Tropical Grasslands-Forrajes Tropicales (2024) Vol. 12(3):124–141
doi: 10.17138/TGFT(12)124-141

Review Article

Paspalum lepton - a valuable adjunct to the suite of grasses used in grazing systems in the subtropics or a potential weed

Paspalum lepton - *un complemento valioso para el conjunto de pastos utilizados en sistemas de pastoreo en los subtrópicos o una maleza potencial*

BRUCE G. COOK[1], DAVID L. LLOYD[2], THE LATE WALTER J. SCATTINI[1] AND ALAN D. ROBERTSON[3]

[1]*Formerly Principal Agronomist (Sown Pastures), Queensland Department of Agriculture and Fisheries, Brisbane, Queensland, Australia.* daf.qld.gov.au
[2]*Honorary Research Fellow, School of Agriculture and Food Sciences, The University of Queensland, St Lucia, Queensland, Australia.* uq.edu.au
[3]*Livestock development consultant and farmer, "Oaky Creek", Willsons Downfall, New South Wales, Australia.*

Abstract

Native and exotic C4 grasses currently used in grazing systems in the subtropics have specific limitations with management, decline in feed quality as they mature and variable adaptation to soils and climates, providing opportunities to identify alternative species to complement or replace them. One option is *Paspalum lepton* (syn. *P. nicorae*), a sward-forming, rhizomatous grass native to subtropical South America with recognized forage value. An early maturing form of this species has become naturalized in Northern New South Wales since its introduction in the 1940s. More recent introductions with forage and amenity potential are being established vegetatively and by seed as it becomes available. This paper reviews published work on *P. lepton* and reports largely unpublished results and observations on its performance in research and development studies in subtropical Eastern Australia. The potential value of and threats posed by *P. lepton* in relation to its adaptation, productivity, competitiveness and role in limiting ingress of existing weedy species are discussed. APG 54281 and APG 54325 are palatable, productive and persistent lines of this grass that have proven to be adapted to livestock production systems in most of the humid lowland subtropics, and to a specific niche in the subtropical uplands of Southeast Queensland where there is a lack of adapted C4 grasses and C3 grasses are only marginally adapted.

Keywords: Adaptation, *Paspalum nicorae, Poaceae*.

Resumen

Las gramíneas C4, nativas y exóticas, que se utilizan actualmente en los sistemas de pastoreo en los subtrópicos tienen limitaciones específicas en cuanto a su manejo, una disminución de la calidad del forraje a medida que maduran y una adaptación variable a los suelos y climas, lo que brinda oportunidades para identificar especies alternativas que las complementen o reemplacen. Una opción es *Paspalum lepton* (sin. *P. nicorae*), una gramínea rizomatosa nativa de América del Sur subtropical con un valor forrajero reconocido. Una forma de maduración temprana de esta especie se ha naturalizado en el norte de Nueva Gales del Sur, luego de su introducción en la década de 1940. Introducciones más recientes, con potencial forrajero y recreativo, se están estableciendo en forma vegetativa o por semilla, a medida que se hacen disponibles. Este artículo revisa el trabajo publicado sobre *P. lepton* e informa resultados y observaciones en gran parte inéditos sobre su desempeño en estudios de investigación y desarrollo en el área subtropical del Este de Australia. En este artículo se discute el valor potencial y las amenazas que plantea *P. lepton* en relación con su adaptación,

Correspondence: B.G. Cook, Brisbane, Queensland, Australia.
Email: brucecook@aapt.net.au

productividad, competitividad y papel en la limitación del ingreso de especies de malezas existentes. APG 54281 y APG 54325 son líneas palatables, productivas y persistentes de esta gramínea que han demostrado estar adaptadas a los sistemas de producción ganadera en la mayoría de tierras bajas de los subtrópicos, y a un nicho específico en las tierras altas subtropicales del sudeste de Queensland, donde hay una falta de gramíneas C4 adaptadas y las gramíneas C3 están adaptadas solo marginalmente.

Palabras clave: Adaptación, *Paspalum nicorae, Poaceae.*

Introduction

Pastoral industries have played an increasingly important role in Australia's economy since British colonization in 1788. However, livestock production has been limited by low productivity and quality of native grasses in most of the natural pasture zones and districts (Burrows et al. 1988). Since the early to mid-1900s, forage and soil conservation research agencies have collected or acquired provenances of higher quality species, primarily grasses and legumes, from tropical, temperate and Mediterranean regions around the world (Smith et al. 2021). Variation within these species has been assessed and accessions showing benefits in animal production potential and adaptation over a range of habitats identified and released to industry as commercial cultivars (Oram 1990). These have been of exceptional economic value to Australia's grazing industries on a wide range of soils and climate in sub-mesic and mesic rainfall zones on about 5% of Australia's grazing lands (EC Wolfe, pers. comm.). This paper draws on research in the subtropical zone of Australia as well as data from similar areas in South and North America. In Australia, the subtropics comprise an area of Eastern coastal and subcoastal land, extending from about 30° S to the Tropic of Capricorn (23.5° S), together with elevated tropical areas in the Mackay and Cairns hinterland that experience similar edaphic and climatic conditions. Geographic and climatic details for evaluation sites in Australia and elsewhere discussed in this paper are listed in Table 1.

Table 1. Evaluation site details.

Site	Latitude	Altitude (masl)	Average annual rainfall (mm)
Australia			
Brisbane, Queensland	27.5° S	30	1,150
Gympie, Queensland	26.1° S	150	1,120
Samford, Queensland	27.4° S	50	1,100
Monduran, Queensland	24.9° S	60	800
Mt Mee, Queensland	27.1° S	460	1,500
Oakey, Queensland	27.4° S	400	685
Stanthorpe, Queensland	28.4° S	805	770
Toowoomba, Queensland	27.6o S	690	960
Rappville, New South Wales	29.1° S	50	1,060
Grafton, New South Wales	29.6° S	10	1,000
Argentina			
Colonia Tatacuá, Corrientes	28.4° S	75	1,270
Brazil			
Bagé, Rio Grande do Sul	31.4° S	210	1,500
Eldorado do Sul, Rio Grande do Sul	30.1° S	110	1,440
Philippines			
Los Baños, Laguna	14.2° N	35	2,100
United States			
Americus, Georgia	32.1° N	145	1,240
Brunswick, Georgia	31.2° N	5	1,140

The humid subtropics of Eastern Australia support various livestock industries, primarily beef and dairy, the latter being dependent on improved pasture to supply the quantity and quality of feed required. Invasive poor-quality grasses such as *Sporobolus* spp. and *Paspalum notatum* Flüggé 'Pensacola' threaten the longevity and productivity of improved pastures. The cooler upland area of Southeast Queensland near the town of Stanthorpe was chosen as an evaluation location owing to a dearth of C4 grasses well-adapted to that area, allied with the need to arrest current ingress of weedy forms of *Eragrostis curvula* (Schrad.) Nees into grazing lands in the area.

Few native grasses with productive value occur in this region of Eastern Australia, and are limited in either their adaptive range, their productivity compared with other exotic species or their susceptibility to uncontrolled grazing by exotic hoofed animals. Those with value include *Bothriochloa bladhii* (Retz.) S. T. Blake, *Dichanthium sericeum* (R. Br.) A. Camus, *Heteropogon contortus* (L.) P. Beauv. and *Themeda triandra* Forssk. Introduced grasses from 14 genera (*Axonopus*, *Bothriochloa*, *Cenchrus* (formerly *Pennisetum*), *Chloris*, *Cynodon*, *Dichanthium*, *Digitaria*, *Eragrostis*, *Megathyrsus, Melinis, Panicum, Paspalum, Setaria* and *Urochloa* (formerly *Brachiaria*) are naturalized or have been commercialized (Cook et al. 2020). They now form an important component of grass-legume and intensive, nitrogen-fertilized grass grazing systems in the humid, sub-humid and semi-arid subtropics of Eastern Australia.

Selection criteria for introduced subtropical grasses include ease of establishment; high yields of quality, palatable forage with no or minor anti-production qualities; long growing season; moderate frost tolerance; relative freedom from pests and disease; commercially viable seed production capacity; and minimal threat to the natural environment.

Nevertheless, introduced species also have shortcomings. Some such as *Chloris gayana* Kunth and *Megathyrsus maximus* (Jacq.) B. K. Simon & S. W. L. Jacobs are intolerant of uncontrolled grazing. Many, including *Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone (Cook and Mulder 1984a), are strongly nitrophilous requiring high levels of nitrogen for persistence and production. Some are susceptible to plant-debilitating disease, with *C. clandestinus* susceptible to 'yellows' disease (Wong and Wilson 1983) and *Digitaria eriantha* Steud. 'Pangola' to rust and virus (Cook et al. 2020). Others accumulate toxic or sub-toxic levels of anti-production compounds, such as oxalate in *Setaria sphacelata* (Schumach.) Stapf & C. E. Hubb. 'Kazungula' and 'Splenda' and *C. clandestinus* (Jones and Ford 1972; Bourke 2007) and cyanide in *Cynodon aethiopicus* Clayton & J.R. Harlan. The strengths and weaknesses of introduced grasses with potential in subtropical Australia are described by Oram (1990) and Cook et al. (2020).

