Origin, evaluation and use of *Macrotyloma* as forage — a review

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Abstract

The legume genus *Macrotyloma* contains 3 species currently used in agriculture. Two of these, *M. axillare* and *M. uniflorum*, are used as forage plants in the tropics and subtropics. Two other species, *M. africanum* and *M. daltonii*, have also shown potential as forage plants. This review examines the origin and evaluation of introduced lines and their use and adaptation as commercially used forages. *M. axillare* (axillaris) is used on drier ridges on the south-east coast of Queensland and could be useful on the drier tablelands of north-east Queensland. In Bolivia and Sri Lanka axillaris is used in dairy pastures. *M. uniflorum* has shown potential as a standover dry season livestock feed in northern Australia, where a breeding program has centred on increasing levels of hardseededness. *M. africanum* may have a place in leys on clay soils in north Queensland. *M. daltonii* may have a place as a short-term forage in northern Australia and possibly a permanent contribution to grazing on southern brigalow soils in Queensland.

Resumen

La leguminosa del género Macrotyloma *incluye tres especies utilizadas actualmente en la agricultura. Dos de estas,* M. axillare *y* M. uniflorum, *son usadas como plantas forrajeras en los trópicos y sub-trópicos. Otras dos especies,* M. africanum *y* M. daltonii, *han mostrado también tener un potencial como plantas forrajeras. Esta revisión examina el origen y la evaluación de líneas introducidas y su uso y adaptación comercial como plantas forrajeras.* M. axillare *(axillaris) es usada en las lomas secas de la costa sur-este de Queensland y podría ser de utilidad en las altiplanicies secas del nor-este de Queensland. Axillaris es usada en Bolivia y en Sri Lanka como pastura para la producción de leche.* M. uniflorum *tiene un potencial para la alimentación del ganado en la época seca al norte de Australia, en donde un programa de cruzamiento genético se ha enfocado al incremento en los niveles de dureza de la semilla.* M. africanum *podría tener un papel en las tierras de cultivo en suelos arcillosos del norte de Queensland.* M. daltonii *podría tener un función como forraje en períodos cortos en el norte de Australia y posiblemente contribuir permanentemente al pastoreo el los suelos de brigalow al sur de Queensland.*

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Introduction

Prior to the revision of the taxonomy of the *Dolichos sensu lato* complex by Verdcourt (1970), the present genera *Dolichos, Lablab,* and *Macrotyloma,* in addition to some other genera, were in the one genus *Dolichos. Lablab* is distinguished from *Dolichos* and *Macrotyloma* on the basis of the blade-like style, elongate non-pedicellate stigma and other characteristics (Verdcourt 1980). The style, standard and pollen characteristics distinguish *Macrotyloma* from *Dolichos* (Verdcourt 1970). The name *Macrotyloma* is derived from the Greek *makros* = large, *tylos* = knob and *loma* = margin in reference to knobby sutures on the pods. *Macrotyloma,* a member of the tribe Phaseoleae and the subtribe Phaseolinae, contains 25 species indigenous to Africa and Asia (Allen and Allen 1981; Lackey 1981).

Origin as wild and cultivated plants

The only two members of the genus *Macrotyloma* with a long history of cultivation are *M. uniflorum*, the horsegram of India, and *M. geocarpum* (formerly *Kerstingiella geocarpa*), Kerstings groundnut. *M. axillare* has had only a recent history of cultivation.

Though wild members of *M. uniflorum* exist in both Africa and India (Verdcourt 1971), its centre of origin as a cultivated plant is regarded as India (Vavilov 1951; Zohary 1970; Purseglove 1974; Smart 1985). Arora and Chandel (1972) are more specific and argue that the primary centre of origin and use of *M. uniflorum* var. *uniflorum* as a cultivated plant is south-west India, on the plains and hills of low altitude (1000 m) extending southwards in the western Ghats. Mehra and Magoon (1974), on the other hand, suggest that *M. uniflorum* has both an African and an Indian gene centre. Two other varieties, var. *stenocarpum* and var. *verucosum* are basically African in origin, although a wild, or long-naturalised form is found in north-eastern Australia (Bailey 1900).

There is general agreement that the gene centre of the Kerstings groundnut is the Nigeria-Cameroon border (Harlan 1971; Harlan *et al.* 1976; Shaw 1976; Harris 1976; Purseglove 1976; Marechal and Baudet 1977). Kerstings groundnut appears not to have been cultivated at its gene centre; rather it is a minor crop in west Africa, cultivated in a similar way to peanuts (Harlan *et al.* 1976; Smartt 1990). Kerstings groundnut is grown as a pulse legume and not as a forage and has been comprehensively reviewed in a study by Nishitani (1989).

Verdcourt (1970; 1971; 1982) gave details of the distribution of *Macrotyloma* species, their general habitat and the altitude at which they are found. The known distribution, in Africa, of *M. axillare, M.africanum,* and *M. daltonii* is presented in Figure 1. In general, *M. axillare* var. *glabrum* is distributed throughout central and south-east Africa, Madagascar, and parts of the Middle East; *M. axillare* var. *macranthum* has a limited distribution in east Africa. *M. daltonii* is distributed throughout the Sudan, the horn of Africa and central Africa, and extends into west Africa and South Africa. *M. africanum* has a similar distribution to *M. daltonii* but tends to be centred more in east Africa. *M. uniflorum* var. *uniflorum*, which contains the cultivated types, and var. *stenocarpum* are distributed throughout east Africa and south-west India; var. *verucosum* and var. *bendirianum* are limited to east Africa.

