A REVIEW OF ASTREBLA (MITCHELL GRASS) PASTURES IN AUSTRALIA

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ABSTRACT

Astrebla *spp. are well adapted to the harsh environment in which they occur. This adaptation is due largely to the structure of the root system and to the differential growth response to rainfall events. Each species exhibits similar growth characteristics throughout their widespread climatic occurrence. Development of the pasture in any particular area depends on the rainfall and past grazing history. Seasonal fluctuations in the contribution of Mitchell grasses to the pasture occur but deterioration is probably not widespread. This deterioration has been noted in pastures that have been heavily overgrazed by sheep during prolonged dry spells, during growing periods or continuously grazed by horses.*

This review indicates that quantitative data on a major grass genus in an important grassland are limited.

INTRODUCTION

Taxonomy

Mitchell grasses are placed in the genus *Astrebla,* erected by Mueller (1876) to accommodate some grasses which earlier had been included in the genus *Danthonia.* The four species now recognized (Hubbard 1928) are *Astrebla elymoides* F. Muell. ex Bailey, hoop or weeping Mitchell; *A. lappacea* (Lindl.) Domin., curly Mitchell; *A. pectinata* (Lindl.) F. Muell., barley Mitchell; and *A. squarrosa* C. E. Hubbard, bull Mitchell. On the basis of species morphology, distribution, anatomy and breeding characteristics Jozwik (1969) concurred with Hubbard's revision of the genus.

A. lappacea was first collected by Sir Thomas Mitchell on the Bogan River near Bourke, New South Wales on August 15, 1835 and described by Lindley under the name *Danthonia lappacea* (Mitchell 1838, i, 309). On his next expedition Mitchell collected specimens of *A. pectinata* near Condobolin, New South Wales on April 6, 1836 and to these Lindley gave the name *Danthonia pectinata* (Mitchell 1838, ii, 26).

During his subsequent expedition into tropical Australia Mitchell again collected *A. lappacea* along the Maranoa River in the vicinity of the present town of Mitchell on October 21, 1846. Lindley failed to recognize this as the same species as his *Danthonia lappacea* and described it under the new name *Danthonia triticoides* (Mitchell 1848, 365). Mueller's description of the new genus *Astrebla* was based on Lindley's *Danthonia pectinata* and *D. triticoides.*

Mitchell also collected *A. pectinata* along the "Victoria" River (now the Barcoo River) in 1846 (Hubbard 1928) and these specimens are housed in the herbarium at the University of Cambridge, England along with the specimens from Condobolin.

A fourth name, *Astrebla elymoides,* was given by Mueller to a distinct species, described and figured in F. M. Bailey (1879).

Unfortunately, Mueller, Bentham, Bailey and others who wrote about Australian grasses during the late 19th and early 20th centuries confused these names. They mostly used the name *A. triticoides* for what should have been called *A. lappacea* (since the two were identical and *lappacea* was the first published specific epithet) and misapplied the names *A. lappacea, A. triticoides* var. *lappacea* and *A. pectinata* var. *triticoides* to bull Mitchell (subsequently described by Hubbard as *A. squarrosa*). Bailey used the name *A. pectinata* var. *curvifolia* for *A. lappacea.*

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Morphology

The Mitchell grasses are perennial, summer growing, tussock grasses whose persistence and extraordinary resistance to drought and continuous grazing by domestic livestock are due largely to their root stock (Francis 1935). The root stock consists of many short, stout, thick, branched, scaly rhizomes. In *A. lappacea* numerous wiry roots spread outwards from the bottom of the rhizome into the surface soil horizon and then turn vertically downward, continuing unbranched through the layer of columnar clay. The roots branch into fine rootlets where the soil cracks cease and a gypsum layer begins (Everist 1964).

Main tillers arise from the root stock and axillary tillers develop from axils on the main tillers (Everist 1964). The leaves lack succulence when mature—a feature contributing to the durability of the Mitchell grasses (Francis 1935).

Floristics and structure

A Mitchell grass pasture in good condition consists of an even, sparsely distributed stand of one or more of the Mitchell grass species occupying a basal cover of 4% or less. Nevertheless the root systems at a depth of 15 cm can overlap to the extent of 40% in such a stand (Everist 1964). Other perennial grasses such as *Dichanthium* spp. (chiefly *D. sericeum*), *Eulalia fulva, Aristida latifolia, Eragrostis* spp., *Panicum* spp., also occur.

