PROTEIN CONTENT AND YIELD OF GRASSES IN THE WET TROPICS AS INFLUENCED BY SEASONAL PRODUCTIVITY, FREQUENCY OF CUTTING AND SPECIES.

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SUMMARY.

1. *Grasses cut at monthly, two-monthly and three-monthly intervals showed (a) minimum values for protein content during the "zenith" period of productivity, (b) a high level of protein content in the period following establishment and during the "low" period of productivity, and (c) transition from high to low protein values and vice versa during the "rapid increase" and "rapid decrease" periods of productivity, i.e., there is a negative correlation between dry-matter yield and protein content.*

2. *The majority of the grasses showed a considerably higher yield of protein under three consecutive monthly cuts than under a single three-monthly cut in the period after establishment. Melinis minutiflora is exceptional in that it yielded 92 per cent. more protein under a system of three-monthly cutting during the first three months than under monthly cutting.*

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3. *Under monthly cutting the highest mean protein content for five cuts was shown by Digitaria milanjiana (14.4 per cent.), Pennisetum clandestinum (13.7 per cent.) and Urochloa bolbodes (13.2 per cent), all of which are leafy grasses.*

4. *Three grasses—Brachiaria decumbens, Hyparrhenia aucta and Panicum maximum No. 1202—yielded more than 1,000 lb. protein per acre per annum under three-monthly cutting. The grasses with the smallest yields were Chloris gayana No. 6585, Panicum maximum var. trichoglume and P. maximum var. coloratum.*

5. *The significance of the leaf to stem ratio relative to protein content is emphasized, and it is demonstrated that the leafy grasses show the highest increases in protein content following fertilizer application during the second year.*

6. *An exception to the general pattern of protein yield throughout the year is shown by Hyparrhenia aucta, which differs from all the other grasses in that from July to October the yield of protein rises to a maximum whereas with the other grasses it falls.*

7. *An inverse relationship between fibre and protein content is shown under each cutting system.*

INTRODUCTION.

Investigation of the chemical composition of pastures has received considerable attention in the temperate zone during the past 25 years. In the tropics, however, comparatively little work has been carried out on the subject. This paper deals with the protein content and yield of various grasses in the wet tropics as influenced by productivity period, frequency of cutting, and species. The term protein is used without qualifying adjective throughout the following pages to denote the value obtained by multiplying by 6.25 the total nitrogen as determined by the method of analysis of the American Association of Official Agricultural Chemists (1935). The seasonal productivity of these grasses has been discussed in a previous publication (Schofield, 1944), which should be read in conjunction with the present paper.

REVIEW OF PREVIOUS WORK.

As this paper is concerned with the performance of grasses under tropical conditions, it has been deemed appropriate to consider, first, some work which has been carried out in the tropics, and to follow with a review of several publications referring to results obtained in the temperate zone.

Edwards and Goff (1935), in Hawaii, examined the effect of location, species and season on the chemical composition of five grasses and showed that the "average per cents of protein for all grasses were practically identical for the four locations." Paterson (1938), in Trinidad, selected a two-months' cutting rotation as the most likely to fulfil the average requirements of the three grasses: elephant grass, Guatemala grass and Para grass, and he calculated the yields of crude protein obtained under a high-cut and a low-cut respectively.

Harrison (1942) carried out digestibility trials with a number of green fodder grasses in the West Indies and showed that the figures "do not differ greatly from the results obtained in other countries with material of similar age, grown under similar conditions and rainfall." Cartmill (1944) examined the effect of season on the protein content of three grasses in coastal northern Queensland: the results obtained will be referred to later.

Fagan and Jones (1924), working in Wales, stated that "the leaf portion of the plant is distinctly richer than the stem, and a knowledge of the relative proportions of these parts will prove a fair guide to the nutritive value of a pasture at any period of the year."

Woodman and associates (1926, 1927, 1928, 1929) in England found that the average seasonal crude-protein content of unfertilized pasture under a weekly system of cutting was 24·7 per cent. (dry matter); under a fortnightly cutting system the figure was 23·5 per cent. and with three-weekly cutting a value of 21·1 per cent. was obtained.

Shutt, Hamilton and Selwyn (1928 and 1930) in Canada demonstrated that frequency of cutting and development of white Dutch clover induced a higher protein content in the herbage and that the latter factor was "the more potent of the two"; another factor contributing to the higher protein percentages was the application of sulphate of ammonia and nitrate of soda.

Greenhill (1930) in England showed that herbage from pasture managed under the Intensive System of Grassland Management and of from three to five weeks' growth was closely comparable in respect of chemical composition and dry matter with that obtained by other workers from "pasture cuts" at one- to three-weekly intervals from unmanured pastures.

Richardson and associates (1931) in southern Australia found that the growth stage had a determining influence on the nitrogen and mineral content of a pasture species.

Archibald and associates (1932) in Massachusetts studied the chemical composition of grass fertilized and grazed intensively and showed the marked effect of nitrogen in producing a succulent grass with a relatively large amount of dry matter.

Du Toit and associates (1935) in the Union of South Africa have demonstrated that pure species grown on the same soil and under the same climatic conditions show appreciable differences in mineral and protein content when harvested after definite intervals, e.g., one month.

Taylor (1941) in Natal carried out rotational grazing experiments on Kikuyu grass pasture liberally fertilized with a mixture in which nitrogen in the form of sulphate of ammonia predominated and showed that the protein value often exceeded 25 per cent.

EXPERIMENTAL PROCEDURE.

Certain details of the productivity experiment with which this investigation was linked have been given in a previous publication (Schofield, 1944). At selected cutting periods a sample of herbage for chemical analysis was taken from the bulked material of each of the grasses after cutting and weighing, and the protein content was determined by the standard method.

DATA FOR FIRST 12 MONTHS.

Monthly Cuts.

Protein Content.

Table 1 shows the protein percentages, on a dry-matter basis, of 19 grasses sampled for chemical analysis five times during the first 12 months under a system of monthly cutting. Figure 1 shows in graphical form the seasonal variation in protein content of six of these grasses: *Panicum maximum* vars. *coloratum, trichoglume* and *typica, Brachiaria purpurascens, Paspalum dilatatum* and *Pennisetum clandestinum.*

Table 1.

PROTEIN CONTENT OF VARIOUS GRASSES AT DIFFERENT DATES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF MONTHLY CUTTING.

—	Protein Percentage (Dry-matter Basis).					Mean.
			SERIES 1.			
Date of cut	26/4/40	28/5/40	25/6/40	22/10/40	19/2/41	..
Number of cut	1st	2nd	3rd	7th	11th	..
Urochloa bolbodes	14·6	13·2	15·6	14·3	8·1	13·2
Panicum maximum var. *trichoglume*	10·9	11·0	13·9	10·5	6·3	10·5
P. maximum No. 1202	14·7	11·5	14·0	9·7	6·7	11·3
P. maximum No. 3783	11·4	10·8	14·3	8·7	7·3	10·5
Digitaria milanjiana	16·7	16·7	18·0	12·5	8·1	14·4
Paspalum dilatatum	16·4	13·6	13·4	11·6	6·9	12·4
Cenchrus ciliaris	14·0	14·3	14·6	10·4	8·2	12·3
			SERIES 2.			
Date of cut	6/5/40	5/6/40	5/7/40	1/11/40	30/1/41	..
Number of cut	1st	2nd	3rd	7th	10th	..
Hyparrhenia aucta	12·7	13·6	15·5	8·6	5·2	11·1
Cynodon plectostachyum	13·1	14·9	12·8	7·4	8·2	11·3
Panicum maximum var. *coloratum*	14·0	15·7	13·3	10·1	5·3	11·7
P. maximum No. 1200	11·1	12·9	13·8	8·2	6·3	10·5
Brachiaria purpurascens	12·8	12·3	12·7	8·8	6·9	10·7
B decumbens.	12·8	12·0	11·6	8·5	5·1	10·0
Chloris gayana No. 6586	11·2	10·1	10·0	6·9	5·4	8·7
			SERIES 3.			
Date of cut	16/5/40	14/6/40	15/7/40	11/11/40	10/2/41	..
Number of cut	1st	2nd	3rd	7th	10th	..
Pennisetum clandestinum	18·3	17·9	14·7	8·3	9·1	13·7
Panicum maximum var. *typica*	9·5	15·3	11·6	7·5	5·8	9·9
P. maximum No. 3820	12·1	12·1	12·6	8·7	5·7	10·2
Chloris gayana No. 6585	10·4	7·4	8·6	6·3	5·7	7·7
Melinis minutiflora	12·3	13·6	12·4	8·9	7·1	10·9
Mean	13·1	13·1	13·3	9·3	6·7	11·1