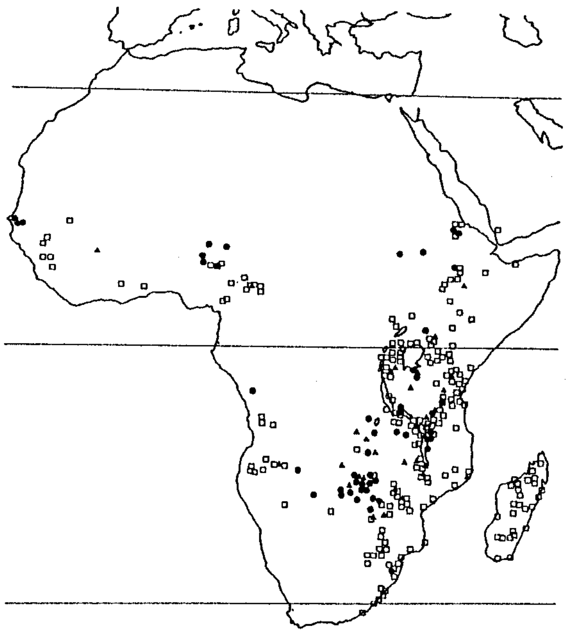

Figure 1. African distribution of *Macrotyloma*. From Verdcourt (1982). *M. africanum* (▲), *M. axillare* (□), *M. daltonii* (●).

The above species may be found in habitats ranging from sand dunes (*M. uniflorum* var. *bendirianum*) through grasslands, bushland and thicket to open forest (*M. axillare* var. *glabrum*) and in mixtures of the above. Soil adaptation appears to be wide, including granite outcrops (*M. uniflorum* var. *stenocarpum*), sands, black clays, red earths, yellowish grey sands and seasonally swampy clay (*M. africanum*) (Verdcourt 1971; Lind and Morrison 1974). *M. daltonii* occurs on black alkaline clays near Bulawayo, Zimbabwe, and on what is probably a heavy clay near Tozi in the Sudan. At Ukiriguru, *M. africanum* occurs on hardpan soils but not on the heavier soils of the mbugas. *M. axillare* is reported as coming from a wide variety of soils (R.L. Burt, personal communication).

Use and adaptation of *M. axillare*

Macrotyloma axillare var. *glabrum* (common name axillaris or perennial horsegram) has been used as a summer-growing perennial pasture plant in south-eastern Queensland, to a limited extent (Cameron 1977). The commercial cultivar Archer was released in 1966 (Oram 1990). Evaluation sites in Australia had a mean latitude of 26.4 °S (SD = 3.2), rainfall 1467 mm (281), annual average temperatures 20.3 °C (1.3) and annual minimum temperature of the coldest months 8.7 °C (2.3) (Russell and Webb 1976). As is typical of *M. axillare*, Archer is a summer-growing perennial best adapted to frost-free subtropical or tropical environments with 1000 mm or more annual rainfall (Cameron 1986; Oram 1990). It has become naturalised near Gympie in south-east Queensland and between Tolga and Walkamin on the Atherton Tablelands in north Queensland.

Archer is particularly well adapted to the Cooroy district of south-east Queensland, where it has a place on the drier ridges (Luck 1964). In this district it has been recommended for use mainly in mixtures with other legumes, to provide growth after they (e.g. *Desmodium* and *Macroptilium atropurpureum*) are wilted or even desiccated, as axillaris has good heat and drought tolerance (Luck and Douglas 1966). If left ungrazed or only lightly grazed, the twining, climbing habit of axillaris makes it a useful suppressor of weeds, especially crofton weed (*Eupatorium adenophorum*) on the coast of south Queensland (Tutt and Luck 1969). Evans (1971) was impressed with the early spring growth of axillaris and saw its unpalatability prior to maturity as an advantage for its persistence in grazed pasture. McCosker and Middleton (1975) envisaged a use for axillaris as a stand-over feed in frost-free areas receiving greater than 1000mm average rainfall. Axillaris was the most successful legume, in terms of establishment and persistence, when aerially sown into an ash seedbed in open eucalypt forest, near Gympie (Cook and Grimes 1977). Axillaris has been examined as a component of tropical pastures utilised by goats in south-east Queensland (Norton *et al.* 1990a).

M. axillare is regarded as a relatively unpalatable, free-seeding creeping perennial of the drylands of Zambia (Verboom 1965), though cattle become accustomed to eating it in Australia (Oram 1990). It has potential as a forage plant in the Kanke district of India (Chatterjee and Singh 1966). Axillaris is drought resistant but does not tolerate heavy grazing in the Philippines (Farinas 1966). It may have potential for foggage grazing in early winter in northern Mashonaland, Zimbabwe (Carew 1978) and was one of a number of promising legumes tested in Kenya (K.M. Ibrahim, personal communication). It has also been tested with some success in northern Thailand (Gibson and Andrews 1978), and gave moderate yields and good persistence (Gibson and Andrews 1985). Axillaris is recommended in three of five agro-ecological zones in the Santa Cruz of Bolivia (Paterson and Horrell 1981) where dry season standover of axillaris has been useful for milk production (Paterson *et al.* 1981). Menendez and Martinez (1980) found axillaris to be unsuitable as a cover or intercrop with grain sorghum, although it was seen to have potential as a forage legume in the Caribbean (Menendez *et al.* 1984). Axillaris has also been recommended for use in the Central Hainan Province of China (He 1987) and in dairy pastures in Sri Lanka (Chadhokar 1983). However, axillaris does not persist in dairy pastures dominated by *Ischaemum indicum* in Fiji (Ranacou 1986).