Because of the wide latitudinal spread of Mitchell grasslands and the incidence of summer and winter rain there can be substantial differences in the minor components at any particular site. Summer rain produces a wide variety of both annual and perennial grasses and non-grasses between the perennial tussocks, e.g., *Dactyloctenium radulans, Iseilema* spp., *Sporobolus* spp., *Boerhavia diffusa, Portulaca* sp. aff. *P. oleracea, Bassia* spp., *Kochia* spp., *Rhynchosia minima* and *Psoralea* spp. (More detailed species lists occur in Blake 1938; Davidson 1954; Everist 1963, 1964; Speck, Fitzgerald and Perry 1964). Regions with significant winter rainfall exhibit pastures which usually contain a higher proportion of non-grass species. *Dichanthium sericeum* is also more common in the south-eastern extremity of Queensland (Purcell 1963) and in New South Wales (Beadle 1948) than in the northern regions. Quantitative floristics of Mitchell grass pastures at a number of locations in Queensland have been recorded by Roberts (1972).

DISTRIBUTION AND ENVIRONMENT

Geographical distribution

Astrebla spp. are endemic to Australia and show their best development in an arc extending from the Kimberley region of Western Australia across the Northern Territory into Queensland and New South Wales with a small area in South Australia. Christian and Donald (1960) estimated a total area of approximately 960,000 km², but a more recent estimate based on Moore and Perry (1970) suggests that the total area is only about 450,000 km² (Dawson, personal communication). Areas of Mitchell grasslands in the various Australian states are presented in Table 1 and Figure 1.

Species distribution

The local distribution of the four species depends on soil moisture. *A. elymoides* occurs on run-on areas (Jozwik, Nicholls and Perry 1970) as does *A. squarrosa* (Weston 1963). *A. lappacea* occurs on well drained soils (Weston 1963). The local distribution of *A. pectinata* is not so clear. Francis (1935) states that *A. pectinata* occurred on soils that are damper and harder than those supporting *A. lappacea.* Blake (1938) recorded *A. pectinata* as dominant in the more arid areas while Weston (1963) reported that *A. pectinata* grows on soils with less tendency to crack.

TABLE 1

Area of Astrebla *grassland in each state*

State	Area (km^2)
Western Australia	13,000
Northern Territory	99,000
Queensland	328,000
New South Wales	4,600
South Australia	1,400

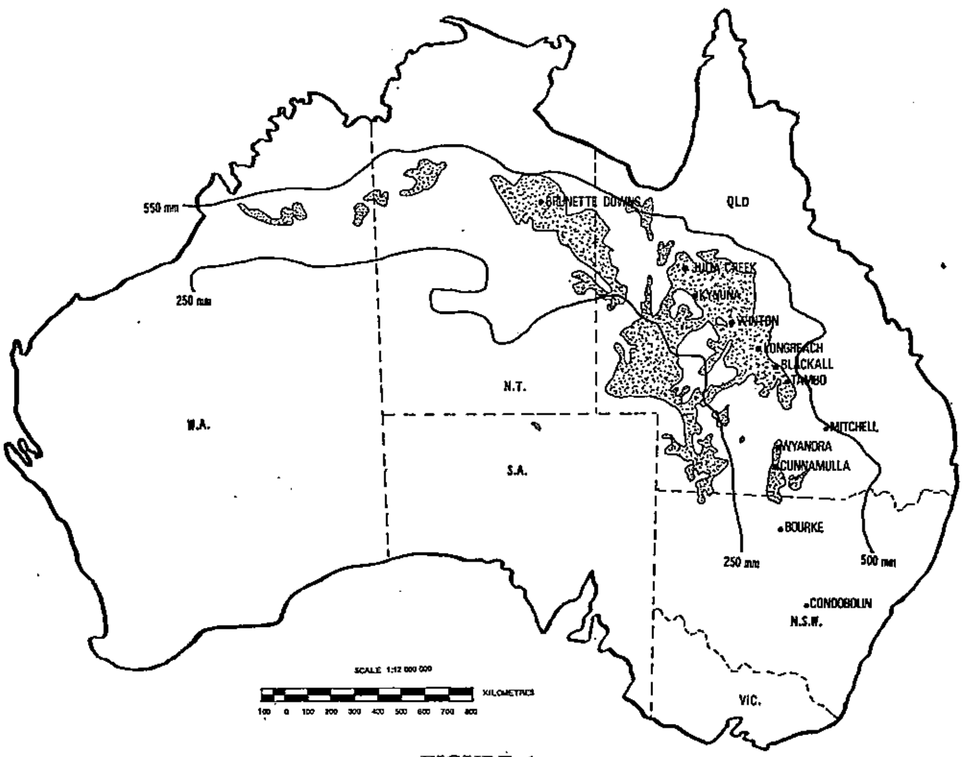

FIGURE 1

Distribution of extensive areas of Mitchell grasses in pastures throughout Australia (after Moore and Perry, 1970).

