A REVIEW OF CARPET GRASS (*AXONOPUS AFFINIS*) IN RELATION TO THE IMPROVEMENT OF CARPET GRASS BASED PASTURE

R. J. MARTIN*

ABSTRACT

The botany, origin, distribution and climatic requirements of carpet grass are described. Factors affecting growth, seasonal production, botanical composition, chemical composition and animal production are discussed. Emphasis is given to management and ecological factors governing competition between carpet grass and other pasture species. It is concluded that research emphasis should be placed on determining the optimum levels of soil fertility and grazing pressure required to suppress carpet grass and to favour growth of more productive existing or introduced pasture species in the absence of mechanical or chemical renovation.

INTRODUCTION

Carpet grass has become naturalized in humid subtropical regions of Queensland and New South Wales. Its invasion of degenerate paspalum (*Paspalum dilatatum*)—white clover (*Trifolium repens*) and kikuyu (*Pennisetum clandestinum*) pastures has been coincident with a decline in animal production (McLennan 1936; Crofts and Jenkins 1957; Kelly 1962; White 1967; Gartner 1969; Cassidy 1971).

The purpose of this review is to assess critically the value of carpet grass as a pasture plant in terms of growth, seasonal production, chemical composition and animal production. Emphasis has been given to defining the ecological factors governing competition between carpet grass and other pasture species.

BOTANICAL DESCRIPTION

Carpet grass was originally identified as *Axonopus compressus* (Swartz) Beauv., a species which included a broad and narrow leaf form. The distinction between the two types was made by Agnes Chase (1938) who recognized *A. affinis*, the narrow leaf form, as a distinct species. In West Africa, Gledhill (1965) described a polyploid series of *Axonopus* spp. of which *A. compressus* (2n=40) was a member. Gledhill (1966) suggested that *A. affinis*, an octaploid functioning as a diploid (2n = 80) might be a further member of this series. Its rapid colonizing ability suggests that the polyploid condition has been accompanied by increased vigour compared to other *Axonopus* species (Gledhill 1966).

The standardized common name of *A. affinis* is narrow-leaf carpet grass. It is more commonly known as mat grass in Queensland and compressum or Durrington grass in New South Wales.

A. affinis has been described on numerous occasions (Chase 1938; Hitchcock 1950; Vickery 1961; Black 1963; Burbidge 1966). It is a glabrous summer growing perennial, 25 to 75 cm high, having short rhizomes and slender to moderately stout arching stolons with short internodes. The grass often forms a dense mat. Leaf blades are 5 to 20 cm long, 2 to 6 mm wide, flat or folded with a rounded or obtuse apex. The inflorescence consists of 2 to 3 slender, sessile, erect spikes, the upper pair approximate and the third a little remote. The spikes are straight and the rhachis is 0.5 to 0.75 mm wide. The spikelets, each 2 mm long, are arranged in 2 neat rows. The fertile floret almost equals the spikelet in length and is white to pale yellow in colour.

---

*Department of Agriculture, Wollongbar Agricultural Research Centre, New South Wales.

ORIGIN AND DISTRIBUTION

The centre of origin of the genus *Axonopus* is in eastern and central Brazil, and northern Paraguay (Black 1963). However, the centre of origin of the species, *A. affinis*, is disputed. Chase (1938) maintained that *A. affinis* is native to the south-eastern United States, the centre of distribution being from Florida to Louisiana. Other authorities (Piper and Carrier 1920; Burton 1951) claim the species is native to the West Indies and Central America.

Carpet grass is now found in tropical and subtropical regions of America, Africa, Asia, Australia and the Pacific Islands (Black 1963). It is used for permanent pasture in Florida, West Indies, Fiji, Malaysia, British Guiana and Hawaii (McIlroy 1964).

CLIMATIC LIMITATIONS

Carpet grass is adapted to humid tropical and subtropical climates, especially on moist sandy soils but does not tolerate prolonged flooding or permanent swampy conditions (Piper and Carrier 1920; Hoover *et al.* 1948; Whyte, Moir and Cooper 1962). It is sensitive to drought conditions. On sandy soil carpet grass was more drought susceptible than paspalum and coastal Bermuda grass (*Cynodon dactylon*) (Burton, De Vane and Carter 1954).