Research studies identified *Paspalum lepton* Schult. as a grass with potential to address many of the shortcomings of native and introduced pasture grasses. Other *Paspalum* introductions have been successfully used in grazing industries in humid and sub-humid areas in the subtropics of Australia, most notably ecotypes of *P. dilatatum* Poir., *P. notatum* and *P. plicatulum* Michx. Two ecotypes of *P. lepton* identified as having value in soil conservation by the USDA Natural Resources Conservation Service were 'Amcorae' (=APG 54281) in 1969, but not released for commercial use, and 'Doncorae' (=APG 54461), which was released in 1993 (Belt and Englert 2008). Neither is currently available commercially (NRCS 2022). 'Amcorae' was discontinued owing to its perceived invasiveness, and 'Doncorae' owing to discontinued seed production. Two cultivars have been commercialized in Eastern Australia, 'Blue Dawn' (Progressive Seeds Pty Ltd 1998) and 'Blue Eve' (Enviroseeds Pty Ltd 1999), both derived from the American 'Amcorae' (Table 2) and used primarily for recreational groundcover. Most of the studies carried out in Australia have been conducted using 2 early introductions of *P. lepton*. APG 54281 from Argentina was initially selected in nursery and grazed plot observations based on palatability, persistence under grazing and its additional potential use as ground cover. APG 54325 from Brazil was chosen on the strength of its productivity, broad palatable leaves and seed production.

This paper reviews strengths and weaknesses of *P. lepton*, focusing on its potential as forage in subtropical Australia, while acknowledging and addressing its potential weediness (Blount et al. 2022). It reports on Australian studies evaluating accessions of *P. lepton* from the Australian Pastures Genebank (APG) to clarify the adaptation, value and potential role of the species in the location specified, focusing especially on the potential benefits and threats.

Taxonomy and Morphology

The morphology of *P. lepton* is described by Cook et al. (2020). This informal Plicatula group species was classified as *P. nicorae* Parodi until a revision by Oliveira and Valls (2008), who assigned it *P. lepton*, based on *Paspalus leptos*, the name given by Josef August Schultes in 1824. It is taxonomically very closely related to *P. plicatulum* (an earlier synonym being *P. plicatulum* var. *arenarium* Arechav.), yet few ecotypes share the characteristics commonly associated with that species (Cook et al. 2020). *P. lepton* commonly has a non-stoloniferous, deeply rhizomatous, sward-forming growth habit and is thus readily distinguished from the caespitose *P. plicatulum*. Leaf color of *P. lepton* varies between greenish yellow, green and greyish green (Reis et al. 2010). Ecotypes reported in our more detailed studies have the greyish-green foliage that has given rise to the Brazilian common name, grama cinzenta (grey grass). An alternative common name used in the USA is Brunswick grass (or brunswickgrass), named for the city of Brunswick on the Southeast coast of Georgia, USA, where *P. lepton* has become naturalized. Splits of this type were forwarded to the Americus Plant Materials Center (APMC), Georgia, in March 1945, where seed was produced and catalogued as SC 20-672 (Hanson 1972).

Reis et al. (2010) compared the morphology of 53 accessions of *P. lepton* from Rio Grande do Sul, Brazil. They noted a high level of morphological variation among the accessions that was not related to their geographical location, and that "this richness of variation represents an extremely valuable source to select better accessions to be used as forage plants".

Origin and Introduction into Australia

P. lepton is native to South America, with a distribution extending from about 16° S in Bolivia to about 35° S in Argentina and Uruguay. It is widely distributed in Brazil (States of Mato Grosso do Sul, Paraná, Rio Grande do Sul, and Santa Catarina), Argentina (Buenos Aires, Chaco, Córdoba (Figure 1), Corrientes, Entre Ríos, Formosa, and Santa Fe), Paraguay (Central, Concepción, Cordillera, Guaira, Itapúa and San Pedro), Uruguay (Canelones) and Bolivia (Santa Cruz) (GRIN 2024; Tropicos 2024a; 2024b).

P. lepton was first introduced to Australia from the USA by a farmer in the late 1940s (B Clarke, pers. comm.) and established in the Rappville district of Northern New South Wales (NSW) (Table 1), where it is now naturalized. Since SC 20-672 was the only accession of *P. lepton* held in the American collection until 1963 (Anon. 1993), it is reasonable to assume that the Rappville ecotype, now conserved in the Australian collection as APG 54488 (Figure 2), is derived from that original Brunswick (USA) accession.

The 44 accessions of *P. lepton* now held in APG have been introduced from Brazil, Argentina, Uruguay and the APMC. They are listed in Table 2 with Australian APG and CPI/ATF accession number together with American PI equivalent where available.

For consistency, APG accession numbers are used throughout the paper to refer to specific ecotypes of the species. Collection details (passport data) for each accession can be sourced at Australian Pastures Genebank (APG, bit.ly/4elcX1y) and Genesys (bit.ly/3BrQ0Ld).

Figure 1. B.G. Cook collecting *P. lepton* APG 54481, W of Tanti, Córdoba, Argentina (1,120 masl, 720 mm AAR). Photograph: B.C. Pengelly.

Figure 2. *P. lepton* APG 54281 (left) and rapidly maturing APG 54488 (right) 6 November 1991. Photograph: B.G. Cook.

Table 2. Accessions of *Paspalum lepton* currently held in Australia and the USA.

APG	CPI/ATF	PI	Origin	APG	CPI/ATF	PI	Origin
	ATF1016	404857	URY	54455	ATF1021	337562	ARG
	ATF1023	331129	URY	54456	ATF1022	337014	BRA
54281	21370	202044[2]	ARG	54457	ATF1024	310135	BRA
54291	21382	209983	ARG	54458	ATF1025	310134	BRA
54306	27657		BRA	54459	ATF1026	310133	BRA
54307	27660		URY	54460	ATF1027	310132	BRA
54320[1]	27693		BRA	54461	ATF1028	310131[3]	BRA
54325	27707		BRA	54462	ATF1029	310130	BRA
54347	37526		URY	54463	ATF1030	310129	BRA
54442	ATF1007	508821	ARG	54464	ATF1031	310128	BRA
54443	ATF1008	508820	ARG	54465	ATF1032	310061	BRA
54444	ATF1009	508819	ARG	54466	ATF1033	304004	BRA
54445	ATF1010	508818	ARG	54467	ATF1034	304003	BRA
54446	ATF1011	490364	USA	54468	ATF1035	284171	AUS
54447	ATF1012	490363	USA	54469	ATF1036	283020	URY
54448	ATF1013	404860	URY	54470	ATF1037	276249	URY
54449	ATF1014	404859	URY	54471	ATF1038	276248	URY
54450	ATF1015	404858	URY	54472	ATF1039	209983	ARG
54451	ATF1017	404471	BRA	54473	ATF1040	202044[2]	ARG
54452	ATF1018	404470	BRA	54481	ATF3124		ARG
54453	ATF1019	404469	BRA	54488	CQ3639		AUS
54454	ATF1020	337563	ARG	54839	CPI 39970		BRA

[1]Re-identification necessary; possibly *P. plicatulum*; [2]'Amcorae', 'Blue Dawn'; [3]'Doncorae', CPI 125877

Adaptation

Soils

While *P. lepton* is found mostly on sandy soils in its native habitat (Nabinger and Dall´Agnol 2019), in Australia it has been found to be adapted to a wide range of friable soils with varying texture and pH ranging from acidic to slightly alkaline (Cook et al. 2020). It has proven poorly adapted to compacted soils and soils with a hard-setting surface in observations on red-brown earth at Oakey, Qld (WJ Scattini, pers. comm). APG 54488 has colonized a large area of low fertility, sandy, sandstone-derived soils of pH 4.5–5 in Northern NSW, where native grasses, including *Imperata cylindrica* (L.) Raeusch., are of poor quality. McCaskill et al. (2019) assessed phosphorus response of a range of 18 grasses and legumes, including APG 54281, and found that most species growing in low soil P environments (Olsen et al. 1954) also had critically low P concentrations in dry matter for livestock production. APG 54281 was 1 of 2 exceptions, having among the highest P concentrations in the dry matter (0.26% P) when grown at the critically low soil P level of 6.6 ppm.