A. lappacea and *A. pectinata* are killed by flooding unlike the more tolerant *A. elymoides* and *A. squarrosa* (Everist personal communication).

Both *A. lappacea* and *A. pectinata* are widely distributed, the former being dominant often with *A. elymoides* co-dominant in the more easterly areas and the latter often with *A. lappacea* co-dominant towards the western edge of *Astrebla* occurrence in Queensland. *A. pectinata* is dominant on the Barkly Tableland and in the Northern Territory (Jozwik 1969). *A. pectinata* is the common species west of the Paroo River in New South Wales and *A. lappacea* is common further east (Beadle 1948). *A. squarroca* occurs mainly in the wetter northern and north-eastern margin of the grassland (Jozwik, Nicholls and Perry 1970). Although this general pattern of dominance exists, any or all of the four species can occur in most areas of the five Australian states. Yet, despite this widespread distribution, growth characteristics for widely separated geographical strains of the same species are generally more similar than those of different species in the one area (Jozwik 1969).

Landforms

Two main landforms support *Astrebla* grasslands. In Queensland and on the Barkly Tableland the first landform comprises the rolling downs with undulating plains of long slopes and shallow gullies developed from Cretaceous sediments of sandstone, siltstone and mudstone which in part may be calcareous (Everist 1951, 1963, 1964). These areas are largely treeless, but *Acacia cambagei*, *A. cana*, *A. pendula*, *Atalaya hemiglauca*, *Ventilago viminalis* and the shrub *Acacia farnesiana* occur in some places whilst *Eucalyptus microtheca* is present along watercourses. The "pebbly downs" of far western Queensland are not true Mitchell grass downs. Although *Astrebla* spp. are often dominant, the country is more accurately described as herb fields (Boyland personal communication).

The second landform is the recent alluvial plains occurring along many of the inland rivers (Everist 1964). Both landforms occur in Western Australia (Speck, Fitzgerald and Perry 1964).

Soils

Astrebla spp. are restricted to grey, brown and red alkaline cracking clay soils with principal profile forms (Northcote 1971) of Ug5. Everist (1964) states that a minimum percentage of 50% clay particles is common, but Perry (1962) reports an *A. pectinata* profile in the Northern Territory with a clay percentage of 40%. Representative soil physical analyses are presented in Table 2. Soils of the two landforms supporting *Astrebla* spp. in Queensland are similar in profile despite diverse origins. While the surface horizon of the rolling downs is a self mulching clay (Everist 1964) the surface horizon on the Warrego River flood plain near Cunnamulla contains a relatively high proportion of fine sand (Allen personal communication). Beneath these horizons, each profile exhibits a zone of massive structured clay below which occurs a slight calcium accumulation, usually in the form of calcium sulphate. Surface cracks, 50–75 mm wide, extend downward in roughly polygonal columns almost to the bottom of the massive structured clay because these clays shrink when they dry. Gypsum is present at this depth and the heavier soil has less tendency to crack.

The soils of the rolling downs in Queensland may be subdivided on the presence or absence of surface pebbles derived from the breakdown of a silcrete cap which originally covered the old weathered Tertiary land surface (Everist 1964; Dawson personal communication). Red and brown clays are common where this stone or pebble cover occurs ("stony" or "pebbly downs"). These soils are weakly self mulching and the surface develops a crust. The soil cracks, but not as strongly as in the grey clays. Where the silcrete stone cover is absent ("ashy downs") brown clays with loose self mulching surfaces frequently occur (Dawson personal communication).

Available nitrogen is low (Perry 1962; Everist 1964); however, extended dry spells between and within seasons together with "Birch effect" nitrogen (Birch 1960) should ensure satisfactory levels for pasture growth. Potassium and calcium are both adequate while phosphorus is variable. Representative soil chemical analyses are presented in Table 2. Mineral nutrition is not considered to be the limiting factor in vegetative growth in the *Astrebla* spp. association (Everist 1964).

Climate

Astrebla spp. reach their best development between the 250 and 550 mm annual rainfall isohyets in regions with pronounced summer rains. Because of the high potential evaporation and low precipitation, plant growth is strongly influenced

TABLE 2

Soil analysis data for selected sites in the Astrebla *grasslands of Queensland (Hubble and Beckmann* 1957)