Both temperature and daylength influence growth of carpet grass. Two temperatures, 16–21°C and 27–32°C, and two daylengths, 10 and 15 hours were tested for effect on growth of tops and roots of carpet grass. The high temperature and long day environment was the most favourable for growth of tops. Root growth was reduced by low temperature, but was unaffected by daylength (Lovvorn 1945).

Knight and Bennett (1953) studied flowering in several grasses, including carpet grass, under controlled daylengths of 8, 10.5, 12, 14 and 16 hours per day. Some flowering occurred in carpet grass under all daylengths, but the greatest weight of seed and the highest percentage of florets containing caryopses was recorded under 12 and 14 hour daylengths. Temperatures below 12.8°C inhibited flowering and low night temperatures had a similar effect to short days on the vegetative appearance of carpet grass.

GROWTH

Response to fertilizer

Yields of carpet grass grown in pure stands are presented in Table 1. Carpet grass does not respond to P or K in the absence of applied N. The response to N is greater in the presence of P and K. The addition of lime to a complete fertilizer mixture does not generally increase yield but responses have occurred (Blaser and Stokes 1942). Carpet grass, growing on fine sand in Florida did not respond to the trace elements Zn, B, Cu, Mn, or Fe (Blaser and Stokes 1943).

Although carpet grass responds to N the efficiency of response is low compared to other pasture species. Efficiency of response to N calculated from Lovvorn's (1944) data was 17 kg D.M. kg^{-1} N applied compared to 22 kg D.M. kg^{-1} N applied for paspalum. Similarly carpet grass yielded 5040 kg D.M. ha^{-1} compared to 14,235 kg D.M. ha^{-1} for pangola grass (*Digitaria decumbens*) when grown under the same conditions (Kretschmer, Hayslip and Hortenstine 1961).

In addition to low total yield, carpet grass has a short growing season. It was found to be inferior to Bermuda grass and pangola grass due to poor winter and early spring growth (Kretschmer, Hayslip and Hortenstine 1961). Early season growth can be increased by early spring application of N (Blaser and Stokes 1943). The most desirable yield curve was obtained when all the N was applied in March (spring) or March and June (summer). Smaller yields and less early feed resulted from late season applications.

TABLE 1

Yield of carpet grass

Location	Fertilizer	Dry matter yield (kg ha^{-1} year^{-1})	Comments
Florida (Blaser *et al.* 1945)	—	1770	81 kg N applied annually. P, K and lime applied at commencement.
	N	2900	
	N P K	3520	
	N P K lime	3280	
Florida (Kretschmer, Hayslip and Hortenstine 1961)	N P K	5040	370 kg N applied annually in 8 dressings.
Georgia (Lovvorn 1944)	—	819	Previously fertilized. 56 kg N applied annually.
	P	829	
	P K	812	
	N P K	1898	
	P K lime	768	
	N P K lime	1776	
Georgia (Burton, De Vane and Carter 1954)	N P K	5197	224 kg N applied annually.

Frequency and height of defoliation

Under glasshouse conditions the yield of both tops and roots of carpet grass was reduced by frequent defoliation (Lovvorn 1945), but the effect was greater for paspalum and Bermuda grass and more pronounced under high soil fertility and temperature conditions. Frequent defoliation did not reduce the yield of carpet grass in field studies, but as cutting height was increased carpet grass yield was reduced (Blaser 1946).

Root growth

Lovvorn (1945) found that carpet grass root yield was not influenced by soil fertility while root yield of paspalum responded to fertilization. Under field conditions, Burton (1943) found that although roots of all species invaded to a similar depth, the yield of paspalum roots (22.08 g) was almost twice that of carpet grass (13.67 g) per 645 cm^2 of sod. 91% of carpet grass roots occurred in the 0–20 cm layer compared to 61% for paspalum. Similarly, Burton, De Vane and Carter (1954) found that 93.6% of carpet grass roots occurred in the upper 0.5 m of soil compared to 65.1% for coastal Bermuda grass. Lack of root response to fertilizer, poor root yield and distribution suit carpet grass to infertile, moist sandy soils, although it occurs on a wide range of soil types in Australia.