Inoculation and establishment

Corby (1974) observed nodules on *M. axillare* in Zimbabwe. *Macrotyloma* generally is effectively nodulated by the unspecialised cowpea type *Bradyrhizobium* (Trinick 1982). This is expected as the commercial cowpea inoculum CB 756 was isolated from *Macrotyloma africanum* nodules collected in Marandellas, Zimbabwe (Edye *et al.* 1974; Diatloff and Date 1978). In a study by Herridge and Roughley (1976), *M. axillare* yield was highest when inoculated with CB 756, not CB 1024 or NA 800/1. Variation in CB 756 culture has proved to be a problem in axillaris with some colony types being ineffective; largely as a result of this, CB 1024 is now recommended for the inoculation of *M. axillare* in Australia (Langdon 1983). Unlike lablab (*Lablab purpureus*) and *M. uniflorum*, black nodules do not occur in *M. axillare* (Cloonan 1963).

No detailed work has been carried out on the establishment of axillaris, as it can be easily established by drill or broadcast methods (Skerman 1977). Establishment has been achieved by aerial sowing into an ash seedbed (Cook and Grimes 1977). However, Carew (1978) reports establishment difficulties on disced veld in Zimbabwe, where axillaris established well on a fully prepared seedbed at the same site. Prodonoff (1968) regarded Archer as being hardseeded, but Crowther and Staples (1978) recorded only 2% hardseed in one seed lot tested. Scarification is usually unnecessary when sowing mechanically harvested seed.

Response to fertiliser

M. axillare responds to fertiliser, particularly superphosphate, on the south coast of Queensland on infertile duplex soils (Tutt and Luck 1969). They recommended applications of 370 kg/ha of molybdenised superphosphate at establishment with a maintenance application of 120–250 kg/ha depending on soil P status. Nitrogen applied at 100 kg/ha suppressed growth at Kimberley Research Station (Parbery 1967).

M. axillare appears not to be able to tolerate extreme acidity or alkalinity. In a study on an Hawaiian oxisol (pH 6), the application of 6 t/ha of lime depressed yield for a short time (Munns and Fox 1976). In further studies, again on an Hawaiian oxisol, relative yield of *M. axillare* reached a maximum at pH 7, requiring 5 t/ha of lime to achieve 90% of maximum yield (Munns and Fox 1977). The yield of *M. axillare* fell dramatically at pH < 6.0. Increased nodule effectiveness accounted for much of the growth increase in the pH range 4.5–7.0. Though nodule size decreased, nodule number increased with increasing pH. Soil adaptation in terms of pH in *M. axillare* appears largely to reflect the effectiveness of the symbiosis rather than plant growth *per se* (Munns *et al.* 1977).

Adaptation to stress

M. axillare is not particularly frost tolerant, with poor survival over the first winter (Jones 1969). Blumenthal and Hilder (1986) found a similar result with *M. axillare* cv. Archer after 58 frosts, but other lines may be more frost tolerant. Variation in the height of the cotyledonary node in *M. axillare* suggests that some accessions may be more frost tolerant than cv. Archer (Blumenthal *et al.* 1989). *M. axillare* can withstand fire (Staples 1980) and drought (Skerman 1977). *M. axillare* displays greater resistance to desiccation than *Desmodium, Leucaena,* and *Stylosanthes.* Apart from the slightly waxy appearance of the plant (possibly as a result of a highly impervious cuticle), no explanation is offered for the apparent high resistance to desiccation (Staples 1982a). *M. axillare* is not tolerant of waterlogging (Skerman 1977); following 21 days of waterlogging, no adventitious roots formed in *M. axillare*, and plant survival was only 12% (Whiteman *et al.* 1984).

Yield potential

Growth of *M. axillare* is maximal at day/night temperatures of 26/21 °C, lower than that reported for other tropical legumes (Herridge and Roughley 1976). High yields of *M. axillare* can be achieved; a crop sown in December in north Queensland produced 3–4 t/ha by May (Staples 1978b). Parbery (1967) obtained 15.5 t/ha on a Kununurra clay under irrigation. Axillaris had good seasonal growth and protein levels compared to a range of tropical legumes in a Brazilian study (de Mattos and Pedreira 1984). Green yields of green panic/axillaris of 39.1 t/ha were achieved in India, compared with 23.7 t/ha for green panic alone (Subramanya *et al.* 1976). Seed yields of almost 500 kg/ha have been achieved from *M. axillare* grown on a trellis in the Philippines (Castillo and Siota 1978).

Pests and diseases

M. axillare is remarkably free of pests and diseases (Skerman 1977). However, it is susceptible to the little leaf mycoplasma (Cameron and

Mullaly 1969), and to the nematodes *Meloidogyne incognita* and, to a lesser extent, *Rotylenchus reniformis* in the Philippines (Valdez 1976).