					%					%							Exchangeable cations (m.e. %)					
Profile	Depth (cm.) (approx.)	pH	Total sol. salts (%)	Chloride (% Na Cl)	$CaCO_3$	Organic carbon	N	C/N ratio	Available P_2O_5 (ppm)	Total P_2O_5	Gravel	Coarse sand	Fine sand	Silt	Clay	Exchange capacity	Ca	Mg	K	Na	H	Saturation (%)
B144*	0-10	8.0	0.05	0.01	0.02	0.44	0.051	9	529	0.167	2	1	16	18	63	58.0	43.0	11.1	1.95	0.90	1.1	98
	10-45	7.4	1.67	0.03						0.113	1	1	16	18	63							
	45-90	7.7	2.35	0.24	0.07					0.118	½	1	13	19	64	45.0	17.8	7.9	1.4	17.5	0.37	99
	90-115	7.8	4.67	0.49						0.081												
B146†	0-8	8.4	0.02	0.01	0.02	0.48	0.046	10	240	0.051	3	5	29	16	50	51.7	39.9	9.3	1.1	1.39		100
	8-45	9.0	0.07	0.02	0.14	0.42	0.041	10	240		½	5	28	14	50							
	45-71	9.2	0.11	0.02	0.36	0.44	0.042	10	344	0.062		4	27	16	52	49.5	32.8	8.2	0.54	7.96		100
	71-84	9.1	0.15	0.04	0.42	0.43	0.038	11	562			3	27	21	48							
	84-115	7.8	1.15	0.21	0.27		0.020		1492	0.177												

*Brown soil of heavy texture: sedentary, Winton—Cloncurry road approximately 32 km south of Kynuna.

†Brown soil of heavy texture: sedentary, 35 km north of Longreach on Winton road.

by water availability and the highest correlation of *Astrebla* spp. growth characteristics is with precipitation (Winders 1936).

The rainfall is extremely variable (Farmer, Everist and Moule 1947). Leeper (1960) has calculated a mean annual rainfall variability for western Queensland which is 10% greater than the "World standard variability". A co-efficient of variation of annual rainfall in the order of 30 to 40% has been quoted for the west Kimberley area of Western Australia (Speck, Fitzgerald and Perry 1964). Monthly rainfall during summer, expressed in terms of probability of obtaining specified amounts, becomes less reliable moving from northern *Astrebla* grasslands southwards (Alexander and Williams 1973). Consequently germination and establishment opportunities for *Astrebla* spp. would be expected to decline as one moves south. An investigation near Julia Creek indicates that germination and establishment of *Astrebla* spp. occurs in most years in that region (Williams personal communication). However, in observations carried out over a 20 year period near Cunnamulla (Roe 1962a) a high density of *Astrebla* seedlings was recorded only in one year (1941). Although heavy summer rainfall alone does not result in a high *Astrebla* seedling population (Roe 1962a), the unusually wet summer of 1940-41 at Cunnamulla was more characteristic of the more northern *Astrebla* grassland regions.

Mean monthly maximum temperatures exceed 35°C during mid summer over most *Astrebla* grasslands. The number of months during which the mean monthly maximum temperatures exceeds 35°C is greatest in the northern *Astrebla* grasslands and declines with increasingly higher latitudes. North of the Tropic of Capricorn frosts do not occur but the incidence of frost increases with higher latitudes so that at Cunnamulla in excess of 50 frosts occur each year (Farmer, Everist and Moule 1947; Fitzpatrick and Nix 1970).

Soil moisture relations

Information on soil moisture relationships under *Astrebla* grassland is meagre.

The self mulching soils supporting *Astrebla* grasslands have a low infiltration rate except at the commencement of the wet season when the soil surface is markedly cracked, but are capable of good moisture storage. Weston (1971) reports that after initial irrigation the infiltration rate fell to approximately 6 mm per hour. During the following 8 to 10 hours it decreased gradually until runoff occurred. However, infiltration rates with rainfall are generally higher than with irrigation and Williams (personal communication) recorded no run off following 250 mm rainfall during 2 months in 1974 on a Mitchell grassland soil near Cunnamulla. For a 90 cm Mitchell grassland soil profile near Tambo, moisture content at −0.1 bar and −15 bar was 53 and 28 cm respectively (Pressland personal communication). This represents 25 cm of available soil moisture for that profile. Allen (1963) reported that following 193 mm of rain over 6 days near Cunnamulla the moisture contents of the soil down to a depth of approximately 61 cm were extremely variable while below this depth soil moisture was unchanged. This supports the conclusion of Roe and Allen (1945) that the growth of *Astrebla* spp. depends on the current season's precipitation rather than on stored soil moisture. The effect of moisture stored from some previous rainfall on the initial *Astrebla* seedling build-up and their subsequent maintenance is not known.