MANAGEMENT

Fertilizer on grass

In North Carolina, Lovvorn (1944) studied the effect of fertilizer treatment on carpet grass invasion of a sown paspalum sward. Fertilizer treatments were nil; P, K lime; and N, P, K, lime. Carpet grass replaced paspalum most rapidly where no fertilizer was applied, P, K and lime reduced the rate of change slightly while application of 56 kg N ha^{-1} year^{-1} in addition to P, K and lime greatly reduced the rate of invasion by carpet grass but did not cause a reversion to paspalum dominance.

In a kikuyu-paspalum-carpet grass pasture on the Atherton Tableland, Gartner (1969) found that urea applied at the rate of 168 kg N ha^{-1} year^{-1} for 3 years was necessary to cause a reversion to kikuyu and paspalum dominance while more than 224 kg N ha^{-1} year^{-1} was required to develop kikuyu dominance. Carpet grass was virtually eliminated after 1 year from swards fertilized with 224 and 448 kg N ha^{-1} $year^{-1}$. The paspalum content of the sward increased to a peak at 224 kg N ha^{-1} $year^{-1}$ but declined with higher levels of applied N due to competition by kikuyu. Mears (1973) obtained similar results at Wollongbar, N.S.W. with application of N on grazed kikuyu-paspalum-carpet grass pasture. Application of N equal to or exceeding 336 kg N ha^{-1} $year^{-1}$ resulted in rapid dominance of kikuyu. Low rates of N in combination with adequate basal nutrients caused a more gradual change. It would be useful to know what maintenance levels would be required to prevent re-invasion of paspalum-kikuyu swards by carpet grass.

At Caboolture in south-eastern Queensland, Cassidy (1971) found that the percentage ground cover of carpet grass, in a carpet grass-paspalum sward, was not altered by the application of calcium ammonium nitrate at 224 kg ha^{-1} $year^{-1}$ for 2 years, even though the yield of paspalum was greatly increased by fertilizer application.

Grazing intensity and frequency of defoliation

In the south-eastern United States carpet grass invades native range wherever it has been closely grazed (Burton 1951; Peevy 1953; Halls *et al.* 1964). Native range consists largely of species of *Andropogon*, *Aristida*, *Panicum* and *Paspalum* all of which have an erect growth habit and do not tolerate close grazing. Similarly in humid subtropical areas of north-eastern Australia the invasion of paspalum-white clover pasture by carpet grass has partly been attributed to overgrazing (Waring 1957; Goodchild 1960).

Duval and Linnartz (1967) recorded botanical changes in range in central Louisiana under heavy (67% utilization), moderate (46% utilization) and nil grazing over a 12 year period. Carpet grass disappeared from ungrazed range. Under moderate grazing it increased from 0.4% to 6.3% and under heavy grazing it increased from 0.6% to 38.5% of the range. Similar results were obtained by varying cutting frequency (Wolters 1972). Carpet grass competed successfully with native grasses when clipped at 2, 4 and 8 week intervals, but diminished significantly with less frequent cutting.

The effect of harvest frequency on competition between carpet grass and paspalum was studied by Lovvorn (1944) in North Carolina. Harvesting every 2 weeks was most favourable to carpet grass while omitting either spring or autumn harvests was most favourable to paspalum. Under more fertile conditions, on a krasnozem soil at Wollongbar N.S.W., the proportion of paspalum, kikuyu and carpet grass was independent of stocking rate over a 3 year period (Mears 1973). Frequency of defoliation together with soil fertility must be considered when interpreting botanical changes involving carpet grass and associated pasture species.