Nursery studies incorporating *P. lepton* were commenced in Queensland in the 1970s at Mt Mee north of Brisbane and at Toowoomba on the Darling Downs (Table 1). Promising accessions were evaluated at regional on-farm sites on the eastern and southern Downs of Southeast Queensland commencing in 1983. APG 54281 proved well adapted to friable, acid sandy soils formed on granite in the Stanthorpe district and to the deep, friable, basalt-based, acid red loams of Mt Mee and the Toowoomba plateau. It also grew well at Monduran on a fertile, brown, non-cracking clay, spreading into native vegetation, predominantly *H. contortus* (BG Cook, observation), and on a dark cracking clay soil at Los Baños in the Philippines in a tropical environment (WW Stür, unpublished). However, APG 54281 failed to persist when sown on a hard-setting, compacted red earth on a grassed airfield runway at Oakey west of Toowoomba, and when sown in a mixture with turf grasses on a compacted recreational football field in Brisbane, Queensland (WJ Scattini, MJ Conway and B Johnson, unpublished). Additionally, a number of accessions have grown well and persisted on a yellow podzolic-soloth soil with a Dy of 5.41 (Northcote 1979) and pH 5.6, on red podzolic soils and on a neutral dark sandy clay loam river alluvium in the Gympie district (BG Cook, unpublished). The studies in the Toowoomba and Gympie districts were complemented by more detailed studies reported later in this paper.

While well drained sandy clay loam soils are considered ideal for *P. lepton* (Anon. 1993), APG 54839 was both persistent and productive on a poorly drained sandy loam meadow podzolic soil at Samford in SE Queensland (Strickland 1978).

Climate

Average annual rainfall at collection sites for *P. lepton* accessions held in APG ranges from 700–820 mm (Córdoba, Argentina) to 1,300–1,900 mm (Rio Grande do Sul, Brazil). P. lepton has persisted well in subtropical Australia where average annual rainfall ranges from 800–1,500 mm. Winter frost frequency at the various subtropical sites varies from 0–10/yr (Gympie, Mt Mee) to 70/yr (Stanthorpe). Frosts are experienced from May to September at Gympie (average of 5.5 in July) and April to October (20 in July) at Stanthorpe. *P. lepton* has been observed to be at least as frost tolerant as the more frost tolerant subtropical C4 grasses, *C. clandestinus* and *S. sphacelata* 'Narok'. Observations indicate that foliage of *P. lepton* is largely unaffected by moderate frost but suffers "leaf burn" by severe frost (defined as occurring at -2 °C) as experienced at Stanthorpe. Affected plants regrow readily from rhizomes with the onset of warmer, seasonal weather. A number of accessions of *P. lepton* from APG exhibit a significant degree of shade tolerance, growing well in light to moderate shade as found under open eucalypt forests.

Persistence

P. lepton is a resilient species when exposed to varying grazing and fertilizer management. When established in areas of suitable soils and climate, it has persisted for at least 20 years, and up to 50 years (limit of observation), even with little or no further management following establishment.

However, for over 30 years, a condition known as "pasture dieback" has spread, afflicting grasses, initially most obviously *Cenchrus ciliaris* L. in Central Queensland. This is now being experienced widely in stands of introduced and native grasses, extending from North Queensland to Northern New South Wales (Buck 2017). Stand decline in several hectares of *P. lepton* APG 54325 near Gympie may be attributable to 'dieback' syndrome. The causal agent of pasture dieback has not yet been identified with confidence, although the paspalum mealybug, *Heliococcus summervillei* Brookes (Pseudococcidae), or a close relative, has been associated with 'dieback' in many stands investigated. This minute sucking insect was thought to be the cause of pasture grass dieback in Southern Queensland in the 1920s in *P. dilatatum*, which was then being increasingly used in pasture improvement. Despite this, long-term persistence of *P. lepton* seems unlikely to be under threat since some affected stands are showing signs of recovery.

Phenology and seed production

When managed effectively, most accessions of *P. lepton* flower profusely and set large amounts of seed. Burson and Bennett (1970) determined that *P. lepton* was an obligate apomict, reproducing by apospory and pseudogamy, although nursery observation at Gympie suggests some outcrossing does occur. Seed collected from a nursery row of APG 54281 growing adjacent to a row of morphologically distinct APG 54320 produced plants that were morphologically different from the maternal parent. Seed proteins from the progeny plants that were compared with those of APG 54281 using sodium dodecyl sulfate-polyacrylamide gel electrophoretic analysis, exhibited major band characteristics more akin to APG 54320 than to APG 54281 (AM Vieritz, unpublished). This suggested that the progeny resulted from fertilization rather than apomixis, supported by Nabinger and Dall´Agnol (2019), who noted that *P. lepton* had been the subject of selection and evaluation, and used in interspecific crosses in the forage improvement program at the Federal University of Rio Grande do Sul.

P. lepton accessions studied in Queensland exhibit a long day photoperiodic flowering response (Figures 3A, 3B) similar to other C4 grasses from higher latitudes (Loch et al. 1999), including *P. dilatatum* and *P. notatum* 'Argentine' and 'Pensacola'. Dates of initial flowering in the study at Samford (Hacker et al. 1999), which ranged from 15 December for APG 54281 to 3 February for APG 54291, were not consistent with flowering time at other sites in the same geographical region. This suggests that like *P. dilatatum*, 'Argentine' and 'Pensacola', *P. lepton* exhibits a qualitative rather than quantitative long day photoperiodic flowering response. The fact that APG 54281 failed to flower at 14.6° N in the Philippines (WW Sturr, pers. comm.) accords with this observation. While harvest date varies widely with time of flowering, it is also subject to environmental conditions and to the management of the seed crop. At Gympie, management comprised maintaining the *P. lepton* sward in a low leafy (ca. 10 cm high) condition to maximize tiller numbers prior to first flowers emerging. At that stage the area was mown to a height of about 4 cm and fertilized with a complete fertilizer including 100 kg N/ha. Under this management, a seed crop started in December–January was ready for harvest in February–March (Cook et al. 2020). Starting the crop prematurely can lead to excessive vegetative growth and lodging of the crop. A second but lower yielding crop in April or early May is achievable with the same procedure if management has created an early harvest. Unlike *P. plicatulum* where ripe seed shatters, *P. lepton* retains the seed in head at maturity, enabling high levels of seed recovery.

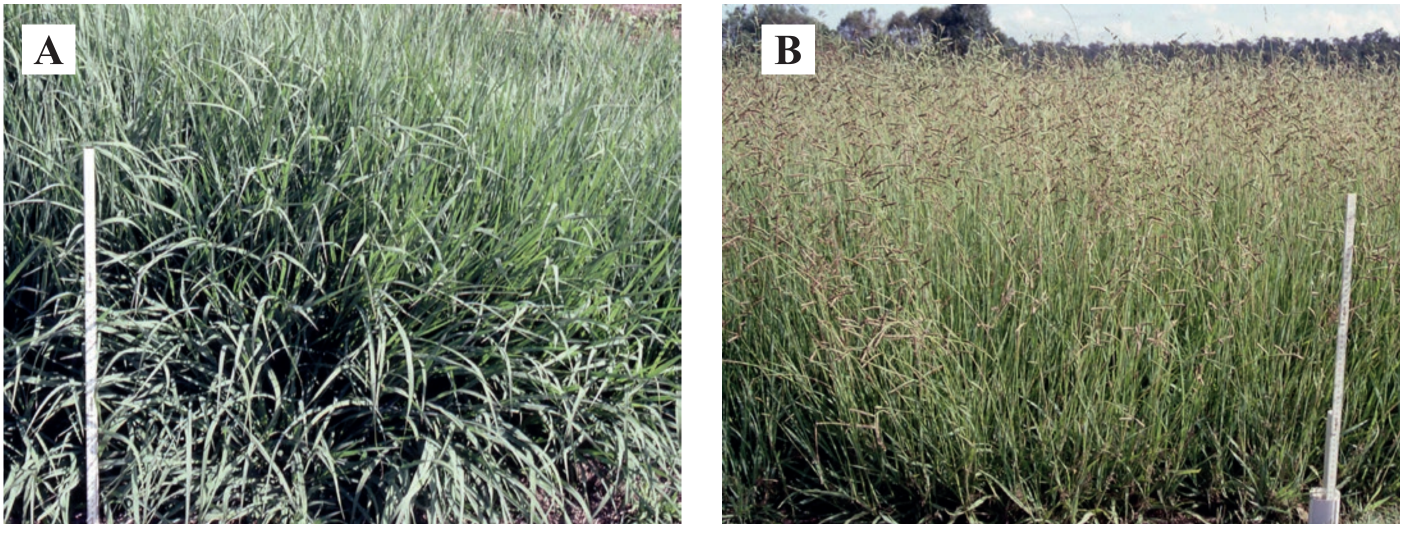

Figure 3. **(A)** N fertilized APG 54325 with 60 cm measure 16 November 1992 (late spring, vegetative). Photograph: B.G. Cook; **(B)** Same plot as in 3a, 20 January 1993 (mid-summer, heavily in seed).

