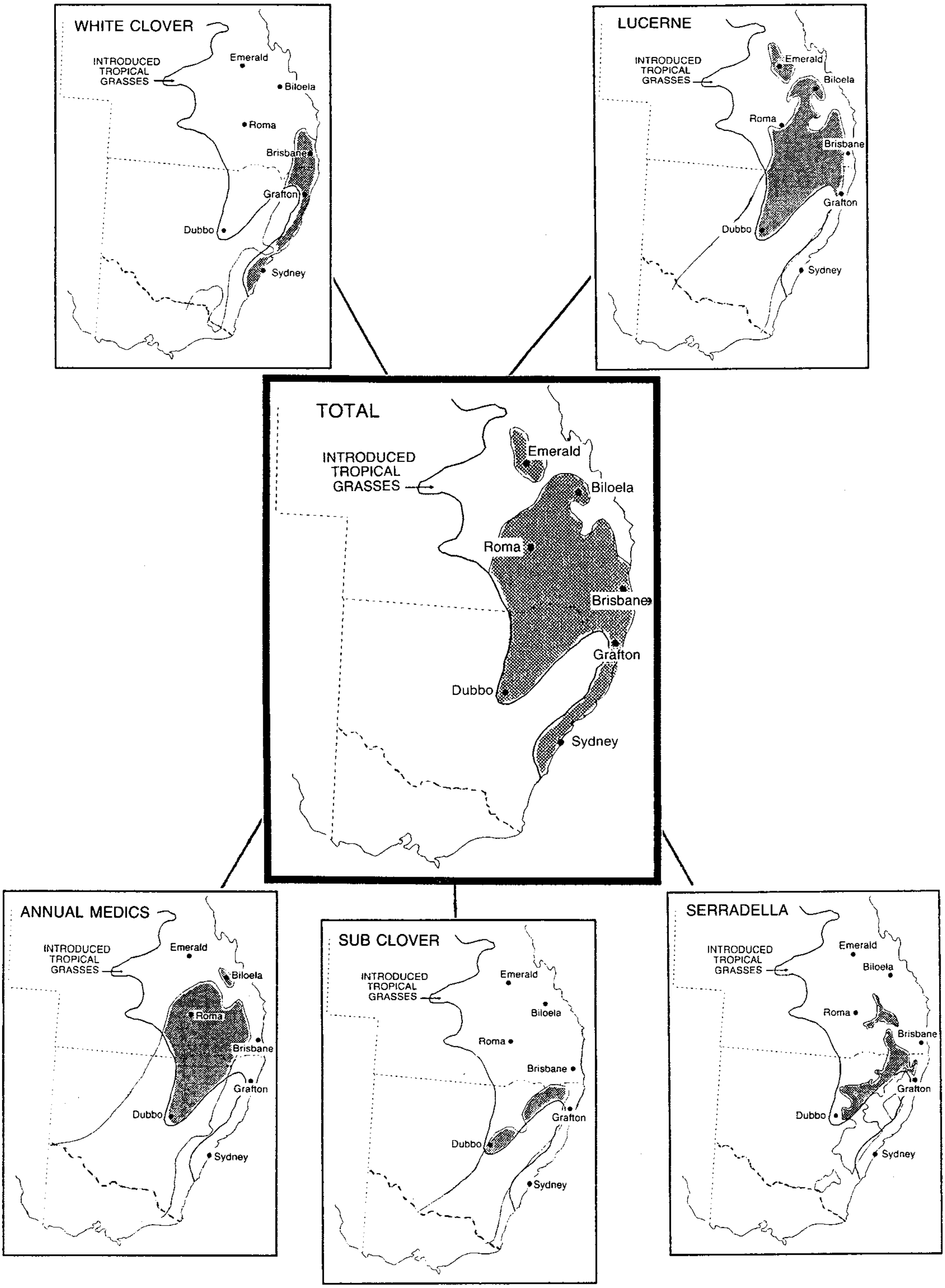

Figure 1. Total area to which both temperate legumes and introduced tropical grasses are adapted in subtropical eastern Australia (centre), and individual areas for the major legumes. Shading shows the area of concurrence of grass and legume.