Grazing management and animal production

To prevent excessive shading by the associated grasses, light grazing is recommended for axillaris-based pasture during establishment. Once established, rotational grazing is recommended (McCosker and Middleton 1975) for the predominantly dairy pastures in southern coastal Queensland. Even under lenient grazing, axillaris failed to persist at Taroom in the southern brigalow of Queensland; from an initial establishment population of 2.2 plants/m^2, the population fell to 0.7 plants/m^2 after one month, and by the following year there were no surviving plants (Russell and Coaldrake 1970). This was probably as much a result of water stress as grazing pressure.

Axillaris often tends to be unpalatable early in its growth; Carew (1978) argues that this is a benefit if it is to be used as a standover feed. However, in established pasture both cattle and goats had a preference for axillaris leaf over grass leaf during summer and autumn (Norton *et al.* 1990b). In unreplicated paddocks steers grazing *M. axillare* maintained better condition through winter than those on native pasture or native pasture plus stylo treatments in an adjacent trial (Staples 1980). In a series of trials in northern Thailand, the content of legume in a mixed legume/grass pasture containing *M. axillare* as a component was greatest at the lightest stocking rate (Falvey *et al.* 1978). For *M. axillare* to establish and persist, fencing and the exclusion of stock from time to time were required (Andrews and Comudom 1977). Animals grazing improved pasture lost less weight in the dry season than those grazing native pasture (Falvey *et al.* 1978). However, management is crucial; even with Brahman cross heifers grazing the pasture on a 6–8 week rotation, at a stocking rate of 1.04 beasts/ha, presentation yield of *M. axillare* declined with time (Falvey and Andrews 1979). Axillaris failed to persist under heavy grazing by indigenous fat-tailed sheep in Malawi (Thomas 1976). Plots were grazed down to 10 cm at each sampling; after 5 such grazings in 1972–73, yield of Archer was reduced from 1786 kg/ha initially to 963 kg/ha after a year; after 3 grazings in 1973–74 no axillaris remained. Under such a system, grass production and total dry matter production were unaffected by the legume. At high stocking rates using goats, siratro yielded better than axillaris; however, at lower stocking rates axillaris yields were higher (Norton *et al.* 1990a).

On oxisol and ultisol soils in Yapacani, Bolivia, the use of *M. axillare* in the dry season is able to increase animal liveweight gain and milk production (Paterson and Horrell 1981). Grazing of forage reserves of *M. axillare* cv. Archer and *Neonotonia wightii* cv. Tinaroo raised milk production by 11–20% in San Javier, Bolivia, with a system of dairy ranching where cows were milked once per day while raising a calf. The legume protein reserve also consistently increased the butterfat content of the milk by an average of 0.4% (Paterson *et al.* 1981). In further studies, Paterson and Samur (1982) found that dry season access to 25% of the grazing area sown to forage legumes (including axillaris) enabled cows to increase body weight at a faster rate than cows grazing grass alone. The performance of calves was not affected by the grazing offered to their dams, but their growth may have been limited by factors other than milk production of their dams.

Problems with meat tainting may occur if livestock graze a *M. axillare* dominant diet for long periods of time. In a study by Park and Minson (1972) the meat from lambs grazing *M. axillare* for a number of months sometimes developed a peculiar odour and flavour. However, the flavour had no significant effect on the acceptability of the meat under organoleptic evaluation.

Use and adaptation of *M. uniflorum*

Horsegram, an annual, is naturalised in northern Australia (Bailey 1910) and can be grown in tropical and subtropical areas with an average annual rainfall ranging from 600–1100 mm. It appears to be adapted to a wide range of soils as long as they are well drained (Oram 1990). CPI 26260, introduced from a commercial source in the USA in 1959, was released as cv. Leichhardt by the Queensland Herbage Plant Liaison Committee in September 1965. It is drought tolerant and makes good growth in areas with rainfall as low as 380 mm in the growing season (Oram 1990). Horsegram tolerates a wide range of temperature regimes from warm temperate to humid tropical (Smartt 1985).

Staples (1966) argued that horsegram could be of greatest benefit to a beef production system when the non-shattering pods are used as a protein-rich standover feed in the dry season. It should not be grown for this purpose in areas where rain can be expected after mid-April. *M. uniflorum*, which requires summer spelling, was recommended as a dry season protein supplement in the waterhole system of Downes (1965) where it was intended to complement Townsville stylo, which requires summer grazing. Preliminary observations showed horsegram to be comparable to lablab and pigeon pea (*Cajanus cajan*) as a dry season supplement for cattle grazing native pasture, but it showed greater potential for self-regeneration of the stand through seedling recruitment each year (Downes 1967a). More recently, the success of the perennial shrubby stylos (*Stylosanthes scabra*) in the seasonally dry tropics of northern Australia has reduced the need for high quality standover feed and there has been little commercial interest in horsegram.

Weston and Smith (1977) examined horsegram as one of the options for cropping exposed dam beds in north-west Queensland. Forage sorghum crops provided the greatest quantity of good quality feed in this situation, but the authors did not examine mixtures of horsegram and sorghums. Wilson *et al.* (1980) found *Vigna radiata, V. sinensis* and *L. purpureus* to be higher yielding than *M. uniflorum* when sown into native Flinders grass pasture in north-west Queensland.