The ergot fungus, *Claviceps paspali* (Sordariomycetes, Ascomycota), infects the ovary in susceptible ecotypes of a number of *Paspalum* species, including *P. lepton*, forming a fungal sclerotium in place of the caryopsis in the spikelet. Seed production of susceptible genotypes is accordingly much reduced. A suite of 34 accessions of *P. lepton* of diverse origins (Table 2) was imported into Australia from the APMC in 1993 and grown in unreplicated nursery microplots to gauge variability within the species. Entries varied considerably in vigor, growth habit, rhizome development, leaf color, leaf width and hairiness, fertile tiller density and susceptibility to ergot, the incidence varying from disease-free to severely infected (BG Cook, observation). The disease has not been recorded in any of the earlier Australian introductions (APG 54281–54347, 54488, 54839), which include the 2 most promising ecotypes.

Seed yields of 4 elite accessions (APG 54281, 54457, 54461 and 54466) at APMC (USDA SCS, unpublished, 1978) averaged 204, 178, 241 and 174 kg seed/ha respectively. An early seed crop of APG 54281 at Grafton (GPM Wilson, unpublished) yielded 350 kg seed/ha in January 1972, and a further 90 kg seed/ha from a follow-up harvest in April the same year. However, small-plot seed crops of APG 54307, 54461 and 54325 at Gympie gave single seed harvest yields equivalent to 689, 1,034 and 1,178 kg seed/ha respectively in late January–early February 1992 (BG Cook, unpublished). After harvest, seed must be dried to a moisture level of 10% (Loch and de Souza 1999) and stored in a low-humidity environment to maintain quality. As with its relatives in the Plicatula group, *P. atratum* and *P. plicatulum*, dried seeds of *P. lepton* rapidly absorb moisture from the atmosphere with a consequent reduction in germinability (JM Hopkinson, pers. comm.).

Forage and Soil Conservation Value

Dry matter production

The sound yielding ability and responsiveness to nitrogen fertilizer of *P. lepton* have been demonstrated in its native environments as well as in the USA and Australia. Pereira et al. (2011) compared performance of 53 accessions of *P. lepton* with that of 'Pensacola' and other grasses at 2 contrasting sites in Rio Grande do Sul, Brazil. Most accessions of *P. lepton* were more productive than 'Pensacola', the 2 most productive achieving 2 to 4 times the amount of dry matter and leaf compared with 'Pensacola' at both sites. In a study at Americus, Georgia, USA, Beaty et al. (1970) measured the responsiveness of an unidentified accession of *P. lepton* to nitrogen fertilizer at 0, 112, 224 and 336 kg N/ha, when cut at 3 mm at 1, 2, 3, 4, 5 and 6-week intervals. Annual DM yields of 4.2, 7.4, 9.2 and 10.6 t DM/ha were measured with the application of 0, 112, 224 and 336 kg N/ha respectively. Harvest frequency had less effect on yield than nitrogen treatment, with annual yields of about 7.0 t DM/ha at 1 and 2-week frequencies to 8.7 t DM/ha when cut at 8-week frequency. In another study at the same site, DM production and N response of *P. lepton* APG 54281 was compared with that of 8 Brazilian accessions (USDA SCS Report 1970). Plots were fertilized with 0, 56, 112 and 224 kg N/ha and cut at 5 cm every 4 weeks after the first cut. Average DM yield across accessions increased almost linearly between 0 and 224 kg N/ha, at a rate of about 48 kg DM/ha for each additional kilogram of nitrogen. Highest annual yields at 224 kg N/ha ranged from 14 to 14.5 t DM/ha from APG 54459, APG 54461 and APG 54464, compared with 12.2 t DM/ha for APG 54281 and 10.8 t DM/ha for APG 54458, the lowest yielding accession.

In an experiment at Samford in Southeast Queensland, Strickland (1978) found that seasonal DM productivity of *P. lepton* APG 54839 measured over 2 years compared well with or exceeded that of 14 other warm season grasses, including *C. clandestinus*, Pangola and *S. sphacelata* APG 55726. Grasses received a standard basal and annual maintenance fertilizer application and were harvested at a height of 5 cm every 30 or 60 days. Nitrogen fertilizer was applied in split applications totaling 476 kg N/ha after every 60-day harvest. Frosts were experienced both years. APG 54839 ranked first for both mean annual and cool season growth over 2 years with 27.9 and 4.5 t DM/ha respectively, significantly better than 18.2 and 1.8 t DM/ha from Pangola. In another study at Samford in 1981, yields of 133 *Paspalum* accessions from several species, including 8 accessions of *P. lepton* (Hacker et al. 1999) were rated on a 1–10 basis at the end of the season. APG 54306 (8 rating) and APG 54325 (7 rating) were the highest yielding *P. lepton* accessions and were among the highest yielding of all species tested.

Following the early nursery sowings in Southeast Queensland and Northern NSW that demonstrated the productive potential and apparent palatability of a number of lines of *P. lepton* on friable soils, more detailed evaluation was carried out at Stanthorpe and Gympie to confirm its productive ability, determine its compatibility with adapted legumes, assess its persistence and spread, and assess its ability to suppress endemic weeds.

The initial study was carried out in 1987–1991 (DL Lloyd, unpublished) near Stanthorpe on the 'granite belt' of upland Southeast Queensland (annual average maximum temperature 21.8 °C, annual average minimum temperature 8.9 °C, average of about 70 frosts/yr). Productivity and persistence of APG 54281 (rhizomatous) and its compatibility with legumes, were compared with 4 other C4 grasses, *P. notatum* 'Competidor' (rhizomatous), *D. eriantha* 'Premier' (caespitose), *C. gayana* 'Katambora' (stoloniferous), *P. dilatatum* 'Common' (shortly rhizomatous), and *C. clandestinus* 'Noonan' (rhizomatous, stoloniferous). The experiment was sown in a replicated, split plot array in which dry matter production and persistence of the grasses were compared with and without the addition of N fertilizer in mixtures with *Trifolium subterraneum* L. subsp. *subterraneum* 'Seaton Park' (annual) or *T. repens* L. 'Haifa' (perennial), all sown at commercial rates. Grasses were sown from seed in December 1987 and legumes oversown in July 1988. Plots were defoliated by grazing in early spring (August) before making the first DM production harvests in December 1988. Grass persistence and ground cover were measured in January each year as % frequency in 10 × 10 cm grids within 1 m^2 quadrats. Nitrogen as ammonium nitrate was applied at 100 kg N/ha/yr in 2 split dressings, the first before growth commenced in late spring and again after the first harvest. Grass harvests were made at approximately 2 monthly intervals during the summer season and all plots were fully defoliated and the forage removed using a self-propelled mower after each harvest. Legume harvests were made during the winter and spring months at times determined by growth. A basal application of 200 kg superphosphate/ha was made at planting and again in June 1989.

'Katambora', 'Common' and 'Noonan' were not well adapted and performed poorly. Data for the first 3 only are presented in Table 3 and 4.

Table 3. Dry matter (DM) production (kg/ha) of *P. lepton* APG 54281, *D. eriantha* 'Premier' and *P. notatum* 'Competidor'.

Treatments	Total DM Production (kg/ha)								
	1988/89			1989/90			1990/91		
	Grass	Weed	Legume	Grass	Weed	Legume	Grass	Weed	Legume
Control									
APG 54281	1,554	1,166		2,908	934		2,139	208	
'Premier'	1,692	1,220		3,126	1,290		1,846	362	
'Competidor'	218	1,916		2,570	1,552		3,023	164	
+ 100 kg N/ha									
APG 54281	3,908	1,722		10,166	326		5,519	108	
'Premier'	3,802	1352		6,552	1856		4,993	198	
'Competidor'	628	4,520		4,766	2,604		4,740	216	
+ *T. subterraneum*									
APG 54281	1,600	868	465	3,553	715	273	2,455	19	839
'Premier'	1,539	616	490	2,023	1,313	565	1,939	345	2,428
'Competidor'	182	1,468	622	2,133	1,747	106	2,629	408	1,053
+ *T. repens*									
APG 54281	1,778	1,130	216	3,131	876	547	2,963	40	358
'Premier'	2,094	1,066	256	2,046	1,755	1,219	3,101	923	1,127
'Competidor'	272	1,488	368	1,840	1,353	893	2,464	344	388

Table 4. Changes in groundcover (% frequency) of *P. lepton* APG 54281, *D. eriantha* 'Premier' and *P. notatum* 'Competidor'.