GROWTH AND DEVELOPMENT OF SWARDS

Germination

A. lappacea seed exhibits post-harvest dormancy but reaches a maximum germination at 12 months (Table 3 (Myers 1942a)). Similar figures for all species of *Astrebla* at 6 and 12 months after harvest have been recorded by Silcock (personal communication). Germination response to temperature is similar for all four species;

TABLE 3

Effect of time after harvest on germination of Astrebla lappacea (*Myers* 1942)

Time after Harvest	1 Week	1 Month	12 Months	18 Months	24 Months
Germination %	26	41	88	80	84

germination occurs in a temperature range of 15°C to 42°C although little germination occurs below 22°C and above 38°C (Jozwik, Nicholls and Perry 1970). Everist (1951, 1963) maintains that a second rain 6 weeks after the germinating rain is necessary to enable tillers and secondary roots to develop, so ensuring successful establishment.

Growth

Although soil moisture is the major factor limiting the growth of the Mitchell grasses, winter temperatures greatly reduce the rate of growth. In controlled environment studies (Jozwik 1970) optimum tillering in *A. pectinata* occurred at 28/23°C while growth per tiller and leaf production increased with temperature up to 30/25°C.

A. lappacea displays different growth responses depending on the amount of rain. If rainfall events of only 40 mm (approximately) occur, fine rootlets, developed from the main roots, induce culm shoot production using stem stored starch and some stored starch from the rhizome. The main root system is stimulated by rainfall events in excess of 75 mm (approximately) and innovation shoots are produced using starch which is rapidly mobilized in the culms, roots and rhizomes and which is very rapidly exhausted (Everist 1964). A similar growth response has been recognized in *A. pectinata* (Jozwik, Nicholls and Perry 1970).

Carbohydrate reserves in the root stock are replenished during active growth. In a pot trial rapid internode elongation and broadening of leaf blades occurred after 40 days and was associated with a rapid build-up of soluble sugars. Rapid transformation of soluble sugars to starch occurred between 40 and 80 days after growth commenced (Haydon 1970). Under field conditions the duration of growth following rain is usually only 4 to 6 weeks, but a similar starch build-up occurs in *A. lappacea* as moisture stress develops (Whalley and Davidson 1968).

Regulation of growth by unidentified hormones has been postulated for *A. lappacea* (Whalley and Davidson 1969). Soil moisture present during otherwise favourable growth conditions induces a rise in the level of growth promoting substances and growth commences using hydrolysed starch. Exhaustion of soil moisture causes a rise in growth inhibitors and growth cessation accompanied by accumulation of starch.

Forage production and composition

The influence of rainfall on forage production is illustrated in Table 4. Peak forage production of the pasture usually occurs three months after the first effective

TABLE 4

Dry matter yields of Mitchell grass pastures at different sites

Yield (kg ha^{-1})	Rainfall (mm)	Growing Season*	Site	Source
400	163	Jan. - March	Brunette Downs, N.T.	Jozwik and Nicholls (1970)
2250	400+	Oct. - April	Elderslie, Winton, Q.	Davies, Scott and Kennedy (1938)
1350†	340+	Oct. - April	Gilruth Plains, Cunnamulla, Q.	Roe and Allen (1945)
2250	—	Dec. - April	Claverton, Wyandra, Q.	Ebersohn (1970)

+Approximate.

*As determined by rainfall.

†Represents highest forage yield during a continuous grazing treatment at 1 sheep/7.5 acres.

summer rain and growth has virtually ceased by April or early May (Murray and Purcell 1967). The effect of summer and winter rainfall on the various components of a Mitchell grass pasture near Winton demonstrates two distinct phases of development (Table 5). Summer rain produced a response mainly from both annual and perennial grass species e.g. *Dactyloctenium radulans* and *Astrebla* spp. respectively

TABLE 5

Relative contributions of components of a grazed Mitchell grass pasture to yield (Davies, Scott and Kennedy, 1938)

Sample Date	Rainfall* (mm)	Total Yield* (kg ha^{-1})	Botanical Constituents % Perennial Grasses	Annual Grasses	Misc. Herbs
22.x.35	19	163	33.59	2.67	63.74
19.xi.35	24	113	49.58	0.84	49.58
17.xii.35	8	86	42.99	1.41	55.60
21.i.36	111	34	92.59	—	7.41
18.ii.36	54	236	71.16	5.03	23.81
10.iii.36	121	1275	48.38	27.28	24.34
8.iv.36	103	2248	67.20	23.36	8.44
6.v.36	10	2089	63.98	30.21	5.81
2.vi.36	59	1895	70.13	19.54	10.33
30.vi.36	—	21.2	79.36	12.76	7.88
30.vii.36	7	1945	71.69	24.36	3.95
25.viii.36	4	1728	74.00	22.31	3.69
23.ix.36	—	1814	79.95	18.40	1.65

*Approximate.

with a smaller response from the miscellaneous herbs group, e.g. *Malvastrum spicatum*; winter rainfall produced a response from only the miscellaneous herbs, e.g. *Daucus glochidiatus.* The herbaceous species e.g. *Plantago varia* responded to winter rain at Cunnamulla and reached a peak contribution three months after rain (Roe and Allen 1945). Selective grazing by livestock steadily reduced the contribution by these species to the pasture.