Sown legumes

From the previous sections it is evident that carpet grass is favoured by low soil fertility and frequent defoliation. Woodhouse and Blaser (1948) stated that these two factors were involved in competition between carpet grass and paspalum and in the maintenance of paspalum-clover pastures. The frequency of defoliation required to encourage paspalum tends to exclude clover which, in turn, lowers the soil N level and consequently favours carpet grass invasion. Paspalum-clover pastures also soon revert to carpet grass if the fertilization programme is discontinued (Burton 1951). Fertility level and frequency of defoliation govern the effect of oversown legumes on competition between carpet grass and other grasses.

Blaser *et al.* (1948) showed that fertilizing and oversowing white clover into carpet grass pasture produced a more favourable botanical change than did oversowing lespedeza or topdressing with a complete fertilizer containing 34 kg N ha^{-1} $year^{-1}$. Oversown white clover resulted in a large increase in the cover of Bermuda grass while the other treatments were invaded by the less productive centipede grass (*Eremochloa ophuiroides*). In North Carolina, Lovvorn (1944) found that the presence of a legume reduced the rate of encroachment by carpet grass into a sown paspalum sward. The general trend was still towards dominance by carpet grass. In Queensland, Bryan (1967) described the effect of fertilizing and oversowing, on the botanical composition of paspalum-carpet grass pasture, with a mixture of Louisiana and Ladino white clovers. After 14 months there was a considerable increase in the cover of clover, half attributed to fertilization and half to oversowing. Most of the increase in clover was at the expense of paspalum. The grazing pressure on this experiment of 62 cows ha^{-1} one day every 2 weeks may have favoured carpet grass.

The above studies indicate that legumes, if managed correctly, can be used to manipulate the botanical composition of carpet grass based swards in favour of more productive grass species. This approach warrants further investigation under Australian conditions.

Chemical and mechanical renovation

Where improved pastures such as paspalum-white clover have been invaded by carpet grass, renovation has often been recommended to break up the dense mat of carpet grass and provide more favourable conditions for improved grasses and legumes. Renovation techniques range from simple procedures such as chemical treatment or ripping to complete land preparation and cropping for 3–4 years before sowing the pasture (Bledsoe and Sell 1940; Woodhouse and Lovvorn 1942; Goodchild 1960; Vane 1960; Kelly 1962; Whittet 1968).

In Alabama, Searcy and Patterson (1961) showed that 2,2–DPA at 4.8 kg ha^{-1} was as good as complete land preparation for renovation and establishment of white clover, provided the grain drills cut through the sod and allowed contact of seed with the soil.

In most cases fertilizer treatment, particularly N, and careful grazing management have been recommended to follow renovation. On the Atherton Tableland, Kelly (1962) found that renovation with a tyned implement gave a temporary build-up of soil N, but carpet grass was not controlled. Annual fertilization and light stocking in combination with renovation was found necessary to encourage better pasture species. This is not surprising as renovation would be expected to have a transitory effect on the underlying ecological factors such as soil fertility and grazing management, which determine the balance between carpet grass and other species in the pasture.

CHEMICAL COMPOSITION

As would be expected the nutritive value of carpet grass depends on the availability of soil nutrients and the stage of maturity. Values for N, P, K, Ca and Mg (Table 2) indicate the levels commonly found in carpet grass under a range of soil and climatic conditions.

In Florida, Blaser and Stokes (1942) varied the P, K and Ca content of carpet grass considerably by fertilization, without affecting growth. Magnesium was highly variable and unaffected by application of dolomitic limestone.

Unfortunately few experimental comparisons have been made between the nutritive value of carpet grass and other species. At Wollongbar, N.S.W., Mears (personal communication) showed the N, P and K content of carpet grass to be lower than paspalum and kikuyu in spring. The Ca and Mg contents for the 3 species were similar.