Treatments	Grass Ground Cover			
	% Frequency (January)			
	1989	1990	1991	1992
Control				
APG 54281	73	85	96	93
'Premier'	74	63	79	81
'Competidor'	35	55	78	92
+ 100 kg/ha N				
APG 54281	73	98	100	100
'Premier'	79	76	87	90
'Competidor'	20	30	87	98
+ *T. subterraneum*				
APG 54281	66	95	100	100
'Premier'	72	68	78	80
'Competidor'	23	47	74	90
+ *T. repens*				
APG 54281	59	93	100	100
'Premier'	69	54	80	80
'Competidor'	23	42	72	89

Over the 3-year period, the total DM production of APG 54281 increased from 6,600 kg DM/ha in the control to 19,600 kg DM/ha in the 100 kg N/ha treatment, compared with 5,900 kg DM/ha to 10,100 kg DM/ha for 'Competidor' and 5,700 kg DM/ha to 15,300 kg DM/ha for 'Premier'. Relatively high levels of production were sustained into the third year by these better adapted grasses, even without N fertilizer. Notably, production of APG 54281 and 'Premier' was high in each year, but production of 'Competidor' was lower in the establishment year, reflecting its low growth rate from seedling to maturity. These 3 grasses consistently produced more DM than the other 3 in the study. 'Noonan', 'Katambora' and *P. dilatatum* produced total 3-year DM production of 1,300, 3,700, and 3,600 kg DM/ha respectively when fertilized with N or sown with legumes (data not shown).

DM production of APG 54281 was unaffected by competition from both legumes when unfertilized. The legumes persisted and increased production with time in a grass stand whose density increased with age (Table 3, Table 4). Total 'Seaton Park' DM production when associated with APG 54281 was 1,600 kg DM/ha, with 'Competidor' 1,800 kg DM/ha, and with 'Premier' 3,500 kg DM/ha, reflecting the competitive effect of the almost complete groundcover produced by the sward-forming *Paspalum* grasses compared with the more open stand of the caespitose 'Premier' (Table 3). 'Seaton Park' production associated with 'Katambora' with a ground cover of only 8% after its establishment year was 5,700 kg DM/ha. However, production of 'Seaton Park' growing with APG 54281 increased from 470 to 830 kg DM/ha from the first to the third year, indicating that while legume DM production was suppressed, it remained productive at a low level as the grass ground cover increased (Table 4). Summarizing, both rhizomatous grasses suppressed the associated legume (total production 1,470 and 1,570 kg DM/ha respectively), more than the 'Premier' (3,490 kg DM/ha), but all yields were lower than 'Seaton Park' grown without significant sown grass competition (6,400 kg DM/ha). Associated grass production of 7,600, 4,900 and 5,500 kg DM/ha respectively was much lower than when fertilized with 100 kg N/ha, and similar to the 6,600, 5,900 and 5,700 kg DM/ha respectively when the grasses were not fertilized with N. The legumes nevertheless provided useful protein for grazing livestock.

Grass DM production trends were similar when the grasses were sown with the perennial legume 'Haifa'. However, DM production of the 'Haifa' component was lower with 'Haifa' than with the annual 'Seaton Park', possibly because of the greater overlap in the production rhythm of *T. repens* with that of the grasses. 'Haifa' produced 7,800 kg DM/ha associated with the poorly adapted 'Katambora'.

Ground cover data, expressed as frequency, show that APG 54281 established well in the first year, but 'Competidor' was slow to develop, its frequency increasing to be equivalent of APG 54281 only after 3 years (Table 4). The cutting management in this study enabled the associated legume to persist and achieve a low level of production. Observation elsewhere suggests that astute grazing management is necessary to enable legumes to produce significant dry matter when grown with APG 54281 and 'Competidor'. Further research involving cutting frequency and/or grazing pressure would be required to test this.

APG 54281 at the same time suppressed the weed component (Table 3), mainly *Eragrostis* sp. and *Sporobolus* sp., particularly in the 2 years following establishment. The ability of *P. lepton* to suppress these weeds to a generally greater extent than that of other well adapted grasses could have strong practical consequences in the Stanthorpe district, if seed of the grass became commercially available. In this area, and more widely, *Eragrostis curvula* has become a serious weed of pastures. It has little nutritive value except in its youngest stage of growth. It sets large quantities of seed that is wind-borne, and therefore has spread rapidly, mainly on sandy and loamy surfaced soils across Southeast Queensland and Northern New South Wales (Csurhes et al. 2016).

In a separate study (DL Lloyd, unpublished) at the same site carried out in the summer of 1992–1993, in the first year after establishment, the productivity of 5 lines of *P. lepton* was compared without fertilizer application. The DM production of the promising, palatable lines, APG 54325 and APG 54281, was 4,400 and 3,900 kg DM/ha respectively. Both may well have a role in combatting the invasion of *E. curvula*.

Beaty et al. (1970) working at Americus, Georgia, endorsed the potential forage value of *P. lepton*, adding that, by virtue of its stability of cover under frequent defoliation and dense tillering, it also had potential to be used in soil erosion control.

Palatability

There are differences of opinion regarding the palatability of *P. lepton*. Barreto (1956) considered it to be a grass with forage potential, noting among other things that it "appears to be very palatable to animals". Observation at the APMC in Georgia, USA supports this view, indicating that *P. lepton* APG 54281 was more productive and more palatable than 'Pensacola' (data unpublished). Palatability of the 8 *P. lepton* accessions in the Samford *Paspalum* evaluation (Hacker et al. 1999) was rated once seed had been harvested at completion. Ratings for the *P. lepton* accessions ranged from 2–8 (mean 4.7 on a 1–10 scale, with 10 the most palatable). The most palatable accessions in an assessment in early winter, when plants were mature and less attractive to stock, were APG 54306, APG 54839 (8 rating) and APG 54281 (6 rating). Least palatable was APG 54291 (2 rating). Only one of the 133 *Paspalum* accessions in the experiment, a *P. plicatulum*, received a rating of 10.

However, in studies in Florida, USA, 2 ecotypes of *P. lepton* have been classified with poor palatability, 1 with dark blue-green leaves, the other with lighter green-yellow leaves (A. Blount, pers. comm.). These are eaten when young, but mature quickly and are avoided by cattle, thereafter outcompeting all relatively more palatable associated grasses. Accordingly, *P. lepton* is now considered a serious weed in perennial grass pastures and 'Pensacola' seed production areas in Florida, Alabama and Georgia (Blount et al. 2022).

In Australia, concerns regarding the palatability and weediness of a mature stand of *P. lepton* APG 54281 led to the termination of *P. lepton* evaluation at Grafton Agricultural Research Station in the early 1970s (GPM Wilson, unpublished). Concerns have also been expressed about the narrow-leafed, low growing and rapidly maturing *P. lepton* 'Rappville ecotype', APG 54488. The authors' observations of APG 54488 in farm pastures in association with native *Digitaria didactyla* Willd., *I. cylindrica* and naturalized *Axonopus fissifolius* (Raddi) Kuhlm., are that it is moderately well grazed when young, becoming fibrous and much less palatable for grazing livestock as it matures. It is less palatable than lines of *P. lepton* and other species, considered more suitable for grazing. For example, APG 54281, which has persisted under regular farm grazing in a number of abandoned species evaluation sites, is always grazed low, and preferentially to invading 'Pensacola', now widely naturalized in the Australian subtropics.

In a study near Gympie, *P. lepton* APG 54281, APG 54307, APG 54325, APG 54461 and APG 54839 were sown in November 1998 into plots on a sandy, clay-loam river alluvium previously dominated by naturalized 'Pensacola'. Once a complete cover was obtained, the area was opened to grazing by cattle. All *P. lepton* plots were equally well-grazed (BG Cook, observation). Further, the *P. lepton* spread through associated grasses, predominantly 'Pensacola', with all *P. lepton* lines being grazed in preference to 'Pensacola'.

In summary, the reputation of *P. lepton* as an unpalatable grass has not been sustained among the more recently introduced accessions of the species, providing they are subjected to regular defoliation.

Nutritive value

Barreto (1956) commented favorably not only on the palatability of *P. lepton* but also on the observation that "pastures where this species predominates support good stocking rates and stock fatten well", suggesting that the grass has sound productivity and quality characteristics. In a field experiment conducted in *P. lepton* grassland in Corrientes Province, Argentina, Bernardis et al. (2001) assessed macro and microelements chemical composition and in vitro organic matter digestibility (IVOMD) of the grass cut at 4 (±2) cm above ground at 4 and 8-week intervals. Cutting frequency did not significantly affect crude protein levels, which were consistently around 7%, but other nutrients were differentially affected. Levels of P, K, Ca, Cu and Zn in the dry matter of *P. lepton* were generally marginal to adequate to satisfy nutritional requirements of growing cattle, but Na levels were low. IVOMD was 74 ±11% and 64 ±15% at 4 and 8 weeks respectively.

Nutritive value of *P. lepton* was assessed by sampling 6-week regrowth of APG 54281 and APG 54325 at Gympie (October 1992, February 1993, November 1993) and Stanthorpe (November 1992, January 1993, February 1993) and submitting the dried material for analysis (Tables 5 and 6). Soluble and total levels of oxalate were determined from bulked samples from the 3 harvests at Gympie (Table 4). Comparable analyses for the subtropical grasses *C. clandestinus*, *C. gayana* and *S. sphacelata* are presented in Feedipedia (Heuzé and Tran 2024), nodes 398, 480 and 381 respectively, and Cook and Mulder (1984b). Pereira et al. (2011) observed a similarity between crude protein levels for *P. lepton* and those measured in other grasses in the experiment, including 'Pensacola', *Paspalum guenoarum* Arechav. and *Chloris uliginosa* Hack. (syn. *Eustachys uliginosa* (Hack.) Herter).