Nutritive value

Mitchell grasses are valued not because of a high nutritive value, but because they remain a feed source when most other pasture plants have disappeared. Pure stands of Mitchell grass have little value for livestock fattening (Blake 1938).

Merino ewes grazing a Mitchell grass pasture near Julia Creek selected species such as *Boerhavia diffusa* and *Dactyloctenium radulans* when available (Weston and Moir 1969). As these species become scarce different portions of the different species of Mitchell grasses were selected. These conclusions have been confirmed by Lorimer (1974). Chemical analyses revealed that those parts selectively grazed had a crude protein content higher than that of whole samples of the same plants. Chemical composition of *Astrebla* spp. changes substantially with ageing of the plant material, denoting large changes in nutritive value (Table 6).

Conservation of Mitchell grass hay for drought feeding has been practised to a limited extent only. Although acceptable to sheep when first fed out, the animals' ability to select is reduced resulting in lower levels of dietary protein and reduced phosphorus in the forage consumed. Supplementation of this low quality conserved fodder is essential for maintenance of flock fertility (Marriott and Harvey 1951).

TABLE 6

Chemical composition of Astrebla *spp.*

Source	Species	Sample Description	Constituents as % D.M.										
			Moisture	Crude Protein	Carbohydrate	Crude Fibre	Ether Extract	Nitrogen-free Extract	Total Ash	Calcium (CaO)	Phosphorus (P_2O_5)	Chlorine (Cl)	Silica
Unpublished data, Agricultural Chemistry Branch, D.P.I., Qld.	*Astrebla* spp.	3-4 weeks old	—	18.4	38.9	28.1	—†	—	—	0.479	0.483	—	—
		Good quality	—	8.0	46.6	32.3	—	—	—	0.75	0.41	—	—
		Poor quality	—	2.6	51.7	33.5	—	—	—	0.66	0.30	—	—
Siebert, Newman and Nelson (1968)	*A. pectinata*	Partly dry	—	6.8	—	28.5	1.4	51.3	12.0	—	—	—	—
		Almost dry	—	5.3	—	26.2	1.4	58.3	8.8	—	—	—	—
		Completely dry	—	4.5	—	26.1	2.0	56.8	10.6	—	—	—	—
Beck and Underwood (1938)	*A. pectinata*	June 1933	7.81	3.5	—	29.9	0.5	54.0	12.6	0.24	0.23	0.20	10.4
		July 1933	8.56	4.4	—	28.8	0.5	51.0	14.5	0.25	0.23	0.20	10.3
		February 1934	8.79	8.9	—	30.2	0.2	48.1	12.6	0.36	0.27	0.73	9.5

†Not analysed for this constituent.

Progressive deterioration in nutritive value of Mitchell grass pastures generally occurs after April and continues until there is new growth (Davies, Scott and Kennedy 1938). Winter rain usually causes "blackening" of standing Mitchell grass pasture (Blake 1938) resulting in further deterioration in nutritive value.

Nitrogen and phosphorus supplementation of Merino ewes on an *Astrebla* grassland near Julia Creek had little beneficial influence on liveweight or wool production (Entwistle 1972). The only consistent effect of nitrogen was to increase wool production during the period October to December when pasture quality would have been lowest. Phosphorus supplementation actually depressed liveweight and wool production during October to December as well as reducing reproductive performance. Entwistle concluded that the seasonal pattern of wool growth largely reflected the pasture's response to rain.

Successional pattern

Attempts to define successional stages and ecological status of Mitchell grass communities have led to different conclusions. Blake (1938) described a condition of apparent relative stability but in reality a state of unstable equilibrium as a "fluctuating climax". Everist (personal communication) describes the botanical composition as "opportunistic"—the result of amount of rainfall and its distribution in time. Everist and Moule (1952) noted that along the eastern edge of the Mitchell grass country *Dichanthium sericeum* tends to replace *Astrebla* in years when the growing season is approximately 4 months and that the reverse occurs when the growing season is reduced to about 2 months. The original dominant under natural conditions at Bollon may have been *Dichanthium sericeum* and the present dominance of *Astrebla* spp. may have been brought about by the grazing animal (Holland and Moore 1962). Closer observation of the relation between *Astrebla* spp. and *Dichanthium sericeum* is necessary.