In the humid coastal sub-tropics, lucerne may be grown with tropical grasses such as rhodes or setaria, but the mixtures are unstable because of summer waterlogging and disease in lucerne, and superior adaptation of the grass. In the colder inland areas, mixtures with rhodes, green panic (*Panicum maximum* var. *trichoglume*), makarikari (*Panicum coloratum* var. *makarikariense*) or purple pigeon grasses are more stable as the lucerne is better adapted and the grass is less aggressive. In the semi-arid western areas of lucerne adaptation in southern Queensland and northern NSW, buffel (*Cenchrus ciliaris*) and birdwood grass (*Cenchrus setigerus*) are useful companion species (W. McDonald, personal communication). Rotational grazing promotes a desirable grass-legume balance (and lucerne persistence in pure swards) by reducing grass competition and by spelling the lucerne (Gramshaw 1978), but good management is not considered a substitute for good legume adaptation (Bishop and Gramshaw 1977).

Lucerne in sub-tropical pasture mixtures enhances beef production even at plant densities of 2-4 plants/m^2 (Christian and Shaw 1952), probably by improving feed quality rather than by supplying symbiotic N (Leach 1978) to the grass. High wool production is obtained from lucerne and grass/lucerne pastures (Lloyd *et al.* 1983), but the use of supplementary grazed lucerne with native pastures for wethers may be uneconomical because of the costs of fencing, cultivation, seed and fertiliser (Cassidy *et al.* 1973).

White clover

In the sub-tropics, white clover grows actively in spring but there is considerable death of stolons over summer. When active growth recommences in autumn this can be from seedlings and/or stolons that have survived over summer (Jones 1982). Soil seed reserves can vary from 1 000 to 10 000 seeds/m^2 (Jones 1982; Garden 1988). Seedlings emerge between February and late September with a peak in June, depending on rainfall. Early germinations produce bigger plants with more stolons than those germinating in July, and these can better withstand dry conditions in spring (Jones 1984; Garden 1988). The preferred cultivar Haifa has extended the adaptation of white clover in the sub-tropics through its high heat tolerance, high seed yield and stronger perennation (Oram 1990). Successful selection of a cultivar with better stolon survival over summer than Haifa could improve the persistence and productivity of white clover in the sub-tropics appreciably.

White clover is widely naturalised on soils of high to moderate fertility in the moist sub-tropics, but grows well on poorer soils if adequate fertiliser is applied. Phosphorus is usually the most important limiting nutrient (Mears *et al.* 1985) and lime is required on soils of pH $<$ 5.0 (Jones 1984).

White clover persists better if there is heavy grazing of the associated tropical grasses over summer as this can improve stolon survival (Jones 1982), although in dry periods it can lead to greater death of stolons and newly emerged seedlings (Garden 1988). Heavy grazing over summer also improves seedling emergence in autumn from the soil seed bank (Jones 1982). White clover combines well with a wide range of tussock and stoloniferous tropical grasses, although it is difficult to manage with kikuyu. Detailed information on white clover in subtropical Australia is given by Ostrowski (1972) and Jones (1987).

Lotus

Grasslands Maku lotus, released in New Zealand (Armstrong 1974), has been widely sown along the eastern seaboard and on the Atherton Tableland. It tolerates soil acidity, low phosphate and excesses of manganese and aluminium better than white clover (Scott and Lowther 1980). Maku spreads well from stolons and rhizomes, and withstands short-term waterlogging but not prolonged drought on sandy soils. A high concentration of condensed tannins in its foliage (W.M. Kelman, personal communication) confers protection from bloat, but excess may impair digestibility. Maku is late-flowering and produces few flowers at latitudes below 32 °S. Application is being made to register an Australian cultivar having early flowering, high seed yields and moderate tannin concentrations (G.P.M. Wilson, personal communication).

Annual medics

Annual medics have been widely naturalised in Australia for over 100 years. The first commercial cultivars were selected in southern Australia from naturalised and introduced material. The most important medics in sub-tropical Australia before 1977 were the commercial cultivars of barrel medic (*M. truncatula* cvv. Jemalong, Cyprus) and snail medic (*M. scutellata* cv. Robinson); and the naturalised burr medic (*M. polymorpha*), woolly burr medic (*M. minima*) and cutleaf medic (*M. laciniata*. Other minor commercial species were strand medic (*M. littoralis*), disc medic (*M. tornata*) and gama medic (*M. rugosa*).