Mineral nutrient levels in the dry matter produced about 6 weeks after the prior harvest were similar at the Gympie and Stanthorpe sites, and for the 2 accessions tested. These values do not express seasonal differences, nor do they identify differences occurring at different growth stages. For example, N % in grass harvested in January was considerably lower than from those in the earlier or later samplings (data not shown) for both accessions at both sites. This may have been attributable to plant growth towards seeding during that period. However, in dairy production systems, a *P. lepton* sward without legume, used as a sole forage would not sustain dairy production (Fulkerson 2007) (Table 5) without N, P and Na supplementation. C4 grasses in general do not have the nutritive value to support high level dairy production without supplementation, except for very short periods in their early regrowth (Milford 1960; Crush and Rowarth 2007). Mineral levels measured in both *P. lepton* accessions were adequate to support growth of beef cattle.

Table 5. Mean percentage from 3 harvests of nutrient in the dry matter of 6-week regrowth of 2 accessions of *Paspalum lepton* grown in 2 locations in Queensland, Australia, and critical values required (Fulkerson 2007) to sustain dairy and beef production.

Accession	N	P	K	Ca	Mg	Na	S	Cl
APG 54281								
Gympie	1.61	0.16	1.64	0.56	0.26	<0.05	0.16	0.97
Stanthorpe	1.71	0.20	1.75	0.51	0.17	<0.05	0.16	1.04
APG 54325								
Gympie	1.56	0.17	1.62	0.51	032	<0.05	0.15	0.99
Stanthorpe	1.63	0.20	1.66	0.58	0.24	<0.05	0.14	1.04
Critical level								
Dairy cattle	2.4	0.33	0.9	0.51	0.2	0.18	0.2	
Beef cattle[1]		0.2–0.3	0.6–0.7	0.45–0.56	0.1–0.2	0–05–0.1		

[1]University of Georgia Extension (2017)

Table 6. In vitro dry matter digestibility (IVDMD), fiber (ADF, NDF) and oxalate determinations on 6-week regrowth samples of 2 accessions of *Paspalum lepton* grown at Gympie, Queensland, Australia.

Accession	Date sampled	IVDMD (%)	ADF (%)	NDF (%)	Oxalate %	
					Total	Soluble
APG 54281	13.10.92	60.2	40.0	70.3	<0.01	<0.01
	16.2.93	56.5	41.3	69.6		
	11.5.93	64.4	35.1	61.7		
APG 54325	13.10.92	62.3	41.2	67.3	<0.01	<0.01
	16.2.93	54.0	39.0	69.7		
	11.5.93	63.7	34.4	62.8		

Digestibility and fiber levels in both lines shown in Table 6 were similar to those of most C4 grasses reported by Milford (1960). Tissue oxalate levels were below the level of determination (<0.01%) in *P. lepton*, which is a point of distinction from 2 of the main grasses used in the humid subtropics and upland tropics, *C. clandestinus* and *S. sphacelata*, both of which can have levels of oxalate that can cause metabolic problems in grazing cattle and horses (Rahman et al. 2013).

In summary, the nutritive value of *P. lepton* APG 54281 and APG 54325 tested in Queensland were in the same range as for other *Paspalum* spp. and in the same domain as other subtropical grasses used commercially (Feedipedia). They did not accumulate undesirable levels of oxalate in their tissues.

Animal performance

Recognizing the limitations of short-term grazing studies, particularly regarding adjustment of the rumen flora in the first 4–6 weeks of diet change, grazing behavior was observed to obtain a rough assessment of productivity on this new species to Australian agriculture. In an unreplicated study of the performance of animals grazing *P. lepton* APG 54325 pasture at Gympie, liveweight gain of a group of Holstein-Friesian heifers averaging 265 kg liveweight with *P. lepton* as the sole nutrient source, was measured over a period of 3 months (March–May). The established grass stand was fertilized with 110 kg N/ha and set-stocked at 5 hd/ ha. The heifers gained an average of 1.3 kg/hd/ day in the first month, declining to an overall average of 0.6 kg/hd/day as feed on offer declined during a period of low rainfall and declining temperatures (Cook et al. 2020). By comparison, Evans and Hacker (1992) in a study with steers grazing *S. sphacelata* 'Narok' at Beerwah in Southeast Queensland, measured liveweight gain of 0.45 kg/hd/day, averaged on a year-round basis over 3 years.

In another unreplicated grazing study near Stanthorpe in which *P. lepton* APG 54325 and *D. eriantha* 'Premier' were sown in separate 0.6 ha paddocks with *T. subterraneum* ssp. *subterraneum* 'Seaton Park' and 'York', the liveweight gain in Hereford steers, average liveweight 390 kg, was measured over a period of 120 days in the year following establishment (DL Lloyd, unpublished). Rainfall measured during the time was 371 mm, compared with the long-term average of 378 mm for the same period. Grazing with a stocking rate of 3.3 steers/ha began in late September 1998 and the final liveweight measurement was made in late February 1999. Prior to commencement of grazing treatments, the collective area was defoliated by grazing heavily with 35 steers for 56 days, and the area closed during the cool months when grasses were relatively dormant, before measurement began. Animal liveweight was measured every 30 days. In the first 30 days until late October (the spring period), average liveweight gains from APG 54325 and 'Premier' were 2.55 kg/hd/day and 1.68 kg/hd/day respectively, the high levels primarily attributable to their association with an excellent *T. subterraneum* component. In the following 90 days the liveweight gains were 1.02 and 0.69 kg/hd/day respectively. In the final 30-day period, stock lost weight probably owing to a combination of low feed quality associated with grass seed production in a drier than average month, and the absence of the annual legume that had set seed and senesced. Average liveweight gains for the 120-day grazing period were 1.02 kg/hd/day for APG 54325 and 0.58 kg/hd/day for 'Premier'.

In summarizing both studies, pastures based on *P. lepton* performed at least equally as well as, perhaps slightly better than, those based on other subtropical species, reflecting the comparable nutritive quality of the grass. Comparability is more significant when assessing the value of the species than the quantitative values measured, which will vary with soil fertility/fertilizer used, seasonal conditions and age of pasture.

Compatibility with legumes

Benefits of incorporating legumes into beef and dairy production systems have been well-demonstrated (Hill et al. 2009; Mannetje 1997). Legume genera including *Medicago*, *Trifolium* and *Adesmia* have been found in *P. lepton* dominant native pastures (Barreto 1956), although no reference is made to legume frequency or grazing management applied. Grass-legume mixtures are an important component of intensive sown forage systems in the subtropics of Australia where, in more humid parts of the region, they are often complemented by nitrogen-fertilized grass. However, the competitive ability of *P. lepton* that enables it to suppress weeds (see Weed Suppression below) also leads to some or total suppression of sown legumes in pastures (Table 3).

While cool season legumes (*Trifolium* spp.) were able to persist with *P. lepton* in the cool (24 hr average annual temperature 15 °C) upland subtropical Stanthorpe environment (Table 3), the outcome in a similar experiment with warm season legumes at Gympie in a mesic sub-tropical lowland environment (24 hr average annual temperature 20 °C) was different (BG Cook, unpublished). *P. lepton* APG 54325 was sown on a degraded red podzolic soil and compared under intermittent grazing with related sward-forming grasses of contrasting growth habits: *P. notatum* 'Competidor' (rhizomatous); naturalized *P. dilatatum* (caespitose) and *A. fissifolius* (stoloniferous). *Arachis glabrata* Benth. 'Prine' (rhizomatous) and *Vigna parkeri* Baker 'Shaw' (stoloniferous), both well adapted perennial legumes known to grow with sward grasses under grazing (Cook et al. 2020), were established with each grass. 'Shaw', which has formed stable combination with the stoloniferous and rhizomatous *C. clandestinus* in farm pastures, grew well with *P. dilatatum* and *A. fissifolius*, and initially with 'Competidor' before sward closure late in the second year. Although it established well with APG 54325, its vigor and frequency declined in the rapidly establishing grass. 'Prine' established slowly from rhizomes, but its frequency gradually increased in combination with all grasses.

Observation elsewhere suggests more controlled, regular grazing may have favored persistence of the test legumes. Under such grazing management, more competitive species such as *Arachis pintoi* Krapov. & W. C. Greg. (stoloniferous), *T. repens* 'Haifa' (stoloniferous) and *Lotus uliginosus* Schkuhr 'Grasslands Maku' (stoloniferous, rhizomatous) have grown successfully with *P. lepton* in mesic locations and *Aeschynomene falcata* (Poir.) DC. in drier locations (AD Robertson, unpublished). Observed over time in some locations, suppressed legumes became more vigorous, despite *P. lepton* cover being maintained. This was presumed to be associated with a decline in soil mineral nitrogen over time following seedbed preparation. A similar pattern of legume growth and persistence has been observed elsewhere when sown with the rhizomatous and stoloniferous *C. clandestinus*.