The first two cuts (April-May and May-June), made during the period following establishment, corresponded to the end of the wet summer season, the autumn and the commencement of winter conditions. As would be expected,

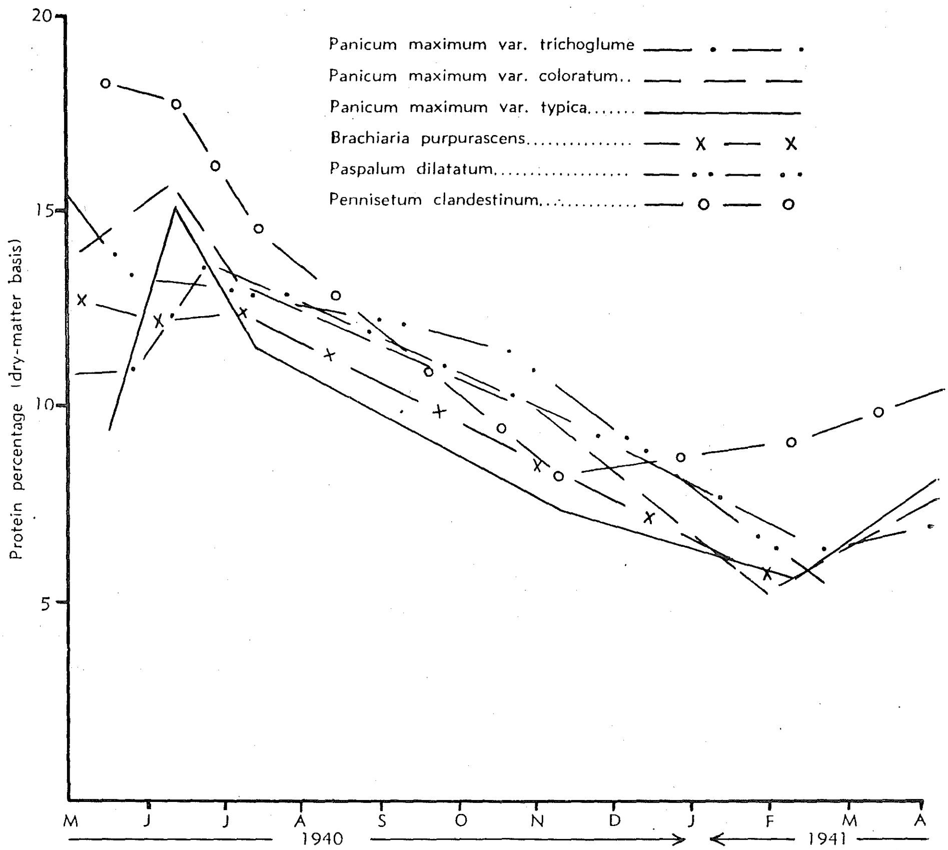

Figure 1.

Showing the seasonal variation in protein content of six grasses during the first 12 months under a system of monthly cutting.

the protein values for all grasses are high throughout this period, the mean being 13·1 per cent. The 3rd cut (June-July) coincides with the commencement of the "low" period of productivity and is characterized by high protein values for all grasses (mean 13.3 per cent.); eight grasses reach their peak at this cut. The 7th cut (October-November) represents the end of the "low" and the beginning of the "rapid increase" period, during which protein values show an appreciable fall, the mean being 9·3 per cent. The 10th cut for series 2 and 3 (January-February), and the 11th cut for series 1 (February) correspond to the "zenith" period, which coincides with a time of great metabolic activity in all grasses and is marked by a continuation of the fall in protein percentage to a much lower level.

The figures given in Table 1 cover five cuts out of a total of 12 for the first year; therefore, the means of the various grasses are valid for comparison of one grass against another over these five cuts only, and do not of course purport to represent the true mean protein composition for the full 12 months.

This pattern of protein content throughout the first 12 months is general for all the grasses examined, but there are points of difference, dependent on species, which deserve comment.

(*a*) An upward trend in protein percentage at the second, as compared with the first cut, is shown by *Cynodon plectostachyum, Melinis minutiflora* and *Panicum maximum* No. 1200 and vars. *coloratum* and *typica*: the increase for the last-named is considerable.

(*b*) Two grasses only—*Cynodon plectostachyum* and *Pennisetum clandestinum*—have a higher protein content at the 10th or 11th cut in January-February than at the 7th cut in October-November. The remaining grasses show decreases, some of which are considerable; e.g., *Urochloa bolbodes* 6·2 per cent. and *Panicum maximum* var. *coloratum* 4·8 per cent. The highest protein percentage at the "zenith" period is shown by *Pennisteum clandestinum*.

(*c*) The magnitude of the difference in protein percentage between the April-May and the January-February cuts varies widely according to the species. It is greatest with *Paspalum dilatatum* (9·5 per cent.), and least with *Panicum maximum* var. *typica* (3·7 per cent.), but the relatively low protein content of the latter grass at the first cut must be considered in this connexion.

(*d*) It is apparent from the data secured that under monthly cutting *Digitaria milanjiana, Pennisetum clandestinum* and *Urochloa bolbodes* may be classified as protein-rich grasses and that five of the remaining grasses—*Panicum maximum* No. 3820 and var. *typica, Brachiaria decumbens,* and *Chloris gayana* Nos. 6585 and 6586—are relatively poor in protein at most stages.

Yield of Protein.

The protein yield at each of the five sampling periods has been calculated from the data for protein percentage and dry-matter yield of herbage (Schofield, 1944) for each of the five cuts and is shown in Table 2. The totals given in the table are, of course, for only five of the 12 cuts made during the first 12 months, and do not represent total yields of protein for the year.

Examination of the totals for the five cuts in conjunction with the dry-matter yield figures in the previous paper shows that, in general, those grasses with the highest dry-matter yield produced the greatest amount of protein per acre. Thus *Brachiaria decumbens,* which throughout the five cuts had a relatively low protein percentage, yielded by far the highest amount of protein because of its high productivity. On the other hand, two protein-rich grasses—*Pennisetum clandestinum* and *Digitaria milanjiana*—produced small total amounts of protein because of their low yield of dry matter. A point of considerable interest is that a negative correlation between protein content and herbage-yield exists at a number of the cuts. Thus for example at the 1st cut $r = -0{\cdot}5084$ (significant 5 per cent.), at the 2nd cut $r = -0{\cdot}5774$ (significant 1 per cent.), at the 3rd cut $r = -0{\cdot}4610$ (significant 5 per cent.), at the

Table 2.

YIELD OF PROTEIN OF VARIOUS GRASSES AT DIFFERENT DATES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF MONTHLY CUTTING.