Seasonal fluctuations in the N content of carpet grass are influenced by temperature, rainfall and stage of maturity. In the south-eastern United States the N content is high in spring and low in summer and autumn. Periods of low rainfall, as in late spring, lower the N content (Leukel, Camp and Coleman 1934; Ritchey and Henley

TABLE 2

Chemical composition of carpet grass

	% of Dry Matter as					Fertilizer	Regrowth	Comments
	N	P	K	Ca	Mg			
Florida (Blaser and Stokes 1942)	1.87	0.13	0.64	0.36	—		3 weeks	
	1.92	0.11	0.87	0.25	—	N K lime		
	1.91	0.17	0.40	0.40	—	N P lime		
	1.91	0.16	0.68	0.40	—	N P K		
	1.90	0.23	0.79	0.57	—	N P K lime		
Florida (Blaser and Stokes 1943)	1.85-1.87	0.13-0.20	0.04-1.40	0.36-0.50	0.16-0.16			Four year average
	1.84-1.91	0.21-0.26	0.79-1.56	0.57-0.69	0.10-0.18	N P K lime		on 3 soils
Louisiana (Campbell *et al.* 1954)	2.09	0.14	—	0.26	—	—		Young leaf
	1.72	0.11	—	0.27	—	—		Full leaf
Hawaii (Younge and Otagaki 1958)	1.04	0.04	—	0.19	—	—	8 weeks	Minimum level
	0.91	0.16	—	0.40	—	P K		recorded
New South Wales (Mears pers. comm.)	1.62	0.21	1.21	0.40	0.20	P K	—	Hand plucks—
	1.89	0.21	1.15	0.39	0.21	N P K		134 kg N ha^{-1}
	2.28	0.24	1.46	0.38	0.24	N P K		336 kg N ha^{-1}
	2.60	0.24	1.01	0.26	0.24	N P K		672 kg N ha^{-1}

1936; Blaser and Stokes 1943). The N content of carpet grass is increased by frequent and close cutting or by maintaining it in a vegetative state (Leukel, Camp and Coleman 1934; Blaser 1946). It increases in autumn after flowering (Ritchey and Henley 1936) and when cold weather limits growth (Kretschmer, Hayslip and Hortenstine 1961).

Blaser and Stokes (1942) induced P deficiency symptoms in carpet grass by omitting P from a complete fertilizer mixture, which lowered the P content from 0.23 to 0.11%. Levels of P as low as 0.039% have been recorded under high rainfall conditions in the D vegetation zone of Hawaii (Younge and Otagaki 1958).

Carpet grass showed deficiency symptoms at 0.4% K, induced by omitting K from a complete fertilizer mixture (Blaser and Stokes 1942).

The nutrient content of carpet grass has not been assessed in terms of animal requirements and few comparisons with other species have been made. Such knowledge would be useful for determining the relative importance of nutritive value, growth and seasonal production of carpet grass for animal production.

ANIMAL PRODUCTION

Animal production studies on carpet grass have been rare. Table 3 is representative of liveweight gains from carpet grass and carpet grass-legume pastures.

In Florida the grazing season on carpet grass extends from mid April to late October or early November. Animals are generally removed when liveweight begins to fall or when pasture growth ceases (Ritchey and Henley 1936, Blaser *et al.* 1948). In Queensland animals remain on carpet grass pasture throughout the year and liveweight losses may occur during the winter (Chester, Marriott and Harvey 1957). The grazing season has been extended and liveweight gains hectare^{-1} greatly increased when white clover or lespedeza has been established in carpet grass pasture (Blaser *et al.* 1948; Hodges, Jones and Kirk 1953).

Animal liveweight gains from carpet grass are low compared to other pasture species (Ritchey and Henley 1936; Hodges, Jones and Kirk 1958). Hodges, Jones and Kirk (1958) reported results from a central Florida grazing experiment which showed carpet grass liveweight gains to be inferior to Pensacola Bahia (*Paspalum notatum*), Argentine Bahia, coastal Bermuda and pangola pastures. Annual beef liveweight gains for carpet grass and pangola grass, fertilized with 1008 kg 9:6:6 ha^{-1} year^{-1} were 185 and 379 kg ha^{-1} respectively.

CONCLUSION

The limited data available suggest that the growth response of carpet grass to temperature is typical of the Panicoid grasses, but it is atypical in its tendency to require long days for flowering.