The relative effects of rainfall and grazing on succession and retrogression have yet to be elucidated. An attempt to describe stages of retrogression on heavily grazed areas around Longreach is represented in Figure 2 (Davidson 1954).

Near Cunnamulla *Dactyloctenium radulans* increased after very heavy grazing had reduced the *Astrebla* spp. population. Herbs such as *Abutilon malvifolium* and *Hibiscus trionum* also appeared and were regarded as indicative of deteriorating pasture (Roe and Allen 1945). Blake (1938) suggested the possibility of cyclic variation in soil salinity as an important factor in vegetation succession. Information on floristics is meagre.

UTILIZATION AND REACTION TO GRAZING

Normal use pattern

Mitchell grass pastures are used almost exclusively for continuous grazing by sheep and cattle. A rotational grazing system near Cunnamulla showed no advantage over continuous grazing during the three years the trial was operating (Roe and Allen 1945). In Western Australia, Northern Territory and northern Queensland, Mitchell grass pastures are used almost exclusively by cattle. In Queensland in March 1973, Mitchell grass pastures supported approximately 50% of the sheep population and 6% of the cattle population (Australian Bureau of Statistics 1973).

Stand dynamics

Depleted soil moisture may be manifest in the size and number of individual tufts (Winders 1936). Good summer rain near Cunnamulla following a severe drought produced a forage yield to which Mitchell grasses contributed only 7.9% (Roe 1941). The adverse season was reflected in the low number of young plants and by the mortality of mature plants. Since droughts are a normal part of the climate of

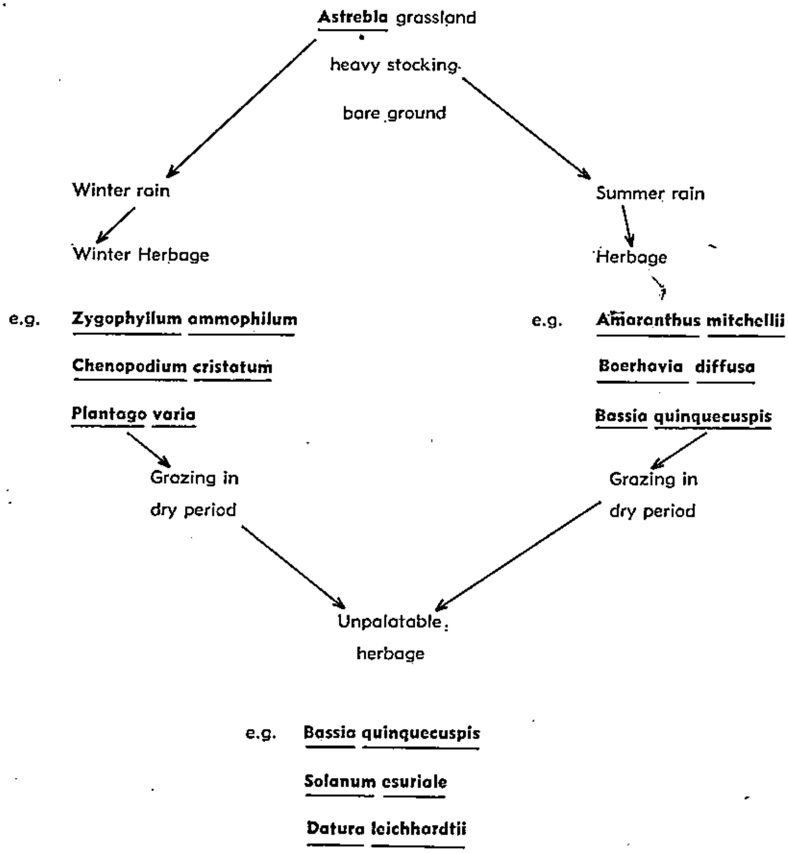

FIGURE 2

Stages of retrogression on heavily grazed areas around Longreach (Davidson, 1954).

Astrebla grasslands in Queensland (Everist and Moule 1952), seasonal fluctuation of *Astrebla spp.* is to be expected particularly in prolonged low annual rainfall periods.

Reduction in the proportion of Mitchell grasses in Mitchell grass pastures can be attributed to the following grazing factors:

i) Removal of seedlings by gross overstocking (Everist, personal communication).

ii) Excessive grazing during active growth (Roe and Allen 1945) Everist (1958, 1963, 1964).

iii) Grazing dormant plants close to ground level (Weston unpublished).

iv) Burrowing for roots (Hirschfeld and Hirschfeld 1936, Roe and Allen 1945).