—	Yield of Protein in Lb. Per Acre.					Total for 5 Cuts.
	SERIES 1.					
Date of cut	26/4/40	28/5/40	25/6/40	22/10/40	19/2/41	..
Number of cut	1st	2nd	3rd	7th	11th	..
Urochloa bolbodes	141	160	147	64	105	617
Panicum maximum var. *trichoglume*	146	140	115	26	62	489
P. maximum No. 1202	145	152	119	52	141	609
P. maximum No. 3783	135	196	103	39	77	550
Digitaria milanjiana	90	105	73	28	78	374
Paspalum dilatatum	96	122	120	42	65	445
Cenchrus ciliaris	113	138	92	30	86	459
	SERIES 2.					
Date of cut	6/5/40	5/6/40	5/7/40	1/11/40	30/1/41	..
Number of cut	1st	2nd	3rd	7th	10th	..
Hyparrhenia aucta	63	82	97	116	155	513
Cynodon plectostachyum	150	170	95	45	81	541
Panicum maximum var. *coloratum*	188	120	95	23	70	496
P. maximum No. 1200	90	107	108	33	47	385
Brachiaria purpurascens	204	209	119	18	70	620
B. decumbens	330	223	174	86	90	903
Chloris gayana No. 6586	83	113	63	22	41	322
	SERIES 3.					
Date of cut	16/5/40	14/6/40	15/7/40	11/11/40	10/2/41	..
Number of cut	1st	2nd	3rd	7th	10th	..
Pennisetum clandestinum	82	76	165	22	69	414
Panicum maximum var. *typica*	215	99	117	37	109	577
P. maximum No. 3820	173	136	76	57	124	566
Chloris gayana No. 6585	161	73	96	18	59	407
Melinis minutiflora	52	113	111	84	81	441
Mean	140	133	110	44	85	512

7th cut r = —0·1894 (not significant) and at the 10th and 11th cuts r = —0·4861 (significant 5 per cent.). The overall correlation coefficient based on the error terms of the analyses, taking cuts as blocks, was equal to —0·4295 (significant 1 per cent.).

Two-monthly Cuts.

Protein Content.

Table 3 shows the protein content of the various grasses at three periods under a system of two-monthly cuts during the first 12 months. The 1st cut (May-June) corresponds to the period following establishment, and comparison of protein figures with those obtained under monthly cutting on the same dates (Table 1) demonstrates that with one exception—*Chloris gayana* No. 6585—all the grasses show considerably lower values: the respective

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Table 3.

PROTEIN CONTENT OF VARIOUS GRASSES AT DIFFERENT DATES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF TWO-MONTHLY CUTTING.

—	Protein Percentage (Dry-matter Basis).			Mean for 3 Cuts.
	SERIES 1.			
Date of cut	28/5/40	23/9/40	21/3/41	..
Number of cut	1st	3rd	6th	..
Urochloa bolbodes	10·8	10·3	3·9	8·3
Panicum maximum var. *trichoglume*	6·1	6·0	3·6	5·2
P. maximum No. 1202	8·1	7·1	4·3	6·5
P. maximum No. 3783	6·8	6·8	4·4	6·0
Digitaria milanjiana	11·4	10·3	6·3	9·3
Paspalum dilatatum	10·5	8·3	4·4	7·7
Cenchrus ciliaris	8·8	9·3	5·1	7·7
	SERIES 2.			
Date of cut	5/6/40	1/10/40	30/1/41	..
Number of cut	1st	3rd	5th	..
Hyparrhenia aucta	9·3	7·4	3·6	6·8
Cynodon plectostachyum	10·6	6·3	6·2	7·7
Panicum maximum var. *coloratum*	8·7	7·2	3·8	6·6
P. maximum No. 1200	7·8	6·3	4·3	6·1
Brachiaria purpurascens	7·7	5·3	5·8	6·3
B. decumbens	7·6	5·6	3·7	5·6
Chloris gayana No. 6586	6·1	4·4	3·9	4·8
	SERIES 3.			
Date of cut	14/6/40	11/10/40	10/2/41	..
Number of cut	1st	3rd	5th	..
Pennisetum clandestinum	13·9	8·8	6·7	9·8
Panicum maximum var. *typica*	7·7	7·2	4·2	6·4
P. maximum No. 3820	8·9	7·5	4·4	6·9
Chloris gayana No. 6585	10·3	4·7	3·7	6·2
Melinis minutiflora	10·7	7·1	4·3	7·4
Mean	9·0	7·2	4·6	6·9

means are 13·1 and 9·0 per cent. This is to be expected under a longer cutting rotation, as is shown by the results of numerous workers, e.g., Woodman, Blunt and Stewart (1926) in Britain, and Paterson (1933, 1935) in Trinidad, demonstrated how the protein percentage decreases as the interval between cutting increases.

The 3rd cut (September-October) represents the end of the "low" period of productivity, and at this time all grasses with the exception of *Cenchrus ciliaris* show a reduction in protein (mean 7·2 per cent.). The 5th and 6th cuts (January-March) cover the "zenith" period of productivity, and, as with monthly cutting, the values for protein are much lower than in the period following establishment, although at a greatly reduced level compared with the more drastic cutting treatment (mean 4·6 per cent.). Actually, the grasses in series 1 should have been analysed at the 5th cut, but due to an oversight the material was discarded after weighing. However, the analyses of these grasses at the 6th cut (21-3-41) are of special interest, because this period represents the mid-point of the wet season and the end of the "zenith" period. Comparison of these figures with those for the remaining grasses in series 2 and 3 cut in late January and early February provides evidence that there is little difference in the protein value of grasses at the commencement and at the end of the "zenith" period of productivity. The highest protein value during the "zenith" period is again recorded by *Pennisetum clandestinum.*

There is a negative correlation between protein content and herbage dry-matter yield at all the cuts examined; at the 1st cut $r = -0{\cdot}4313$ (significant 1 per cent. level), at the 3rd cut $r = -0.3476$ (not significant) and at the 5th and 6th cuts $r = -0{\cdot}4890$ (significant 5 per cent. level).

The pattern of protein variability throughout the 12 months under a system of two-monthly cutting is common to most grasses in the experiment, a result in close agreement with findings under the monthly rotation. However, there are important differences between grasses, which can be regarded as characteristic of the species concerned, and some of these will be discussed.

(*a*) The explanation of the apparent exceptional behaviour of *Chloris gayana* No. 6585, which has been commented upon previously, is due to its late-maturing and leafy nature. The fact that this strain at the 1st cut under a two-monthly rotation had a protein content of 10·3 per cent. (strain No. 6586, 6·1 per cent.) whereas on the same date under monthly cutting, but at the 2nd cut, the figure was 7·4 per cent. (strain No. 6586, 10·1 per cent.) is both interesting and important, and demonstrates the value of late maturity combined with leafiness.

(*b*) The majority of grasses at the 3rd cut in September-October (mean 7·2 per cent.), corresponding to the "low" period of productivity, show a tendency to lower values than at the 1st cut (mean 9.0 per cent.). The largest differences are shown by *Chloris gayana* No. 6585, *Pennisetum clandestinum, Cynodon plectostachyum* and *Melinis minutiflora.* It is noteworthy that the grasses in series 1 (cut 23-9-40) show the least difference in protein content between the 1st and the 3rd cuts; this is probably because the date of the 3rd cutting in series 1 is more typical of "low" productivity conditions than the corresponding dates in series 2 and 3, where the influence of the "rapid increase" period of productivity is very evident in the reduced protein level of the grasses.

(*c*) At the 5th or 6th cut, made during the "zenith" period of productivity, all the grasses except *Cynodon plectostachyum, Brachiaria purpurascens* and *Chloris gayana* No. 6586 have a substantially lower content of protein than at the 3rd cut.

(*d*) The protein content of *Paspalum dilatatum, Melinis minutiflora, Chloris gayana* No. 6585, *Urochloa bolbodes* and *Pennisetum clandestinum* is very much lower at the 5th or 6th cut.