M. uniflorum is used as an annual pulse and forage crop in India where it is grown as a dryland wet season crop in areas receiving less than 875 mm average annual rainfall. In areas of higher rainfall, it is grown as a dry season crop as it is drought tolerant and cannot tolerate waterlogging, and disease problems are more severe in the wet season (Purseglove 1974; Bogdan 1977; Kay 1979; Smartt 1985; Khadka 1987; Smartt 1990; Rehm and Espig 1991). Horsegram can grow well on light, sandy soils, red loams, black soils and gravels in India (Kay 1979). It is used extensively as a pulse crop and is often sown as a late catch crop if the season is too dry for the preferred pulses. In 1960 half the area under pulse in Tamil Nadu was sown to horsegram (Veeraswamy 1960). Horsegram is also extensively grown in Karnataka, occupying 40% of the total area under pulses. Its drought tolerance makes it the only suitable legume on the poor light red soils. It is also grown as a mixed crop with ragi, cotton, niger, groundnuts and jowar and is grown as a 'rabi' crop after kharif paddy (Sreekantaradhya *et al.* 1974). Horsegram is also sown widely in Nepal, particularly in the middle mountain region (Khadka 1987). A lot of work in India has been done on the agronomy and genetic improvement of horsegram for use as a pulse crop, but this is beyond the scope of this review. A range of tropical legumes, including horsegram, were tested for use as cover crops in coconut plantations but they were found to be unsuitable as they do not tolerate shade; root crops were found to be best for this purpose (Nair 1979).

Inoculation and establishment

Corby (1974) observed nodules on *M. uniflorum* var. *stenocarpum* in Zimbabwe. CB 756 is effective in nodulating *M. uniflorum*; however, CB 1024 is also recommended for inoculation. Black nodules are produced by CB 756 but they are still effective (Cloonan 1963). Norris (1967) found no response to lime pelleting in *M. uniflorum*. In Australia, *M. uniflorum* is usually nodulated by native *Bradyrhizobium* already existing in the soil (Skerman 1977). In a pot study by Gowda (1978), *M. uniflorum* grown with grass was capable of fixing 161 kg/ha/year N and increased the grass yield in pots compared to grass alone.

M. uniflorum can be established under clean seedbed or sod seeding conditions (Macadam and Swain 1959). Broadcasting was as successful as drilling into native pasture of a savanna woodland in north Queensland (Downes 1967b). If coupled with strategic burning and grazing management, *M. uniflorum* can be successfully oversown into native pasture.

Response to fertiliser

Though *M. uniflorum* is generally regarded as having a low nutrient requirement (Skerman 1977), inoculation and the application of 10 kg/ha P increased nodulation, N content, dry matter and grain yield (Sahu 1973). Soil N was also increased over that of the uninoculated and unfertilised control. Leaf N was increased with the application of N, P and S but not by S-triazines (Rao and Perur 1975). On a lateritic upland soil in India with pH range 5.1–5.7, and low in N and

P, horsegram responded to applications of Ca, N and P but not K (Sarkar 1976).

Adaptation to stress

Horsegram lacks frost tolerance (Jones 1969; Blumenthal and Hilder 1986), but this is not important for early flowering annual summer crops. It is reasonably salt tolerant at low levels of NaCl; however, yield declines markedly at higher levels (Russell 1976). Horsegram has a high degree of drought tolerance (Smartt 1990). It has a high leaf temperature and diffusive resistance and low transpiration rate when compared to lablab — parameters related to drought tolerance (Manian *et al.* 1988).

Yield potential

Staples (1966) recorded dry matter yields of 6600 kg/ha with seed yields making up 2200 kg/ha. Downes (1965) quotes yield in excess of 2800 kg/ha. In a more arid environment Wilson *et al.* (1980) could achieve yields of only 770 kg/ha dry matter. Horsegram, like other tropical legumes, cannot tolerate shading, and yield is much reduced under conditions of reduced sunlight (Nair 1979). In India, when grown as a pulse, yields of 170–340 kg/ha are normally obtained, but up to 700 kg/ha has been recorded. When grown as fodder, green yields of 5-12 t/ha can be achieved after 6 weeks (Purseglove 1974). Ludlow and Wilson (1970), when comparing 10 tropical legumes, found *M. uniflorum* to have the fastest relative growth rate in the first week after sowing (0.199 g/g); however, it had no advantage over the other species in weeks 2 and 3. It had lower net assimilation rates than calopo, siratro, and lotononis, and together with siratro and centro, had the greatest leaf area ratio.

In a study by Aii and Stobbs (1980), *M. uniflorum* had the highest soluble leaf and stem protein levels of all legumes (and grasses) tested, being higher than siratro, *Aeschynomene india, Desmodium intortum* and *D. uncinatum*. Horsegram seed is high in protein (22%; Patnaik *et al.* 1984) but is unpalatable compared to other pulses (Kadka 1987).

Pests and diseases

Cultivar Leichhardt is relatively free of diseases and pests in Australia. Bean fly (*Agromyza phaseoli*) can cause some loss of seedlings (Oram 1990). In India the gram caterpillar *(Azazia rubicans)*, and occasionally the green pod boring caterpillar, can be destructive (Purseglove 1974; Kay 1979). Powdery mildew (*Sphaerotheca fuliginea*) may cause damage as plants approach maturity, especially if rain occurs at this stage; leaf spot *(Cercospora* sp.) has also been reported. In areas receiving greater than 1100 mm rainfall, a leaf spot (*Ascochyta* sp.) can cause severe damage (Staples 1966; Skerman 1977; Oram 1990). The most serious diseases in India are a root rot caused by *Rhizoctonia* sp. and anthracnose (*Glomerella lindemuthiancum*). A dieback caused by *Vermicularia capsici* and leaf spot (*Xanthomonas phaseoli*) can also infect crops (Kay 1979). Incidence of horsegram yellow mosaic virus, which is spread by the whitefly (*Bemisia tabaci*), can reach very high levels in India (Muniyappa 1983). In Louisiana horsegram failed to persist largely because of fungal diseases (Thro *et al.* 1987).