Carpet grass is characterized by low dry matter yield and response to fertilizer, short growing season, poor root development, inferior chemical quality and low animal production. Its ability to tolerate low fertility and overgrazing enables it to invade poorly managed pastures.

Having defined carpet grass as a relatively undesirable pasture plant, it remains to be determined how the botanical composition of carpet grass based pastures can be altered in favour of more desirable pasture species. The literature suggests that carpet grass can be displaced by more desirable species by increasing the soil fertility, including the use of fertilizer N or with legume fixed N, and by reducing the grazing pressure, without the aid of mechanical or chemical renovation. Research emphasis should be placed on determining the optimum levels of these factors required to favour suppression of carpet grass and growth of more productive pasture species.

TABLE 3

Liveweight gains from carpet grass and carpet grass-legume pastures

Location	Species	L.W. gain (kg ha^{-1} $year^{-1}$)	Fertilizer	Comments
Georgia (Stephens 1942)	Carpet grass, lespedeza	92	Unfertilized	Very little lespedeza present. Animal numbers kept constant where possible. Ten year average.
Florida (Ritchey and Henley 1936)	Carpet grass	154	56 kg nitrate of soda ha^{-1} $year^{-1}$	Animals had access to common salt and bonemeal, removed from pasture during winter. Five year average. Irrigated.
Florida (Blaser *et al.* 1948)	Carpet grass	84	Unfertilized	Grazed to maintain maximum growth rate of grass. Grazed only during growing season. Four year average.
	Carpet grass	166	N P K lime	
	Carpet grass, lespedeza	245	P K lime	
	Carpet grass, white clover	693	P K lime	
Florida (Hodges, Jones and Kirk 1953)	Carpet grass	78	N P K lime	Animals removed when weight gain ceased. Nine year average.
	Carpet grass, white clover	277	P K lime	
Florida (Hodges, Jones and Kirk 1958)	Carpet grass	68	560 kg 6:6:6 ha^{-1} $year^{-1}$	
	Carpet grass	185	1008 kg 9:6:6 ha^{-1} $year^{-1}$	
Queensland (Chester, Marriott and Harvey 1957)	Carpet grass	98	Unfertilized	Calculated from mean daily liveweight gain.
	Carpet grass, white clover	124	P Cu lime	

REFERENCES

BLACK, G. A. (1963)—Grasses of the genus *Axonopus*, a taxonomic treatment. *Advancing frontiers of plant sciences*. **5**: 1-186.

BLASER, R. E. (1946)—The effect of cutting methods and sod treatments on the yield and protein content of carpet grass, *Axonopus affinis* Chase. *Journal of the American Society of Agronomy*. **38**: 394-397.

BLASER, R. E., GLASCOCK, R. S., KILLINGER, G. B., and STOKES, W. E. (1948)—Carpet grass and legume pastures in Florida. University of Florida Agricultural Experiment Station Bulletin 453.

BLASER, R. E., and STOKES, W. E. (1942)—The chemical composition, growth, and certain deficiency symptoms of carpet grass, *Axonopus affinis*, as affected by lime and fertilizer mixtures. *Journal of the American Society of Agronomy*. **34**: 765-768.

BLASER, R. E., and STOKES, W. E. (1943)—Effect of fertilizer on growth and composition of carpet and other grasses. University of Florida Agricultural Experiment Station Technical Bulletin 390.

BLASER, R. E., STOKES, W. E., WARNER, J. D., RITCHEY, G. E., and KILLINGER, G. B. (1945)—Pastures for Florida. University of Florida Agricultural Experiment Station Bulletin 409.

BLEDSOE, R. P., and SELL, O. E. (1940)—Permanent Pastures. Georgia Experiment Station Bulletin 207.

BRYAN, W. W. (1967)—Botanical changes following application of fertilizer and seed to run-down paspalum, kikuyu and mat grass pastures on a scrub soil at Maleny, south-east Queensland. *Tropical Grasslands*. **1**: 167-170.