(*e*) The data given in Table 3 indicate that under a monthly system of cutting *Pennisetum clandestinum, Digitaria milanjiana, Urochloa bolbodes, Cenchrus ciliaris, Cynodon plectostachyum, Paspalum dilatatum,* and *Melinis minutiflora* may be regarded as high-protein grasses, whereas *Panicum maximum* var. *trichoglume* and *Chloris gayana* No. 6585 are protein-poor.

Yield of Protein.

Table 4 shows the yield of protein obtained at three selected two-monthly cuts. As with monthly cutting, yield of protein depends very largely on yield of dry-matter. Thus the relatively low yields of the protein-rich *Digitaria milanjiana* and *Pennisetum clandestinum* have caused these grasses to produce 370 lb. and 307 lb. of protein per acre only as against 598 lb. per acre from *Urochloa bolbodes,* which is in the same protein-content category.

Table 4.

YIELD OF PROTEIN OF VARIOUS GRASSES AT DIFFERENT DATES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF TWO-MONTHLY CUTTING.

——	Yield of Protein in Lb. Per Acre.			Total for 3 Cuts.
SERIES 1.				
Date of cut	28/5/40	23/9/40	21/3/41	..
Number of cut	1st	3rd	6th	..
Urochloa bolbodes	382	115	101	598
Panicum maximum var. *trichoglume*	152	75	60	287
P. maximum No. 1202	265	94	178	537
P. maximum No. 3783	321	72	115	508
Digitaria milanjiana	151	62	157	370
Paspalum dilatatum	186	93	106	385
Cenchrus ciliaris	254	52	129	435
SERIES 2.				
Date of cut	5/6/40	1/10/40	30/1/41	..
Number of cut	1st	3rd	5th	..
Hyparrhenia aucta	154	217	211	582
Cynodon plectostachyum	290	126	126	542
Panicum maximum var. *coloratum*	247	66	169	482
P. maximum No. 1200	128	83	72	283
Brachiaria purpurascens	379	66	153	598
B. decumbens	630	203	219	1,052
Chloris gayana No. 6586	146	42	73	261
SERIES 3.				
Date of cut	14/6/40	11/10/40	10/2/41	..
Number of cut	1st	3rd	5th	..
Pennisetum clandestinum	151	69	87	307
Panicum maximum var. *typica*	255	55	151	461
P. maximum No. 3820	361	87	207	655
Chloris gayana No. 6585	344	60	135	539
Melinis minutiflora	225	126	137	488
Mean	264	93	136	493

Similarly, the protein-poor grasses show very marked differences in yield of protein per acre. *Brachiaria decumbens* because of its very high initial productivity easily outyields all the other grasses with 1,052 lb. per acre, while *Panicum maximum* var. *trichoglume* and *Chloris gayana* No. 6586 have the extremely low yields of 287 lb. and 261 lb. protein per acre respectively.

There is a negative correlation between protein content and herbage dry-matter yield in the first 12 months under a system of two-monthly cutting. At the 1st cut r = — 0.4313 (significant 1 per cent.), at the 3rd cut r = — 0·3476 (not significant) and at the 5th and 6th cuts r = — 0·4890 (significant 5 per cent.); the overall correlation coefficient based on the error terms of the analyses is — 0·3736 (significant 5 per cent.).

Three-monthly Cuts.

Protein Content.

The protein contents of the grasses under a system of three-monthly cutting are given in Table 5. Figure 2 contrasts the behaviour of *Pennisetum clandestinum* and *Panicum maximum* var. *typica* under two-monthly and three-monthly cutting, respectively, and illustrates in a general way the trend of protein variation under each system. In comparison with the more frequent

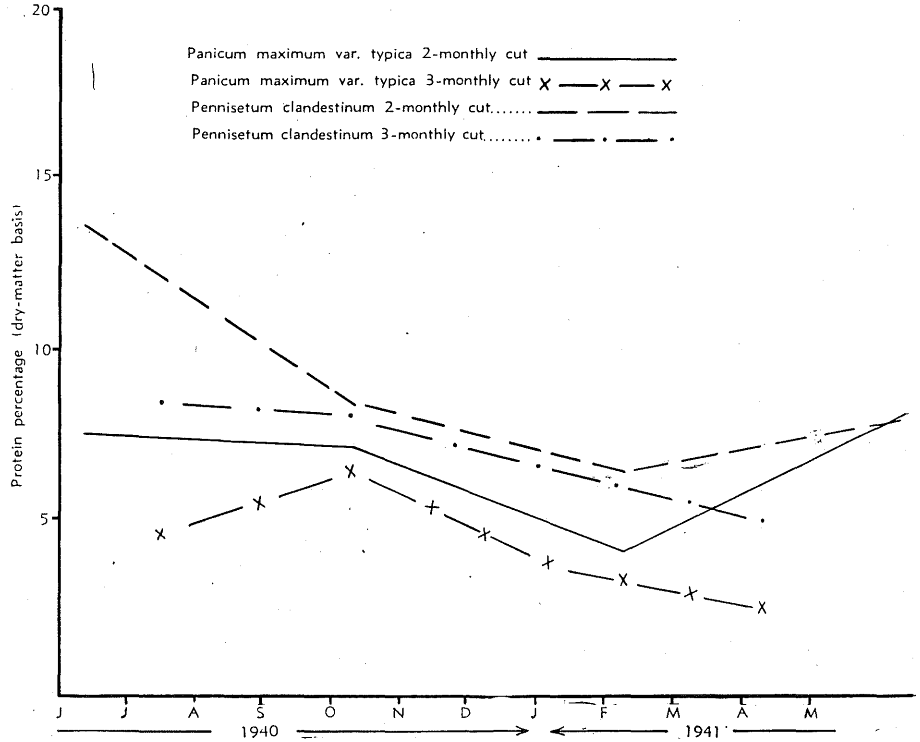

Figure 2.

Contrasting the seasonal variation in protein content of two grasses during the first 12 months under systems of two-monthly and three-monthly cutting, respectively.

Table 5.

PROTEIN CONTENT OF VARIOUS GRASSES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF THREE-MONTHLY CUTTING.

—	Protein Percentage (Dry-matter Basis).				Mean.
	SERIES 1.				
Date of cut	25/6/40	23/9/40	20/12/40	21/3/41	..
Period	Period Following Establishment.	Latter Part of "Low" Period.	End of "Rapid Increase" and Commencement of "Zenith" Period.	Latter Part of "Zenith" Period.	
Urochloa bolbodes	7·6	9·3	4·6	3·8	6·3
Panicum maximum var. *trichoglume*	5·7	4·5	4·1	3·5	4·4
P. maximum No. 1202	6·7	6·0	4·5	3·1	5·1
P. maximum No. 3783	5·3	6·1	4·9	2·8	4·8
Digitaria milanjiana	10·1	8·8	5·8	4·0	7·2
Paspalum dilatatum	8·0	7·4	5·6	4·2	6·3
Cenchrus ciliaris	7·4	8·2	6·5	4·0	6·5
	SERIES 2.				
Date of cut	5/7/40	1/10/40	31/12/40	31/3/41	..
Hyparrhenia aucta	6·4	6·7	3·3	3·4	4·9
Cynodon plectostachyum	7·2	5·5	5·7	3·6	5·5
Panicum maximum var. *coloratum* ..	7·0	5·9	5·2	3·0	5·3
P. maximum No. 1200	7·1	5·4	..	2·5	5·0
Brachiaria purpurascens	5·7	4·8	5·6	3·2	4·8
B. decumbens	5·4	5·4	4·2	1·9	4·2
Chloris gayana No. 6586	5·0	3·8	5·2	2·7	4·2
	SERIES 3.				
Date of cut	15/7/40	11/10/40	10/1/41	10/4/40	..
Pennisetum clandestinum	8·6	8·1	6·8	5·3	7·2
Panicum maximum var. *typica* ..	4·9	6·7	3·9	2·7	4·6
P. maximum No. 3820	5·9	6·2	4·3	2·8	4·8
Chloris gayana No. 6585	4·3	3·5	3·5	3·0	3·6
Melinis minutiflora	7·5	6·1	4·2	3·6	5·3
Mean	6·6	6·2	4·9	3·3	5·3

cutting rotations, three-monthly cutting shows a continuation of the fall in protein values already commented on under the two-monthly cutting system.