Summarizing, *P. lepton* has a strong suppressive effect on associated legumes, with the level potentially controlled by grazing management and legume growth form. This is a topic for further study.

Weed suppression

The suppressive quality of *P. lepton* demonstrated with some legumes (Table 3) is potentially valuable in suppressing some of the more serious pasture weeds. Grasses, including *E. curvula, I. cylindrica, Hyparrhenia hirta* (L.) Stapf, *Sporobolus indicus* (L.) R. Br. var. *major* (Büse) Baaijens, *Sporobolus indicus* (L.) R. Br. var. *pyramidalis* (P. Beauv.) Veldkamp, *Sporobolus natalensis* (Steud.) T. Durand & Schinz and non-poaceous species such as *Senecio madagascariensis* Poir. (Asteraceae) and *Pteridium esculentum* (G. Forst.) Cockayne (order Polypodiales, Dennstaedtiaceae), have become weeds of sown pastures in many parts of the Australian subtropics. These are largely unpalatable and/or rapidly maturing species whose low nutritive value limits production from grazed pastures. Farmers who have established *P. lepton* and researchers working with the species have confirmed the ability of *P. lepton* to compete vigorously with these species. Thus, it may become part of an integrated weed control strategy that commonly includes heavy grazing and use of selective chemical herbicides in which recommended stock withholding periods are observed.

Observation in the Stanthorpe animal production studies suggests *P. lepton* has been more effective than *D. eriantha* 'Premier' in suppressing invasion by *E. curvula*, supported by observation in commercial pasture sown to *P. lepton* APG 54325 nearby (AD Robertson, unpublished). Critically, *P. lepton* seedlings develop quickly, forming a dense stand that suppresses seedling regeneration of the weed species (Tables 3 and 4). Further, the established grass is resistant to continuous heavy grazing, a treatment that can suppress or eliminate *I. cylindrica* by the intensive, regular defoliation of its young growth.

Suppression and control of taller grasses (*Sporobolus, Eragrostis, Hyparrhenia, Imperata*) is important because they reduce productivity of land and, at the same time, develop a fuel load that poses a substantial fire threat. This would be almost eliminated if mature and dry tall grasses were replaced by palatable *P. lepton*.

Difficulty to control

The potential of palatable lines of *P. lepton* to become a weed unless well managed is exacerbated by a difficulty to effect control, either chemically or with cultivation. Studies in Georgia indicated that 3 years of cultivation and cropping with corn (*Zea mays* L.) was necessary for complete control of *P. lepton* (USDA Soil Conservation Service, unpublished). Attempts to control APG 54281 by spraying with 2, 2-DPA and cultivation and cropping with soybean (*Glycine max* (L.) Merr.) has proved unsuccessful at Grafton Research Station (GPM Wilson, unpublished). Blount et al. (2022) support the view that *P. lepton* is not readily controlled by cultivation alone, adding that cultivation may result in favoring vegetative spread of the grass through movement of rhizome pieces. Additionally, they note that it is tolerant of a number of herbicides including metsulfuron and glyphosate that are effective on other species of *Paspalum*. Studies carried out at Gympie have demonstrated that mature stands of *P. lepton* are weakened by recommended rates of glyphosate but recover quickly; and stands that are severely weakened (and sometimes killed) by double rates of glyphosate may still recover (BG Cook, unpublished). Herbicide screening has found that mature plants in pots were not affected by haloxyfop, triclopyr, sulfometuron methyl and metsulfuron methyl at normal or double rates (DS Loch, in Cook et al. 2020). The only chemical to control P. lepton was the pre-emergence herbicide, dithiopyr (24%) at 3.5 L/ha. Hexazinone, a chemical not included in the above screening, has been found effective in controlling *P. lepton* in Florida, and is recommended there at rates of 1.12–2.24 kg/ha (Blount et al. 2022). Since *P. lepton* has a low level of seed dormancy (Cook et al. 2020), seed is unlikely to accumulate within the soil seed bank. Using this chemical, the grass is therefore unlikely to regenerate once the vegetative stand is controlled and further seed set prevented. However, as also occurs with *P. notatum*, in areas where mature seed has been set, small colonies of *P. lepton* have developed in nearby swards of *A. fissifolius* and *P. dilatatum*.

Conclusions

All grasses currently used in the subtropics have weaknesses and strengths with regard to their adaptation, flexibility in production systems, nutritional value, seasonal growth patterns and productivity. *P. lepton* is no exception:

Weaknesses

- Some ecotypes of *P. lepton* mature rapidly and become unpalatable (e.g., APG 54488), enhancing their ability to invade natural and modified systems;
- *P. lepton* is competitive, with a propensity to suppress many potentially associated legumes, particularly in more fertile, humid environments;
- *P. lepton* is difficult to control with herbicide and/or cultivation;
- As with most C4 grasses, *P. lepton* may be susceptible to "pasture dieback", although not well substantiated.

Strengths

While there are clearly forms of *P. lepton* with certain undesirable traits, our studies have confirmed that 2 promising lines, APG 54281 and APG 54325 have the following beneficial qualities:

- Well adapted to friable sandy and loamy-surfaced soils;
- One of only 3 C4 grasses well adapted to the relatively cool subtropical uplands;
- Establishes quickly with production in establishment season, superior to *P. notatum*;
- Moderate to good drought and frost tolerance;
- Responsive to N fertilizer application yet persistent without fertilizer on soils of low nitrogen fertility;
- Forage yields at least comparable with those of other adapted grasses during a long growing season;
- Forage of similar quality to other useful C4 grasses, with no anti-production factors recorded;
- Readily accepted by livestock resulting in sound animal performance when well managed;
- High seed yield, providing potential for low-cost seed;
- Resistance to ergot disease;
- Colonization and persistence with a high level of groundcover under regular defoliation;
- Tolerance of prolonged heavy grazing;
- Soil conservation potential;
- Compatible with some legumes including *Trifolium subterraneum* and *Arachis glabrata* in appropriate environments;
- Suppression of weeds, including low quality, unpalatable, invasive grasses;
- Acceptance by commercial livestock producers.

From the studies in subtropical Eastern Australia and the experience of others, we may conclude that the more desirable forms of *P. lepton* have characteristics that identify them as addressing many of the inherent shortcomings of other grasses currently used in its zone of adaptation. Thus, this is a species with significant commercial forage/pasture potential, although caution should be exercised and management applied to minimize the environmental threat.

Acknowledgments

The authors are indebted to the many farmers on whose land we conducted *P. lepton* research over many years, and to the laboratory scientists who carried out the various soil and plant analyses so necessary in gaining an understanding of a "new" species. We would also like to acknowledge the support readily provided by Dr Gilbert Lovell, formerly of the Americus Plant Materials Center, Georgia, USA, by way of discussion and provision of seed, and to Emer. Prof. Ann Blount, formerly of University of Florida, for her valuable discussion regarding issues with *P. lepton* in Florida and Georgia.

References

(Note of the editors: All hyperlinks were verified 24 September 2024).

Anonymous. 1993. Release of 'Doncorea' Brunswickgrass. United States Department of Agriculture Soil Conservation Service, Americus Plant Materials Center, Americus, Georgia.

Barreto IL. 1956. Las especies afines a *Paspalum plicatulum* en Rio Grande del Sur (Brasil). Revista Argentina de Agronomía 23:56–58.

Beaty ER; Powell JD; Lawrence RM. 1970. Response of Brunswick grass [*Paspalum nicorae* (Parodi)] to N fertilization and intense clipping. Agronomy Journal 62(3):363–365. doi: 10.2134/agronj1970.00021962006200030016x

Belt SV; Englert JM. 2008. Improved conservation plant materials released by NRCS and cooperators through December 2007. Plant Materials Technical Note No. 71. United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), N Plant Materials Center (PMC), Beltsville, Maryland, USA. bit.ly/3XKpggO

Bernardis AC; Goldfarb MC; Fernández JA; Casco J. 2001. Valor nutritivo y contenido mineral bajo dos frecuencias de corte de *Paspalum nicorae*. Información Tecnológica 12(5):65–70. bit.ly/4e7BRBx

Blount A; Wallau M; Sellers B; Hancock D; Dillard L; Dubeux J; Mackowiak C; Vendramini J; Cooper C. 2022. Brunswick grass (*Paspalum nicorae*): A weed contaminant in southern pastures and Bahia grass seed production fields. UF/IFAS 2022(1):SS-AGR-405 doi: 10.32473/edis-ag408-2022

Bourke CA. 2007. A review of kikuyu grass (*Pennisetum clandestinum*) poisoning in cattle. Australian Veterinary Journal 85(7):261–267. doi: 10.1111/j.1751-0813.2007.00168.x

Buck SR. 2017. Pasture dieback: Past activities and current situation across Queensland (2017). Project Report. Department of Agriculture and Fisheries, State of Queensland. Australia. bit.ly/3BrOLM3

Burrows WH; Scanlan JC; Rutherford MT, eds. 1988. Native pastures in Queensland: the resources and their management. Department of Primary Industries Information Series Q187023, Queensland, Australia.