When most annual medics proved susceptible to blue-green aphids and spotted alfalfa aphids, new aphid-resistant cultivars such as Paraggio and Sephi (barrel) and Sava (snail) were quickly selected and released. However replacements for the best older cultivars have required a breeding programme which will provide a new generation of synthetic cultivars with improved herbage yields, wider adaptation, and a reduction in excessive hardseededness which has restricted the regeneration of older cultivars in South Australia (Crawford *et al.* 1989). Excessive hardseededness is not a problem in the sub-tropics; although hardseededness is high initially, it is less durable because the seed has less opportunity to dry out in summer after ripening. Adaptation of medics to acid soils below a pH of 6 has been widened with the release of murex medic (*M. murex* cv. Zodiac) (Gillespie 1988; Oram 1990) and an associated acid-tolerant strain of *Rhizobium meliloti* which also broadens the soil adaptation of burr medic (Howieson and Ewing 1986). In the sub-tropics, a new cultivar of snail medic (cv. Kelson) provides a late-flowering, high-yielding plant for ley pastures on clay soils (Weston and Lehane 1989).

In mixed pasture with a sub-tropical grass, annual medics grow in winter and spring when the grass is dormant. Symbiotic nitrogen from the medics increases grass growth in summer, so that the pasture has a higher total yield, higher quality and less seasonality of growth. Soil total nitrogen also increases substantially. Total pasture yield may be increased up to 5-fold by inclusion of annual medics, due to the combined effect of medic growth in winter and extra grass growth in summer (Clarkson *et al.* 1987). This pattern of growth and the benefits accrued from annual medics will also occur with the other temperate annual legumes.

Seasonal herbage yield of medics on suitable soils in southern Queensland is a linear function of winter rainfall, but the harvest index of seed is much lower in marginal areas than in favourable areas because of heat and aridity during seed set. Thus low seed production is likely to be more important than low herbage production in determining the limits of adaptation of medics in the sub-tropics (Clarkson 1989). There is no clear ideotype for the sub-tropics. Although the earliest flowering medics have the highest average seed yields (Cornish 1985; Clarkson 1986), seed production depends on a complex interaction between: variable germination time (there is no clear 'break' in the season as occurs in Mediterranean climates); the different effects of germination time on flowering time of early and late-flowering cultivars (Clarkson and Russell 1975, 1979; Hochman 1987); timing of winter rain; and seasonal temperature patterns. Successful medics have a range of maturities, drought resistance of seedlings, hardseededness and seed size (Young 1987). Woolly burr medic, although well adapted, is not sown commercially because the burrs cause vegetable fault in wool which reduces its value, and because new genotypes in other species have superior aphid tolerance and herbage production. Similarly, unselected burr medic, which was commercially available as a by-product of the medic seed industry, has been replaced by new cultivars such as Santiago (Oram 1990), and by barrel medic because of its superior production.

The contribution of annual medics in enhancing animal production in the sub-tropics is well documented (Howard 1961; Coaldrake *et al.* 1969; Tothill 1973; Russell 1985).

Sub clover

Sub clover has been grown commercially in Australia since 1889, but the first sowings in the sub-tropics were in the 1950s. Although sowings in the sub-tropics were initially unsuccessful because of poor survival of *Rhizobium* inoculum grown on agar, the problem of legume nodulation was solved in the 1960s when peat inoculum became available. High oestrogenic potency in the old cultivars Dwalganup, Tallarook, Dinninup and Yarloop caused infertility in sheep. Recent cultivars, for example, Esperance, Junee, Karridale and Green Range, generally have low oestrogenic activity, higher hardseededness (for improved persistence) and wider adaptation which will enhance their value in the sub-tropics. However, the importance of newly-acquired resistances to clover scorch, clover stunt virus, root rots and red-legged earth-mite (Nichols 1987; Oram 1990) in the adaptation of sub clover in the sub-tropics is unknown.

Sub clover is widely used to augment native pastures in northern New South Wales and on the granite belt of southern Queensland where increases in stocking rates of sheep, from 1.5 dry sheep equivalents (DSE)/ha on cleared native pasture to 3-9 DSE/ha where legumes are sown, are obtained (Swann 1982).

Serradella

Cultivation of serradella in Australia began with imported French serradella (*O. sativus*) before 1950 and a naturalised strain of yellow serradella (*O. compressus*) in Western Australia in 1955 (Gladstones and McKeown 1977). These late-flowering types (for example, cv. Pitman) did not persist in Queensland (except on the granite belt), probably because of low seed yields, insufficient hardseededness and the occurrence of a pod-boring insect in spring. New selections with earlier flowering, high hardseededness and higher seed yields (Gladstones 1984) have been commercialised.