The 1st cut (June-July) corresponds to the period following establishment, and comparison of these figures (mean 6·6 per cent.) with those obtained on the same date under monthly cutting (corresponding to the 3rd cut in Table 1—mean 13·3 per cent.) demonstrates that all grasses show a marked reduction in protein content. The 2nd cut (September-October—mean 6·2 per cent.) represents the latter portion of the "low" period of productivity, at which time six grasses show increases, 12 show decreases and one grass remains at the same level compared with the previous cut. The 3rd cut (December-January—mean 4·9 per cent.) corresponds to the end of the "rapid increase"

Table 6.

THREE-MONTHLY CUT—FIRST 12 MONTHS.
Summary of Results—Protein Content.

Grass.	Mean Protein Percentage.	Percentage of Mean.	Significance Table. 1 Per Cent. Level.	Significance Table. 5 Per Cent. Level.
1. *Pennisetum clandestinum*	7·20	136·3	> Nos. 6-18	> Nos. 6-18
2. *Digitaria milanjiana*	7·17	135·9	ditto	ditto
3. *Cenchrus ciliaris*	6·52	123·6	> Nos. 10-18	> Nos. 8-18 (7)
4. *Urochloa bolbodes*	6·32	119·8	> Nos. 14-18	> Nos. 9-18
5. *Paspalum dilatatum*	6·30	119·3	ditto	ditto
6. *Cynodon plectostachyum*	5·50	104·2	> No. 18	> Nos. 16-18
7. *Melinis minutiflora*	5·35	101·3	ditto	> No. 18 (17)
8. *Panicum maximum* var. *coloratum*	5·27	99·9	ditto	> No. 18
9. *P. maximum* No. 1202	5·07	96·1	No significant	ditto
10. *Hyparrhenia aucta*	4·95	93·7	difference	ditto
11. *Brachiaria purpurascens*	4·82	91·4		ditto
12. *Panicum maximum* No. 3820 ..	4·80	90·9		ditto
13. *P. maximum* No. 3783	4·77	90·4		ditto
14. *P. maximum* var. *typica*	4·55	86·2		No significant
15. *P. maximum* var. *trichoglume* ..	4·45	84·3		difference
16. *Brachiaria decumbens*	4·22	80·0		
17. *Chloris gayana* No. 6586	4·17	79·1		
18. *C. gayana* No. 6585	3·57	67·7		
G. Mean	5·28	100·0		
S.E. Mean of 4	·4144	7·85		
Sig. difference P. = 0·05	..	22·28		
Sig. difference P. = 0·01	..	29·71		

Season.	Seasonal Mean Composition.	Percentage of Mean	Significance Table 1 Per Cent Level.	Significance Table 5 Per Cent Level.
1. Period following establishment ..	6·59	124·9	> Nos. 3-4	> Nos. 2-4
2. Latter portion of "low" period of productivity	6·28	118·9	ditto	> Nos. 3–4
3. End of "rapid increase" and commencement of "zenith" period of productivity	4·88	92·5	> No. 4	
4. Latter portion of "zenith" period of productivity	3·37	63·8		
G. Mean	5·28	100·0		
S.E. Mean of 18	·1954	3·70		
Sig. difference P. = 0·05	..	10·50		
Sig. difference P. = 0·01	..	14·00		

and commencement of the "zenith" period of productivity, and shows with four exceptions a marked decrease in protein content. The 4th cut (March-April—mean 3·3 per cent.), at the later end of the "zenith" period, shows a very marked fall in protein content for all grasses except *Chloris gayana* No. 6585 compared with the 2nd cut. The effect of seasonal productivity on protein content is shown clearly by the mean figures in Table 5 for each of the four cuts corresponding to the four productivity periods.

Because samples from every cut have been analysed and each of the four cuts corresponds more or less to one of the four periods of productivity in the first 12 months, the analysis of variance method has been applied to the protein percentage figures. The F value for grasses is 6·27, which is highly significant, and for seasonal effect F is 57·13, which is very highly significant. A summary of results is given in Table 6.

The chief points of interest in Table 6 are: (1) The grasses with the highest protein percentages include *Pennisetum clandestinum*, *Digitaria milanjiana*, *Cenchrus ciliaris*, *Urochloa bolbodes* and *Paspalum dilatatum*. (2) The analysis of seasonal effect demonstrates that (*a*) protein content in the period following establishment and in the "low" period of productivity is significantly higher at the 1 per cent. level than values in the "rapid increase" and "zenith" periods; (*b*) protein content in the "rapid increase" period is significantly higher at the 1 per cent. level than values in the "zenith" period; (*c*) protein content in the period following establishment is significantly higher at the 5 per cent. level than values in the "low" period of productivity.

The correlation coefficients for protein percentage and herbage dry-matter yield have been calculated for each productivity period during the first 12 months, and the values are given below.

—	Period Following Establishment.	Latter Part of "Low" Period.	End of "Rapid Increase" and Commencement of "Zenith" Period.	Latter Part of "Zenith" Period.
Correlation Coefficient ..	— 0·4843	— 0·2272	— 0·7307	— 0·3944
Degrees of Freedom	16	16	16	16
Significance	5 per cent.	Not significant	1 per cent.	Not significant

The overall correlation coefficient calculated on the error terms of the analyses is —0·3303 (50 D.F.), significant at 2 per cent. level.

Differences between certain species relative to their protein content at various cuts under a system of three-monthly cutting merit comment. The greatest differences in protein at the 1st cut under three-monthly compared with monthly cutting are shown by *Pennisetum clandestinum*, *Paspalum dilatatum* and *Panicum maximum* No. 1202, and the smallest by *Melinis minutiflora* and *Panicum maximum* var. *typica* and No. 1200. In comparison with two-monthly cutting, the more lenient system at the initial cut showed a substantially lower protein content only with *Chloris gayana* No. 6585 and *Pennisetum clandestinum*.

A comparison of protein content at the 1st and 4th cuts under three-monthly cutting demonstrates that the greatest difference is shown by *Digitaria milanjiana* and the smallest by *Chloris gayana* No. 6585.

Examination of the values of protein content under the three cutting rotations during the "zenith" period of productivity brings out the following points:—

(1) Comparison of monthly and two-monthly cutting shows that the greatest differences occurred with *Urochloa bolbodes, Cenchrus ciliaris* and *Panicum maximum* No. 3783, and the smallest differences with *Brachiaria decumbens, Panicum maximum* No. 3820 and *Brachiaria purpurascens.*

(2) Comparison of two-monthly and three-monthly cutting indicates that the greatest differences occurred with *Cynodon plectostachyum, Brachiaria purpurascens* and *Digitaria milanjiana* and the smallest differences with *Hyparrhenia aucta, Paspalum dilatatum, Urochloa bolbodes* and *Panicum maximum* var. *trichoglume.*

The mean protein figures under three-monthly cutting show that only *Digitaria milanjiana* and *Pennisetum clandestinum* exceeded 7 per cent. and that only *Chloris gayana* No. 6585 fell below 4 per cent.

The highest protein value during the "zenith" period was given by *Pennisetum clandestinum* (5·3 per cent.); the next three grasses were *Paspalum dilatatum* (4·2 per cent.), *Digitaria milanjiana* and *Cenchrus ciliaris* (4·0 per cent.). The lowest protein value was given by *Brachiaria decumbens* (1·9 per cent.), which indicates the very poor quality of this grass in the wet season after three-months' growth under three-monthly cutting.