Grazing management and animal production

Despite good establishment *M. uniflorum* cv. Leichhardt failed to persist under grazing on a sedentary clay loam at Taroom, Queensland. From an initial population at establishment of 2.4 plants/m^2, no plants remained one year later and no new seedlings established (Russell and Coaldrake 1970). Under *in situ* dry season grazing in north Queensland, horsegram gave steer liveweight gains of 0.25–0.64 kg/head/day over 4 years for periods of 63–98 days. Liveweight gain was strongly correlated with horsegram and total N yields. Effective stands lasted only 2 seasons from each planting. A light cultivation in the late dry season increased seedling recruitment over the next wet season (Staples *et al.* 1983).

A toxic factor (as yet unidentified) appears to be present in raw horsegram seed (Ray 1969). Rats fed raw horsegram seed did not grow normally, but when the seed was autoclaved they did (Ray 1970). There is no evidence to suggest that this toxic principle causes any reduction in weight gain in cattle. The unique ways in which calcium oxalate crystals form in the testa of the seed during ripening are characteristic of *M. uniflorum*, and enable fragments to be identified as contaminants of other foodstuffs and fodders (Solbrig 1983).

After Leichhardt was released in 1965 it was found to be an unreliable component of permanent pasture. Soft seed was identified as the primary cause of this lack of persistence, as seed reserves were readily depleted by grazing or by germination as a result of rain in the dry season or false starts to the wet season. Thus, Staples (1974) initiated a breeding program to transfer the wild characteristic of small and hard seeds from the African *M. uniflorum* var. *stenocarpum* to the Asian var. *uniflorum*, whilst maintaining the desirable characters of the domesticated material such as early flowering, vigorous early growth and non-shattering pods. The program was largely successful, but the new lines produced were not tested under grazing in the field due to a change in emphasis in pasture research in the dry tropics following the release of *Stylosanthes scabra* cv. Seca in 1976. However, two introductions and two bred lines were fed to cattle in pens, and it was concluded that a minimum level of 15% hard seed was required to ensure that adequate numbers of hard seed passed through the digestive tract of cattle (Norton *et al.* 1989). This would ensure that sufficient seeds were available in the field for the recruitment of seedlings to develop a productive sward in the next wet season. One of the bred lines used in this study did have sufficient hard seed (Norton *et al.* 1989).

Plant breeding

Both inter- and intra-specific crosses are possible in *Macrotyloma*. The basic chromosome number of the genus is 2n = 20 (Verdcourt 1982). Staples (1982b) reported fully fertile progeny of crosses between *M. uniflorum* var. *stenocarpum* and *M. uniflorum* var. *uniflorum* as well as vigorous (but largely infertile) F_1 progeny from *M. uniflorum* var. *stenocarpum* x *M. africanum* crosses.

Evaluation as introduced lines

Sites of evaluation of *Macrotyloma* in northern Australia are shown in Figure 2 and results are shown in Table 1. Results from single sites in New Zealand, Africa and Asia are presented in Table 1. Data from other testing sites have not been included in the Table because of poor site descriptions.

Results of testing in a wide range of environments show some clear trends: i) *M. africanum* appears to be better adapted to clay soils at low latitude but has limited seedling recruitment at higher latitudes. ii) *M. axillare* can be productive and persistent on a wide range of soils (except perhaps clay) under lenient grazing, but cannot tolerate frost. iii) *M. daltonii* can regenerate through seedling recruitment on clay soils at low latitude, but not in central Queensland (possibly because of seasonal conditions at the time of testing). iv) *M. uniflorum* is highly productive in the first season at most sites, but seedling recruitment is poor at high latitude sites; some seedling

Figure 2. Sites of *Macrotyloma* evaluation in northern Australia.

Table 1. Sites of evaluation of *Macrotyloma*, in order of latitude, giving details of average annual rainfall, soil and trial type. Q = Queensland, WA = Western Australia, NZ = New Zealand.