The cultivars Avila (late-flowering replacement for Pitman), Madeira, Elgara and Paros (yellow serradella) and Jebala (slender serradella, *O. pinnatus*) are suited to the sub-tropics (Oram 1990). Expansion of the area sown to serradella is being restricted by the high level of hard seed in commercial seed. While mechanical and heat treatments are being investigated, no suitable commercial treatment is yet available.

Serradella is adapted to moderately to very acid soils with low nutrient content. Although it requires some P and S fertiliser for growth, its P requirement is less than that of burr medic or sub clover (Paynter 1990). Some cultivars, for example Paros, are adapted to soils with high exchangeable aluminium levels. Serradella nodulates well with *Rhizobium lupini* which colonises and persists well in sandy soils (Chatel and Parker 1973).

Serradella has grown well in mixtures with rhodes grass or Premier digit grass (*Digitaria smutzii*) in Queensland, and also with Consol lovegrass (*Eragrostis curvula* f. *conferta*) in New South Wales (Freebairn 1990). With low inputs of superphosphate, rhodes grass/serradella pasture has greatly increased wool production and liveweight of sheep at Leyburn on the Darling Downs (Johnson and Lloyd 1991).

Other species

About 40 species of *Trifolium* from east Africa show some potential in moist, seasonally waterlogged environments of sub-tropical Australia. The most promising accessions are the annuals *T. mattirolianum, T. ruepellianum, T. tembense* and *T. usambarense* (Wilson 1985). The perennials *T. semipilosum* and *T. burchellianum* have established and persisted on krasnozem, alluvial and dry hill soils in coastal New South Wales (Garden 1977; Cameron *et al.* 1989; Wilson 1985).

Improving temperate legumes

The primary emphasis should be on understanding the critical pathways to adaptation and productivity of each species so that suitable genotypes and management may be combined within sustainable and profitable systems. Priority areas are listed below:

1. Improved persistence in lucerne, clovers and lotus through: better survival of stolons, rhizomes or tap roots; tolerance to excesses of soil acidity, manganese and aluminium and deficiencies of phosphorus; and ability to maintain a leaf canopy under variable grazing. The gene pools of *Lotus pedunculatus* (<20 lines at present), and of other *Lotus* species need to be enlarged.
2. Producing a non-bloating lucerne, for example, by genetic engineering (Larkin *et al.* 1986).
3. Breeding and selection of annual medics, sub clover and serradella with the correct maturity characteristics, high herbage and seed yields, high hardseededness and low seed losses in summer (Hagon 1974; N.M. Clarkson, unpublished data), and low bloat risk (medics, sub clover).
4. Maintenance of a comprehensive gene pool for all species, from which to select for resistance to waterlogging, salinity (Russell 1976) and new pests and diseases as they arise.
5. Refining knowledge of minimum fertiliser requirements of all species for P and S nutrition of plants and animals (Clarkson *et al.* 1989; Johnson and Lloyd 1991).
6. Improved nodulation of medics and sub clover on acid and acidified soils (Williams 1980) through the use of lime and acid-tolerant *Rhizobium*; and a more cold-tolerant *Rhizobium* for serradella (Bolland and Gladstones 1987).
7. Understanding and managing competition between legumes and winter cereals during establishment, and between legumes and tropical grasses under grazing. Studies on seed

dynamics of annual legumes (Heida and Jones 1988) should include the effects of management, herbicides and tillage methods in ley farming systems.

National plant improvement programmes

Historically, temperate legumes have become commercialised from naturalised genotypes (for example annual medics and sub clover), or from collections of exotic strains. However, new pests and diseases and the need for wider adaptation have prompted extensive collections from other countries to provide the large gene pool from which these and future problems may be overcome by selection and breeding. This has led to the establishment of National Plant Improvement Programmes.

The most recent programme is for white clover (Curll 1987), coordinated by NSW Agriculture & Fisheries at Glen Innes. Other national programmes have been in place for some years for annual medics (Crawford *et al.* 1989), sub clover (Collins and Stern 1987) and serradella (Gladstones 1984); similar schemes are planned for lucerne and *Lotus pedunculatus*. The advantages of national coordination include more comprehensive testing of material, identification of wide adaptation and specialist niches, and improved prospects for a profitable seed industry.

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