When the accessibility of protein to ruminants is hampered by a high fibre content there is an appreciable decrease in availability of digestible nutrients. Montgomery White (private communication) has pointed out that there is a marked difference in the coefficients obtained from Rhodes grass at the 0·5 and 1·0 per cent. levels of nitrogen. Such findings serve to emphasize the importance of utilizing protein-rich herbage obtained from suitable strains of gramineous and leguminous species selected on a climatic-regional soil type basis.

Yield of Protein.

Table 7 shows that four grasses—*Brachiaria decumbens, Hyparrhenia aucta, Panicum maximum* No. 1202, and *Melinis minutiflora*—reached a total yield of protein approximating to 1,000 lb. per acre per annum, while *Panicum maximum* var. *coloratum* yielded only 450 lb.

The data have been subjected to the analysis of variance; the F value for varieties is 2·172, which is significant at the 5 per cent. level only, and for seasons F is 19·616, which is very highly significant. The results of these analyses, summarized in Table 8, are of special interest for the following reasons:—(1) It is demonstrated that, in general, grasses with the highest herbage yields produced the highest yields of protein, an exception being *Pennisetum clandestinum,* which gave the lowest yield of green matter (13·6 tons

Table 7.

YIELD OF PROTEIN OF VARIOUS GRASSES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF THREE-MONTHLY CUTTING.

—	Yield of Protein in Lb. Per Acre.				Total.
SERIES 1.					
Date of cut	25/6/40	23/9/40	20/12/40	21/3/41	..
Period	Period Following Establishment.	Latter Part of "Low" Period.	End of "Rapid Increase" and Commencement of "Zenith" Period.	Latter Part of "Zenith" Period.	
Urochloa bolbodes	327	150	187	208	872
Panicum maximum var. *trichoglume*	208	84	90	140	522
P. maximum No. 1202	329	137	190	447	1,103
P. maximum No. 3783	302	133	170	240	845
Digitaria milanjiana	265	97	103	329	794
Paspalum dilatatum	254	116	94	147	611
Cenchrus ciliaris	230	66	89	172	557
SERIES 2.					
Date of cut	5/7/40	1/10/40	31/12/40	31/3/41	..
Hyparrhenia aucta	278	365	296	202	1,141
Cynodon plectostachyum	282	156	152	227	817
Panicum maximum var. *coloratum*	141	70	137	102	450
P. maximum No. 1200	235	57	..	50	..
Brachiaria purpurascens	360	112	108	92	672
B. decumbens	758	160	231	181	1,330
Chloris gayana No. 6586	234	75	150	129	588
SERIES 3.					
Date of cut	15/7/40	11/10/40	10/1/41	10/4/41	..
Pennisetum clandestinum	249	147	62	189	647
Panicum maximum var. *typica*	397	96	174	157	824
P. maximum No. 3820	362	110	175	198	845
Chloris gayana No. 6585	198	64	84	177	523
Melinis minutiflora	529	123	164	179	995
Mean (17 grasses only)*	319	112	139	195	764

**Hyparrhenia aucta* and *Panicum maximum* No. 1200 excluded.

per acre per annum), but due to its high protein content yielded 647 lb. of protein per acre; (2) The significance of herbage productivity in determining protein yield is well shown in the analysis of seasonal effect. The yield during the period following establishment is significantly higher than that during the "zenith," "rapid increase" and "low" periods of productivity at the 1 per cent. level, but yield during the "zenith" period is also significantly higher at the 2 per cent. level than that at the "low" period of productivity. Comparison with Table 6 shows clearly that protein value at the "zenith" and the "low" periods of productivity shows a complete reversal of position due to the preponderant nature of the seasonal factor on herbage yield.

Table 8.

THREE-MONTHLY CUT—FIRST 12 MONTHS.

Summary of Results—Yield of Protein.

Grass.	Total Yield of Protein in Lb. Per Acre.	Percentage of Total Yield (Mean of 18 Grasses).	Significance Table. 5 Per Cent. Level.
1. *Brachiaria decumbens*	1,330	169·4	> Nos. 6-18
2. *Hyparrhenia aucta*	1,141	145·3	> Nos. 11-18
3. *Panicum maximum* No. 1202	1,103	140·4	> Nos. 13-18
4. *Melinis minutiflora*	995	126·7	> Nos. 16-18
5. *Urochloa bolbodes*	872	111·0	No significant difference
6. *Panicum maximum* No. 3820	845	107·6	
7. *P. maximum* No. 3783	845	107·6	
8. *P. maximum* var. *typica*	824	104·9	
9. *Cynodon plectostachyum*	817	104·0	
10. *Digitaria milanjiana*	794	101·1	
11. *Brachiaria purpurascens*	672	85·6	
12. *Pennisetum clandestinum*	647	82·4	
13. *Paspalum dilatatum*	611	77·8	
14. *Chloris gayana* No. 6586	588	74·9	
15. *Cenchrus ciliaris*	557	70·9	
16. *Chloris gayana* No. 6585	523	66·6	
17. *Panicum maximum* var. *trichoglume*	522	66·5	
18. *P. maximum* var. *coloratum*	450	57·3	
Mean of 18 varieties	785·33	100·0	
S.E. total of 4	163·70	20·84	
Sig. difference P. = 0·05	464·61	59·16	

Season.	Mean Yield in Lb. Per Acre.	Percentage of G.M.	1 Per Cent. Level.	2 Per Cent. Level.
1. Period following establishment	316·83	161·4	> Nos. 2, 3 and 4	
2. Latter part of "zenith" period	195·33	99·5	No significant difference	> No. 4
3. End of "rapid increase" and commencement of "zenith" period	147·56	75·2		No significant difference
4. Latter part of "low" period	125·61	64·0		
G.M.	196·33	100·0		
S.E. Mean of 18	19·292	9·83		
Sig. difference P. = 0·02	65·60	33·41		
Sig. difference P. = 0·01	73·00	37·8		

Comparison of Protein Yield under Monthly and Three-monthly Cutting.

The data collected during the first three months of the experiment—corresponding to the period following establishment, when protein values were at their highest—enable a comparison to be made of protein yields of various grasses under monthly and three-monthly cutting systems respectively. Table 9

Table 9.

YIELD OF PROTEIN OF VARIOUS GRASSES DURING THE FIRST THREE CUTS UNDER A SYSTEM OF MONTHLY CUTTING COMPARED WITH THE CORRESPONDING YIELD AT THE FIRST CUT UNDER A SYSTEM OF THREE-MONTHLY CUTTING.

—	Yield of Protein in Lb. Per Acre.		
	Sum of First 3 Cuts : Monthly System of Cutting.	First Cut : Three-monthly System.	Difference.
SERIES 1.			
Date of cuts	25/4/40 ; 28/5/40 ; 25/6/40	25/6/40	..
Urochloa bolbodes	448	327	121
Panicum maximum var. *trichoglume*	401	208	193
P. maximum No. 1202	416	329	87
P. maximum No. 3783	434	302	132
Digitaria milanjiana	268	265	3
Paspalum dilatatum	338	254	83
Cenchrus ciliaris	343	230	113
SERIES 2.			
Date of cuts	6/5/40 ; 5/6/40 ; 5/7/40	5/7/40	..
Hyparrhenia aucta	242	278	+ 36
Cynodon plectostachyum	415	282	133
Panicum maximum var. *coloratum*	403	141	262
P. maximum No. 1200	305	235	70
Brachiaria purpurascens	432	360	72
Brachiaria decumbens	727	758	+ 31
Chloris gayana No. 6586	259	234	25
SERIES 3.			
Date of cuts	16/5/40 ; 14/6/40 ; 15/7/40	15/7/40	
Pennisetum clandestinum	323	249	74
Panicum maximum var. *typica*	431	397	34
P. maximum No. 3820	385	362	23
Chloris gayana No. 6585	330	198	132
Melinis minutiflora	276	529	+ 253
Mean	338	313	65

summarizes these results, which reveal marked differences between certain species in their reactions to the two systems. These differences are commented on briefly below.