BURBIDGE, N. T. (1966)—"Australian Grasses 1". (Angus and Robertson, Sydney).

BURTON, G. W. (1943)—A comparison of the first year's root production of seven southern grasses established from seed. *Journal of the American Society of Agronomy*. **35**: 192-196.

BURTON, G. W. (1951)—Adaptability and breeding of suitable grasses for the south-eastern states. *Advances in Agronomy*. **3**: 197-241.

BURTON, G. W., DE VANE, E. H., and CARTER, R. L. (1954)—Root penetration, distribution and activity in southern grasses measured by yields, drought symptoms and P^{32} uptake. *Agronomy Journal*. **46**: 229-233.

CAMPBELL, R. S., EPPS, E. A., MORELAND, C. C., FARR, J. L., and BONNER, F. (1954)—Nutritive values of native plants on forest range in central Louisiana. Louisiana Agricultural Experiment Station Bulletin 488.

CASSIDY, G. J. (1971)—Response of a mat grass—paspalum sward to fertilizer application. *Tropical Grasslands*. **5**: 11-22.

CHASE, A. (1938)—The carpet grasses. *Journal of the Washington Academy of Sciences*. **28**: 178-182.

CHESTER, R. D., MARRIOTT, S., and HARVEY, J. M. (1957)—Observations on top-dressing a copper-deficient pasture in south-eastern Queensland. *Queensland Journal of Agricultural Science*. **14**: 1-22.

CROFTS, F. C., and JENKINS, H. V. (1957)—Defining and subdividing the red soil problem. In "Seven years pasture research on the far north coast of New South Wales". University of Sydney School of Agriculture Report No. 2.

DUVAL, V. L., and LINNARTZ, N. E. (1967)—Influences of grazing and fire on vegetation and soil of longleaf pine—bluestem range. *Journal of Range Management*. **20**: 241-247.

GAMMON, N. (1953)—Sodium and potassium requirements of Pangola and other pasture grasses. *Soil Science*. **76**: 81-90.

GARTNER, J. A. (1969)—Effect of fertilizer nitrogen on a dense sward of kikuyu, paspalum and carpet grass. 1. Botanical composition, growth and nitrogen uptake. *Queensland Journal of Agricultural and Animal Sciences.* **26**: 21-33.

GLEDHILL, D. (1965)—Carpet grasses (*Axonopus* spp.) in West Africa. Proceedings of the IX International Grassland Congress, Sao Paulo, Brazil 1965. 469-470.

GLEDHILL, D. (1966)—Cytotaxonomic revision of the *Axonopus compressus* (SW.) Beauv. complex. *Boletim Da Sociedade Broteriana.* **40**: 125-147.

GOODCHILD, N. E. (1960)—Beat mat grass with pasture renovation. *Queensland Agricultural Journal.* **86**: 529-530.

HALLS, L. K., HUGHES, R. H., RUMMEL, R. S., and SOUTHWELL, B. L. (1964)—Forage and cattle management in longleaf-slash pine forests. United States Department of Agriculture Farmers Bulletin 2199.

HITCHCOCK, A. S. (1950)—"Manual of the grasses of the United States." (U.S. Government Printer: Washington.)

HODGES, E. M., JONES, D. W., and KIRK, W. G. (1953)—Winter clovers in central Florida. University of Florida Agricultural Experiment Station Bulletin 517.

HODGES, E. M., JONES, D. W., and KIRK, W. G. (1957)—Grass pastures in central Florida. University of Florida Agricultural Experiment Station Bulletin 484A.

HOOVER, M. M., HEIN, M. A., DAYTON, W. A., and ERLANSON, C. O. (1948)—The main grasses for farm and home. In "Grass, the Yearbook of Agriculture". (United States Government Printing Office; Washington).

KELLY, T. K. (1962)—Results from replanting pasture. *Queensland Agricultural Journal.* **88**: 8-11.

KNIGHT, W. E., and BENNETT, H. W. (1953)—Preliminary report of the effect of photoperiod and temperature on the flowering and growth of several southern grasses. *Agronomy Journal.* **45**: 268-269.