Site	Soil type	Type of trial	Species	Lines	Performance	Reference
Merluna, Q. 13°04'S 1250 mm	Yellow earth	ungrazed rows	*M. africanum*	8	good	Crowther
			M. axillare	22	poor	and Staples
			M. daltonii	7	poor	(1978)
			M. uniflorum	18	poor	
	Mottled yellow earth	intermittently grazed swards	*M. axillare*	1	failed to persist	Anning
			M. uniflorum	1	failed to persist	(1982)
Kalinga, Q. 15°12'S 1000 mm	Red earth	intermittently grazed rows	*M. axillare*	1	vigorous, persistent	Anning *et al.*
			M. uniflorum	1	poor	(1981)
	Red earth	intermittently grazed swards	*M. axillare*	1	failed to persist	Anning
			M. uniflorm	1	failed to persist	(1982)
Koolburra, Q. 15°14'S 1130 mm	Grey leached earth	intermittently grazed swards	*M. axillare*	1	failed to persist	Anning
			M. uniflorm	1	failed to persist	(1982)
Lakeland Downs, Q. 15°32'S 1120 mm	Friable red earth	grazed paddock	*M. axillare*	1	persistent, productive	Anning (1977)
Southedge, Q. 16°48'S 1100 mm	Yellow duplex	intermittently grazed swards	*M. axillare*	1	failed to persist	Anning
			M. uniflorm	1	failed to persist	(1982)
Parada, Q. 17°10'S 710mm	Sandy loam	ungrazed rows	*M. axillare*	1	good in dry season	Downes
			M. uniflorum	1	good in dry season	(1967b)
	Red sandy loam	ungrazed rows	*M. africanum*	8	good	Crowther
			M. axillare	22	good	and Staples
			M. daltonii	7	good	(1978)
			M. uniflorum	18	good	
	Sandy clay loam	intermittently grazed swards	*M. axillare*	1	vigorous, persistent	Anning *et al.*
			M. uniflorum	1	poor	(1981)
Arriga, Q. 17°12'S 900 mm	Grey clay	ungrazed rows	*M. africanum*	1	good	I.B.
			M. axillare	2	waterlogged	Staples
			M. uniflorum	12	waterlogged	(unpublished)
Kimberley, WA. 17°20'S 700 mm	Kununurra clay	ungrazed plots	*M. axillare*	1	persistent and high yielding	Parbery (1967)
	Cockatoo sand	ungrazed plots	*M. axillare*	1	poor establishment and low yield	Parbery (1967)
Normanton, Q. 17°40'S 929 mm	Cracking clay	ungrazed plots	*M. axillare*	1	poor	Hall *et al.*
			M. uniflorum	2	1 line promising	(1987)
Burketown, Q. 17°43'S 767 mm	Cracking clay	ungrazed plots	*M. uniflorum*	2	1 line promising	Hall *et al.* (1987)
Boomerang, Q. 18°12'S 710 mm	Red friable earth	ungrazed rows	*M. africanum*	8	good	Crowther and
			M. axillare	22	good	Staples
			M. daltonii	7	good	(1978)
			M. uniflorum	18	good	
	Red friable earth	intermittently grazed rows	*M. axillare*	1	vigorous, persistent	Anning *et al.*
			M. uniflorum	1	poor	(1981)
Meadowbank, Q. 18°15'S 700 mm	Red friable earth	intermittently grazed	*M. axillare*	1	persisted vigorously	Miller (1977)
	Red friable earth	grazed paddock	*M. axillare*	1	increased LWG over native pasture	Staples (1978a)
	Red friable earth	grazed plots	*M. axillare*	20	good persistence	Staples (1978a)
Chiang Mai, Thailand 18°48'N 1400 mm			*M. axillare*	1	amongst most successful legumes	Gibson and Andrews (1978)
Charters Towers, Q. 19°40'S 600 mm	Basaltic black earth	ungrazed plots	*M. africanum*	1	poor	Clem
			M. daltonii	1	good in year 1	(1978)
			M. axillare	1	good persistence	
Victoria Province, Zimbabwe 20°S 600 mm	Granitic sands	ungrazed plots	*M. axillare*	1	good establishment	Clatworthy (1977)
Collinsville, Q. 20°40'S 710 mm	Basaltic black earth	ungrazed plots	*M. africanum*	1	poor	Clem
			M. daltonii	1	good in year 1	(1978)
			M. axillare	1	good persistence	
	Cracking clay	ungrazed plots	*M. africanum*	1	poor	Clem
			M. daltonii	1	good in year 1	(1978)
			M. axillare	1	good persistence	

Table 1. Sites of evaluation of *Macrotyloma*, in order of latitude, giving details of average annual rainfall, soil and trial type. Q = Queensland, WA = Western Australia, NZ = New Zealand.