(1) *Panicum maximum* vars. *coloratum* and *trichoglume* are noteworthy for their high yield of protein during the first three months under monthly compared with three-monthly cutting.

(2) The majority of grasses show a considerably increased yield of protein under three consecutive monthly cuts than under a single three-monthly cut in the period immediately following establishment.

(3) The yield of *Brachiaria purpurascens* for five separate monthly cuts (1st, 2nd, 3rd, 7th and 11th) amounted to 620 lb. protein; from four three-monthly cuts the total was 672 lb., which indicates that frequent cutting during the flush periods of growth would be more satisfactory than allowing this grass to mature for periods of three months throughout the year.

(4) *Melinis minutiflora* is outstanding among the 19 grasses in that it yielded almost twice as much protein from a single cut when three months old than from three monthly cuttings during the same period. Frequent early cutting of this grass should, therefore, be avoided.

(5) Negligible differences in protein yield during the first three months under the two systems of cutting are shown by *Digitaria milanjiana, Hyparrhenia aucta, Brachiaria decumbens, Chloris gayana* No. 6586, *Panicum maximum* var. *typica* and *P. maximum* No. 3820.

DATA FOR SECOND 12 MONTHS.

As stated previously (Schofield, 1944), fertilizer consisting of a mixture of superphosphate and blood, calculated for each grass on the basis of the nutrients removed in the herbage during the first 12 months (estimated from the protein and P_2O_5 figures), was dusted evenly over the whole of each sub-plot immediately after each cut had been made during the second period of 12 months. Due to unfavourable meteorological conditions during the early part of the second year, the effectiveness of the application was delayed until November.

Monthly Cuts.

Protein Content.

Table 10 summarizes the protein percentages for the 13th, 16th, 19th, and 22nd monthly cuts of the 12 grasses which were retained for the second 12 months. Figure 3 shows the marked seasonal variation in protein content which occurs with *Panicum maximum* vars. *coloratum, trichoglume* and *typica, Paspalum dilatatum* and *Pennisetum clandestinum* during the second year. These four cuts correspond approximately to the four productivity periods of the year. The 13th cut (April-May) falls in the "rapid decrease" period, which is characterized by a low protein content for all grasses (mean 8·7 per cent.). The 16th cut (July-August) falls in the early portion of the "low productivity" period, and is marked by a relatively high protein content for all grasses (mean 12·0 per cent.) with the exception of *Melinis minutiflora,* which shows no increase over the preceding period. Increases ranging from

6·9 per cent. with *Panicum maximum* var. *trichoglume* to 1·8 per cent. with *Chloris gayana* No. 6585 were recorded. The 19th cut (October-November) falls at the end of the "low" and the beginning of the "rapid increase" period, a time when fertilizer is becoming effective. The protein figures show a marked decrease for all grasses (mean 8·4 per cent.) with the exception of *Melinis minutiflora.* The 22nd cut (January-February) with a mean of 9·4 per cent. falls in the early portion of the "zenith" period, and the protein figures offer interesting contrasts between the various species. As already observed, the "zenith" period represents a time of great metabolic activity leading to a decrease in protein percentage, but the second 12-months period differs from the first 12 months because of the fertilizer applications made throughout the second year. It has been shown (Schofield, 1944) that two grasses —*Panicum maximum* var. *typica* and *Digitaria milanjiana*—respond markedly in dry-matter yield to fertilizer addition. Apart from yield response, however,

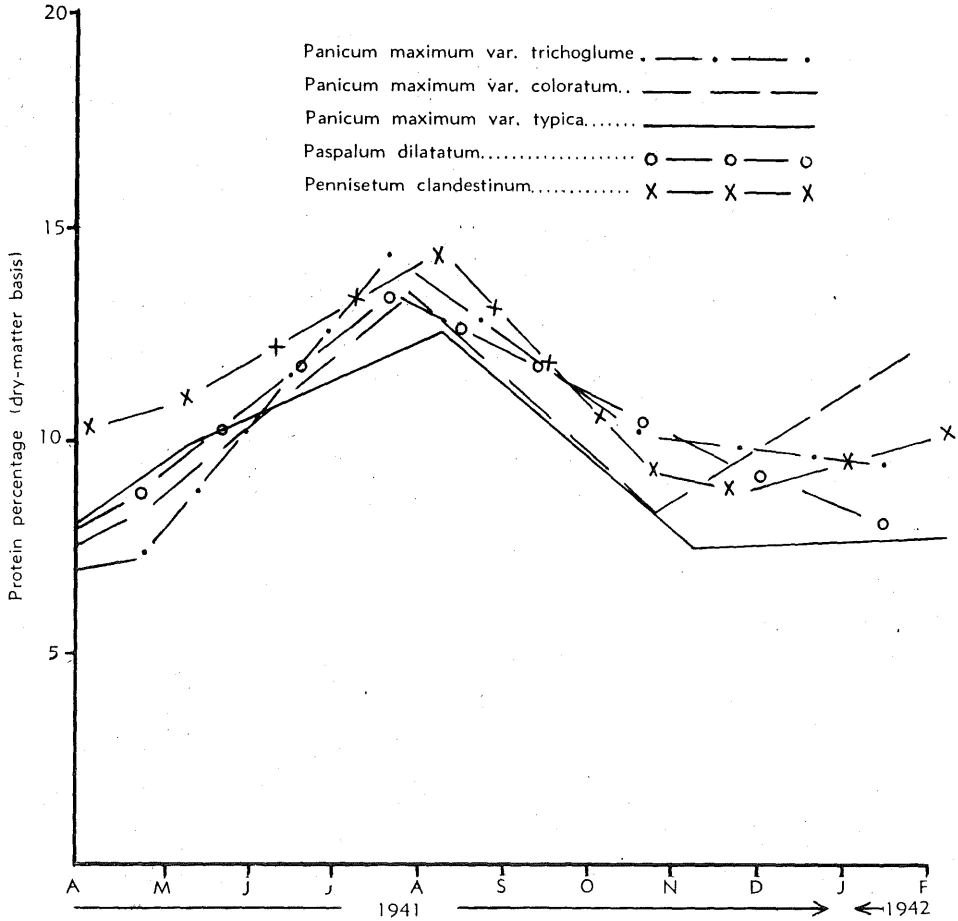

Figure 3.

Showing the seasonal variation in protein content of five grasses during the second 12 months under a system of monthly cutting.

Table 10.

PROTEIN CONTENT OF SELECTED GRASSES AT DIFFERENT DATES DURING THE SECOND 12 MONTHS UNDER A SYSTEM OF MONTHLY CUTTING.