KRETSCHMER, A. E., HAYSLIP, N. C., and HORTENSTINE, C. C. (1961)—One year's results comparing yield and quality of six grasses grown alone and with white clover in south Florida. *Soil and Crop Science Society of Florida Proceedings.* **21**: 120-128.

LEUKEL, W. A., CAMP, J. P., and COLEMAN, J. M. (1934)—Effect of frequent cutting and nitrate fertilization on the growth behaviour and relative composition of pasture grasses. University of Florida Agricultural Experiment Station Bulletin 269.

LOVVORN, R. L. (1944)—The effects of fertilization, species competition, and cutting treatments on the behaviour of Dallis grass, *Paspalum dilatatum* Poir., and carpet grass, *Axonopus affinis* Chase. *Journal of the American Society of Agronomy.* **36**: 590-600.

LOVVORN, R. L. (1945)—The effect of defoliation, soil fertility, temperature, and length of day on the growth of some perennial grasses. *Journal of the American Society of Agronomy.* **37**: 570-582.

MCILROY, R. J. (1964)—"An introduction to tropical grassland husbandry" (Oxford University Press; London).

MCLENNAN, L. W. (1936)—Carpet grass. Has it a place in north coast pastures? *Agricultural Gazette of New South Wales.* **47**: 555-558, 601-603.

MEARS, P. T. (1973)—Effect of stocking rate on the nitrogen response characteristics of kikuyu (*Pennisetum clandestinum*) pasture. Ph.D. Thesis. University of Queensland.

PEEVY, F. A. (1953)—Fertilizing and seeding forage on forest range in Louisiana. *Agronomy Journal.* **45**: 164-166.

PIPER, C. V., and CARRIER, L. (1920)—Carpet grass. United States Department of Agriculture Farmer's Bulletin 1130.

RITCHEY, G. E., and HENLEY, W. W. (1936)—Pasture value of different grasses alone and in mixture. University of Florida Agricultural Experiment Station Bulletin 289.

SEARCY, V. S., and PATTERSON, R. M. (1961)—Renovating carpet grass pasture with herbicides and tillage. Proceedings of the 14th Southern Weed Conference.

STEPHENS, J. L. (1942)—Pastures for the coastal plain of Georgia. Georgia Coastal Plain Experiment Station Bulletin 27.

VANE, N. (1960)—"Pastures for the Kyogle District". (V. C. N. Blight, Government Printer; Sydney).

VICKERY, J. W. (1961)—Gramineae. Contributions from the New South Wales National Herbarium. Flora Series No. 19, Part 1.

WARING, W. J. (1957)—"Pastures for the Murwillumbah district" (A. H. Pettifer, Government Printer; Sydney).

WHITE, R. E. (1967)—Nutrient requirements of white clover based pastures on a krasnozem basalt at Maleny, south-eastern Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry.* **7**: 509-514.

WHITTET, J. N. (1968)—"Weeds" 2nd Ed. (V. C. N. Blight, Government Printer; Sydney).

WHYTE, R. O., MOIR, T. R. G., and COOPER, J. P. (1959)—"Grasses in agriculture". F.A.O. Agriculture Series No. 42.

WOLTERS, G. T. (1972)—Production and persistence of common carpet grass in relation to site and harvest frequency. *Journal of Range Management.* **25**: 360-363.

WOODHOUSE, W. W., and BLASER, R. E. (1948)—This is our unfinished business. In "Grass. The Yearbook of Agriculture" (United States Government Printing Office; Washington).

WOODHOUSE, W. W., and LOVVORN, R. L. (1942)—Establishing and improving permanent pastures in North Carolina. North Carolina Experiment Station Bulletin 338.

YOUNGE, O. R., and OTAGAKI, K. K. (1958)—The variation in protein and mineral composition of Hawaii range grasses and its potential effect on cattle nutrition. Hawaii Agricultural Experiment Station Bulletin 119.

(Accepted for publication January 2, 1975)