By selective grazing of seedheads and pawing up the tussocks, horses are capable of destroying Mitchell grass pastures (Francis 1935). With the present trend towards replacement of sheep by cattle in western Queensland further information on dietary habits of cattle is necessary. The effect of kangaroo populations which have undoubtably increased following the development of artesian water supplies, also warrants study. The recent use of non-protein nitrogen supplementation, which has permitted grazing animals to ingest plant stem that may not have been otherwise accepted, poses an added threat to the stability of *Astrebla* grasslands.

Whilst it has been convenient to discuss separately the effects of rainfall and of grazing, it is difficult in practice to distinguish between the two (Davidson 1954). Where reduction in Mitchell grass could be measured, it is difficult to single out one factor or the other because of fluctuations in seasonal conditions (Roe and Allen 1945). However, Everist (personal communication) is of the opinion that fluctuation in *Astrebla* spp. in the pasture attributable to seasonal rainfall conditions far outweighs the effects of normal grazing management. Extremes in management may have an immediate impact on the grassland but the long-term effect is far less easy to predict.

In experiments the stocking rate can be varied on a seasonal basis; this is impractical in the pastoral industry. Inevitably normal stocking rates established at the beginning of a below average season constitute overgrazing as the season continues to deteriorate, unless stock numbers can be reduced. However, it would be impossible to attribute with certainty a resulting reduction of Mitchell grasses to either reduction in rainfall or to over-grazing alone. Very heavy stocking during a prolonged series of dry seasons appears to cause deterioration of the stand (Francis 1935; Roe and Allen 1945). When seasonal conditions again become favourable recovery is usually rapid (Everist 1935, 1963).

Following the break of a prolonged drought in the Charleville area Francis reported that where Mitchell grasses had not been overstocked they seemed to be as good as they ever had been (Everist 1935). Following the 1940 drought good rain near Cunnamulla produced numerous *Astrebla* seedlings (Roe 1941). This reinforces Francis' (1935) report that it is very desirable where possible to allow *Astrebla* spp. to seed freely. One factor aiding the regeneration of *Astrebla* spp. following drought is the reduced level of livestock numbers so that trampling damage to all plants is lessened and plants are better able to complete their growth while soil moisture is available.

Under-utilization can also be deleterious to the vegetation as it permits the development of weeds e.g. *Salsola kali* (Roe 1962b) and accumulation of old plant material (Winders 1936) and can lead to death of Mitchell grass tussocks (Everist 1964). On the ashy downs the continual trampling by livestock compacts the soil tending to increase moisture storage (Blake 1938).

Artificial reseeding of Mitchell grasses into Mitchell grasslands has proved unsuccessful and the practice has been discontinued (Everist personal communication). One suggestion for poor field germination is the large variation in the number of caryopses per spikelet in commercial seed (Myers 1942b). Successful natural spread of Mitchell grass has been reported by Hirschfeld and Hirschfeld (1936).

GENERAL

Carrying capacity figures for Mitchell grassland (Roe and Allen 1945; Davidson 1954; Weston 1963; Christian, *et al.* 1954; Everist 1963), can only be regarded as a guide because of the inherent variability of rainfall. Hence one of the most important factors in *Astrebla* grassland management is to attain flexibility in livestock numbers and movement.

Burning of Mitchell grass pastures is unnecessary and undesirable in most years. However, during excessively wet years Mitchell grasses grow so vigorously as to exclude ephemerals from between the tussocks. An accidental burn in March on a pasture in such condition near Longreach was followed rapidly by Mitchell grass regrowth from tussocks and growth of herbage in the interstices. An inspection some years later revealed no difference in botanical composition or vigour of the pastures in the burnt and an unburnt paddock (Everist personal communication). A fire treatment followed by five years of below average rainfall near Blackall caused no difference in the *Astrebla* spp. population (Purcell and Lee 1970). However, heavy yielding Mitchell grass pastures near Julia Creek tended to contain more *Aristida latifolia* after burning (Weston 1963).

While "pedestalling" of old tussocks has been observed by the author on badly degraded pasture, Perry (1970) considers most landscapes carrying *Astrebla* grasslands are not erodable. However, Everist (unpublished) maintains that a certain amount of sheet erosion passes unnoticed.

CONCLUSION

Astrebla grasslands, because of their greater livestock carrying capacity when compared with other arid pastures under comparable rainfall, are of considerable importance to the pastoral industry in Queensland and the Northern Territory. Species of *Astrebla* are well adapted to the harsh climatic environment and exhibit a remarkable ability to respond to rainfall, even after protracted dry periods. The ability to do this in the presence of grazing animals is one of the factors contributing to the relatively stable nature of the grassland.

Because of the importance to livestock production of the species associated with *Astrebla* spp., future research should aim at a greater understanding of these associated species. An understanding of the optimum balance between *Astrebla* spp. and the associated species is necessary for long term stable production from *Astrebla* grasslands.

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