Site	Soil type	Type of trial	Species	Lines	Performance	Reference
Emerald, Q. 23°30'S 650 mm	Cracking clay	ungrazed rows	*M. axillare*	1	productive	Clewett (1984)
			M. daltonii	2	unproductive	
Biloela, Q. 24°20'S 690 mm	Basaltic clay	ungrazed plots	*M. axillare*	1	poor	Cameron and Mullaly (1969)
			M. geocarpum	1	poor no seed set	
			M. uniflorum	5	good in year 1	
Howard, Q. 25°20'S 1075 mm	Gleyed podzolic	ungrazed until third year, plots	*M. axillare*	1	persisted for more than 3 years	Evans (1967)
			M. uniflorum	1	failed to persist	
Gayndah, Q. 25°36'S 780 mm	Black earth	ungrazed rows	*M. axillare*	1	vigorous and persistent	Bowen and Harding (1981)
			M. uniflorum	4	later lines better than Leichhardt	
	Black earth	ungrazed plots	*M. axillare*	1	failed to persist	G. Robbins and J. Bushell (pers. comm.)
Taroom, Q. 25°39'S 700 mm	Sedentary clay loam	ungrazed plots	*M. axillare*	1	established but did not persist	Russell and Coaldrake (1970)
			M. uniflorum	1	established but did not persist	
Narayen, Q. 25°46'S 700 mm	Clay loam and Granitic sand	grazed plots	*M. daltonii*	3	failed to persist 3 seasons	Strickland (1974; 1977)
Belli, Q. 26°03'S 1000 mm	Yellow duplex	ungrazed plots	*M. axillare*	1	high yield but low population	Stillman (1979)
Wandoan, Q. 26°07'S 700 mm	Grey clay	ungrazed rows	*M. africanum*	7	failed to persist	Conway *et al.* (1988)
			M. axillare	3	failed to persist	
			M. daltonii	2	persisted at least three seasons	
			M. uniflorum	2	failed to persist	
Nanango, Q. 26°42'S 800 mm	Solodic	ungrazed plots	*M. axillare*	1	poor	Jones and Rees (1972)
			M. africanum	1	poor	
			M. uniflorum	1	poor	
Samford, Q. 27°22'S 1055 mm	Red-yellow podzolic	intermittently grazed plots	*M. uniflorum*	1	failed to persist more than one season	Jones *et al.* (1967)
Pittsworth, Q. 27°30'S 700 mm	Sedentary black earth	ungrazed plots	*M. axillare*	1	4% survival of first winter	Jones (1969)
			M. uniflorum	1	failed to survive first winter	
	Black earth	ungrazed plots	*M. axillare*	1	poor	Jones and Rees (1972)
			M. africanum	1	poor	
			M. uniflorum	1	poor	
Wellcamp, Q. 27°35'S 700 mm	Black earth	ungrazed plots	*M. africanum*	3	poor seedling recruitment	Blumenthal and Hilder (1986)
			M. axillare	2	persistent after 58 frosts	
			M. daltonii	8	high level of seedling recruitment	
			M. uniflorum	2	failed to regenerate	
Logan Village, Q. 27°45'S 1000 mm	Sandy podzolic	intermittently grazed plots	*M. uniflorum*	1	high yield in first season but failed to persist	Middleton (1978)
Millmerran, Q. 27°53'S 700 mm	Grey clay	ungrazed rows	*M. africanum*	7	failed to persist	Conway *et al.* (1988)
			M. axillare	3	failed to persist	
			M. daltonii	2	persisted at least 3 seasons	
			M. uniflorum	2	failed to persist	
Boonah, Q. 28°00'S 900 mm	Prairie soil	ungrazed plots	*M. axillare*	1	poor	Jones and Rees (1972)
			M. africanum	1	poor	
			M. uniflorum	1	poor	
Whangarei, NZ 35°43'S 1700 mm		ungrazed plots	*M. axillare*	1	poor persistence	Goold and McMeikan (1980)

Note: persistence in the perennial species (*M. axillare* and *M. geocarpum*) is predominantly from plants established in the first year; persistence in the annual species (*M. uniflorum, M. daltonii* and *M. africanum*) is entirely from the recruitment of new seedlings in each year.

recruitment occurs at some low latitude sites. *M. africanum* may have a place in leys on clay soils in northern Australia. *M. axillare*, if leniently grazed, may have wide adaptation. *M. daltonii* may have a place as a short-term forage in the north of Australia, and may be able to make a permanent contribution to grazing on southern brigalow soils. *M. uniflorum* is limited in its role as a high-protein standover feed for the dry season.

As at 1984 the Australian collection of *Macrotyloma axillare*, *M. daltonii*, and *M. africanum* contained 53 living accessions, most of which were collected in Africa and Madagascar by Staples (1971); since then a further 10 accessions have been introduced. This collection has been classified into morphologic-agronomic groups for further testing in the tropics and subtropics of Australia (Blumenthal *et al.* 1989). The Australian collection of *M. uniflorum* contained 40 accessions in 1984 (Blumenthal and Hilder 1985). The most recent major collection of *M. uniflorum* was that of Staples (1986), who collected 17 accessions in India between September 1984 and January 1985. Apart from the Staples collection, only 4 other accessions have been introduced since 1984. The Department of Tropical Agriculture, Agriculture Faculty of Gemblou (Belgium) has a collection of 21 accessions of *Macrotyloma* (Marechal and Baudoin 1988). Both *M. axillare* and *M. uniflorum* have been the subject of research in a number of tropical and subtropical environments.

Potential of other species

Collections of the other 20 species of *Macrotyloma* are small and have not been evaluated as forage. Representatives of *M. ellipticum* (3 accessions), *M. maranguense* (3), *M. schweinfurthii* (1) have been evaluated in pots at Toowoomba (M.Blumenthal and T.Hilder, unpublished data). *M. maranguense*, like *M. geocarpum*, forms geocarpic pods, which may be a useful mechanism of persistence and warrants further investigation. *M. ellipticum* is erect in habit, has large internodes and does not require further evaluation.

Conclusions

Whilst not widely used as forage, members of the genus *Macrotyloma* make a valuable contribution to feeding systems in some parts of the world, and have the potential to make an even greater contribution in the future. *M. axillare* is used on drier ridges on the south-east coast of Queensland and on the drier tablelands in north-east Queensland. In Bolivia and Sri Lanka axillaris is used in dairy pastures. *M. uniflorum* has shown potential as a standover dry season livestock feed in northern Australia where a breeding program is centred on increasing levels of hardseededness to improve persistence in pastures. *M. africanum* may have a place in leys on clay soils in north Queensland. *M. daltonii* may have a place as a short-term forage in northern Australia and as a permanent contribution to grazing on southern brigalow soils in Queensland if a seed bank is allowed to develop.

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