Burson BL; Bennett HW. 1970. Cytology, method of reproduction, and fertility of Brunswick grass, *Paspalum nicorae* Parodi. Crop Science 10(2):184–187. doi: 10.2135/cropsci1970.0011183X001000020021x

Cook BG; Pengelly BC; Schultze-Kraft R; Taylor M; Burkart S; Cardoso Arango JA; González Guzmán JJ; Cox K; Jones C; Peters M. 2020. Tropical forages: An interactive selection tool. 2nd and Revised Edn. International Center for Tropical Agriculture (CIAT), Cali, Colombia and International Livestock Research Institute (ILRI), Nairobi, Kenya. www.tropicalforages.info

Cook BG; Mulder JC. 1984a. Responses of nine tropical grasses to nitrogen fertilizer under rain-grown conditions in south-eastern Queensland. 1. Seasonal dry matter productivity. Australian Journal of Experimental Agriculture and Animal Husbandry 24(126):410–414. doi: 10.1071/EA9840410

Cook BG; Mulder JC. 1984b. Responses of nine tropical grasses to nitrogen fertilizer under rain-grown conditions in south-eastern Queensland. 2. Concentrations and uptakes of nitrogen, phosphorus and potassium in plant tops. Australian Journal of Experimental Agriculture and Animal Husbandry 24(126):415–420. doi: 10.1071/EA9840415

Crush JR; Rowarth JS. 2007. The role of C4 grasses in New Zealand pastoral systems. New Zealand Journal of Agricultural Research 50(2):125–137. doi: 10.1080/00288230709510287

Csurhes S; Leigh C; Walton C. 2016. Invasive plant risk assessment: African lovegrass *Eragrostis curvula*. Department of Agriculture and Fisheries Biosecurity Queensland, Queensland, Australia. bit.ly/3MYmyiB

Enviroseeds Pty Ltd. 1999. *Paspalum nicorae* 'Blue Eve'. Australian Plant Breeders Rights Search, Australian Government, IP Australia. bit.ly/3MTpHjM

Evans TR; Hacker JB. 1992. An evaluation of the production potential of six tropical grasses under grazing. 3. Responses to set stocking rates under continuous grazing. Australian Journal of Experimental Agriculture 32(2):693–699. doi: 10.1071/EA9920693

Fulkerson B. 2007. Tech note Kikuyu grass (*Pennisetum clandestinum*). Future dairy. bit.ly/3ZAGRtS

GRIN (Germplasm Resources Information Network). 2024. *Paspalum lepton* Schult. GRIN taxonomy. USDA, Agricultural Research Service, National Plant Germplasm System, National Germplasm Resources Laboratory, Beltsville, MD, USA. bit.ly/4gM8tCL

Hacker JB; Williams RJ; Vieritz AM; Cook BG; Pengelly BC. 1999. An evaluation of a collection of Paspalum species as pasture plants for Southeast Queensland. Genetic Resources Communication No. 32. CSIRO Tropical Agriculture, St Lucia, QLD, Australia. bit.ly/3XQQ3cz

Hanson AA. 1972. Grass varieties in the United States. Agriculture Handbook No. 170. Agricultural Research Service, United States Department of Agriculture, Washington, DC, USA.

Heuzé V; Tran G. 2024. Category: Cereal and grass forages. Animal Feed Resources Information System. A programme by INRA, CIRAD, AFZ and FAO. bit.ly/3XxwxAb

Hill JO; Coates DB; Whitbread AM; Clem RL; Robertson MJ; Pengelly BC. 2009. Seasonal changes in pasture quality and diet selection and their relationship with liveweight gain of steers grazing tropical grass and grass–legume pastures in northern Australia. Animal Production Science 49(11):983–993. doi: 10.1071/EA06331

Jones RJ; Ford CW. 1972. The soluble oxalate content of some tropical pasture grasses grown in south-east Queensland. Tropical Grasslands 6(3):201–204. bit.ly/3MZYko5

Loch DS; Cook BG; Harvey GL. 1999. Location of seed crops: grasses. In: Loch DS; Ferguson JE, eds. Forage Seed Production. Volume 2: Tropical and Subtropical Species. CABI Publishing, Wallingford, UK. p. 113–128.

Loch DS; Souza FHD de. 1999. Seed harvesting and drying: grasses. In: Loch DS; Ferguson JE, eds. Forage Seed Production. Volume 2: Tropical and Subtropical Species. CABI Publishing, Wallingford, UK. p. 191–212.

Mannetje L't. 1997. Harry Stobbs memorial lecture, 1994. Potential and prospects of legume-based pastures in the tropics. Tropical Grasslands 31(2):81–94. bit.ly/4gu9QWl

McCaskill MR; Mitchell ML; Zollinger R; Armstrong RD; Partington D. 2019. Dry matter and nutritive value responses of native, naturalised and sown pasture species to soil Olsen P. Crop and Pasture Science 70(12):1097–1109. doi: 10.1071/CP18544

Milford R. 1960. Nutritional value of 17 subtropical grasses. Australian Journal of Agricultural Research 11(2):138–148. doi: 10.1071/AR9600138

Nabinger C; Dall'Agnol M. 2019. Guia para reconhecimento de espécies dos Campos Sulinos. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), Brasilia, DF, Brazil. 132p. bit.ly/3XXi8P8

NRCS (Natural Resources Conservation Service). 2022. Discontinued conservation plant releases. bit.ly/3XDlYMf

Northcote KH. 1979. A factual key for the recognition of Australian soils. 4th edn. Rellim Technical Publishers, Glenside, South Australia.

Oliveira RC de; Valls JFM. 2008. New synonyms and occurrences for *Paspalum* L. (Poaceae). Hoehnea 35(2):289–295. (In Portuguese). doi: 10.1590/S2236-89062008000200010

Olsen SR; Cole CV; Watanabe FS; Dean LA. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular No. 939, United States Department of Agriculture (USDA), Washington, DC, USA. bit.ly/3zFE9bV

Oram RN, ed. 1990. Register of Australian herbage plant cultivars. 3rd ed. Australian Herbage Plant Registration Authority, Division of Plant Industry, CSIRO Publishing.

Pereira EA; Dall'Agnol M; Nabinger C; Huber KGC; Montardo DP; Genro TCM. 2011. Agronomic production of a collection of *Paspalum nicorae* Parodi access. Revista Brasileira de Zootecnia 40(3):498–508. (In Portuguese). doi: 10.1590/S1516-35982011000300006

Progressive Seeds Pty Ltd. 1998. *Paspalum nicorae* 'Blue Dawn' Progressive Seeds Pty Ltd, Kholo. Qld. Australia. bit.ly/3BiRHuE

Rahman MM; Abdullah RB; Wan Khadijah WE. 2013. A review of oxalate poisoning in domestic animals: tolerance and performance aspects. Journal of Animal Physiology and Animal Nutrition 97(4):605–614. doi: 10.1111/j.1439-0396.2012.01309.x

Reis CAO dos; Dall'Agnol M; Nabinger C; Schifino-Wittmann MT. 2010. Morphological variation in *Paspalum nicorae* Parodi accessions, a promising forage. Scientia Agricola 67(2):143–150. doi: 10.1590/S0103-90162010000200003

Smith RW; Harris CA; Cox K; McClements D; Clark SG; Hossain Z; Humphries AW. 2021. A history of Australian pasture genetic resource collections. Crop and Pasture Science 72(9):591–612. doi: 10.1071/CP20336

Strickland RW. 1978. The cool season production of some introduced grasses in south-east Queensland. Tropical Grasslands 12(2):109–112. bit.ly/39wlxbr

Tropicos. 2024a. *Paspalum nicorae* Parodi. Tropicos.org Missouri Botanical Garden. Accesed on 07 November 2022. tropicos.org/name/25512327

Tropicos. 2024b. *Paspalum lepton* Schult. Tropicos.org. Missouri Botanical Garden. Accesed on 07 November 2022. tropicos.org/name/25514127

University of Georgia Extension. 2017. Mineral Supplements for Beef Cattle. Bulletin 895. bit.ly/4gGn7es

Wong PTW; Wilson GPM. 1983. Reaction of Kikuyu cultivars and breeding lines to Kikuyu yellows disease. Australasian Plant Pathology 12(3):47–48. doi: 10.1071/APP9830047

(Received for publication 13 September 2023; accepted 30 August 2024; published 30 September 2024)