—	Protein Percentage (Dry-matter Basis).				Mean for 4 Cuts.
	SERIES 1.				
Date of cut	21/4/41	18/7/41	17/10/41	15/1/42	..
Number of cut	13th	16th	19th	22nd	..
Urochloa bolbodes	9·0	13·6	12·0	10·4	11·2
Panicum maximum var. *trichoglume*	7·3	14·2	10·1	9·6	10·3
Digitaria milanjiana	8·9	11·6	9·1	8·3	9·5
Paspalum dilatatum	8·9	13·4	10·3	8·0	10·1
	SERIES 2.				
Date of cut	30/4/41	29/7/41	27/10/41	28/1/42	..
Number of cut	13th	16th	19th	22nd	..
Hyparrhenia aucta	8·6	10·6	6·4	9·0	8·6
Panicum maximum var. *coloratum*	8·7	13·4	8·3	12·0	10·6
Brachiaria decumbens	7·6	11·1	6·3	10·5	8·9
Chloris gayana No. 6586	8·4	11·4	6·4	11·7	9·5
	SERIES 3.				
Date of cut	9/5/41	8/8/41	6/11/41	4/2/42	..
Number of cut	13th	16th	19th	22nd	..
Pennisetum clandestinum	11·0	14·3	..	10·1	11·8
Panicum maximum var. *typica*	9·9	12·7	7·5	7·8	9·5
Chloris gayana No. 6585	7·4	9·2	..	7·7	8·1
Melinis minutiflora	8·4	8·6	8·1	7·7	8·2
Mean	8·7	12·0	8·4	9·4	9·7

it can be expected that fertilizer will have what Konig (1937) described as a *direct* influence on chemical composition. Fagan and Davies (1937) have further shown that two factors—the ratio of stem to leaf and the stage of maturity—have a profound effect on this influence. Therefore, stemmy species cannot be expected to show the improvement in chemical composition as a result of fertilizer application which occurs with leafy grasses, except where the cutting rotation (or grazing management) is so drastic as to effectively curtail the production of stem. Thus it is to be expected that differences in chemical composition between leafy and stemmy grasses will be least under frequent and greatest under lenient cutting or grazing; but always in making such comparisons the pronounced effect of season must be considered. Examination of protein values at the 13th cut ("rapid increase" period), when fertilizer was not effective, with those recorded at the 22nd cut (early portion of the "zenith" period) where fertilizer was active show interesting comparisons between various grasses, but do not reveal any extreme differences.

The marked decrease in protein content shown by *Panicum maximum* var. *typica* is noteworthy, and is explained by the strong negative correlation between herbage yield and crude protein; a yield increase amounting to 694 per cent. green matter occurred at the 22nd cut over the value at the 13th cut with this variety. The increase of 3·3 per cent. shown by the stemmy strain of *Chloris gayana* (No. 6586) is the result of frequent cutting, which has enabled material much richer in leaf to be harvested than under a longer cutting rotation.

Yield of Protein.

The respective yields of protein for the cuts discussed in the previous section are given in Table 11. These figures demonstrate the marked fall

Table 11.

YIELD OF PROTEIN OF SELECTED GRASSES AT DIFFERENT DATES DURING THE SECOND 12 MONTHS UNDER A SYSTEM OF MONTHLY CUTTING.

—	Yield of Protein in Lb. Per Acre.				Total for 4 Cuts.
	SERIES 1.				
Date of cut	21/4/41	18/7/41	17/10/41	15/1/42	..
Number of cut	13th	16th	19th	22nd	..
Urochloa bolbodes	20	12	13	49	94
Panicum maximum var. *trichoglume*	21	13	11	28	73
Digitaria milanjiana	36	8	10	32	86
Paspalum dilatatum	30	3	5	14	52
	SERIES 2.				
Date of cut	30/4/41	29/7/41	27/10/41	28/1/42	..
Number of cut	13th	16th	19th	22nd	..
Hyparrhenia aucta	10	14	14	107	145
Panicum maximum var. *coloratum* ..	19	6	7	102	134
Brachiaria decumbens	22	10	8	106	146
Chloris gayana No. 6586	13	5	7	26	51
	SERIES 3.				
Date of cut	9/5/41	8/8/41	6/11/41	4/2/42	..
Number of cut	13th	16th	19th	22nd	..
Pennisetum clandestinum	25	6	..	79	110*
Panicum maximum var. *typica* ..	33	11	18	173	235
Chloris gayana No. 6585	25	6	..	31	62*
Melinis minutiflora	28	10	15	138	191
Mean	24	9	11	74	117

* Sums of three cuts only.

in yield during the second 12 months under a system of monthly cutting, which is most noticeable during the "low" and the beginning of the "rapid increase" periods. One grass only—*Hyparrhenia aucta*—shows an increase during the "low" period compared with the "rapid decrease" period. The outstanding feature is the very marked increase in yield (mean 74 lb. protein per acre) during the "zenith" period shown by all grasses, but particularly by *Panicum maximum* var. *typica* and *Melinis minutiflora*. The lowest yields are given by the two strains of *Chloris gayana* and *Paspalum dilatatum*. It should be noted that *Digitaria milanjiana* did not show a marked response to fertilizer application until after the date given in Table 11 (15-1-42). Considerable yield increase did occur, however, on 12-2-42 and 17-3-42 (Schofield, 1944), and therefore the yield of protein for this grass rose very steeply in February and March.

Two-monthly Cuts.

Protein Content.

Table 12 summarizes the protein percentages for the 7th, 9th and 11th cuts under two-monthly cutting during the second 12 months. Figure 4 shows in graphical form the seasonal variation in protein content of *Panicum maximum* vars. *coloratum, trichoglume* and *typica, Paspalum dilatatum* and *Pennisetum clandestinum* during this period. The 7th cut (May-June) corresponds approximately to the "rapid decrease" period, and as with the second 12 months under monthly cutting all grasses exhibit a low protein content (mean 7.6 per cent.). The 9th cut (September-October) represents the latter part of the "low" productivity period, corresponding to the time when the

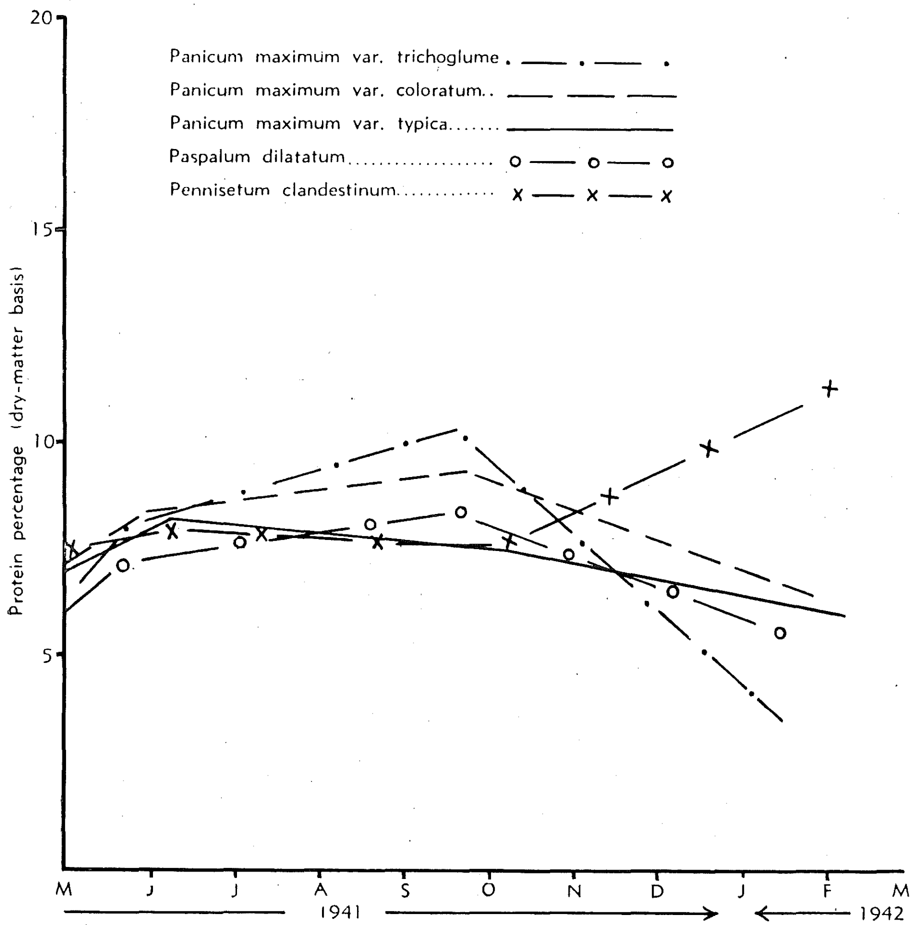

Figure 4.

Showing the seasonal variation in protein content of five grasses during the second 12 months under a system of two-monthly cutting.

Table 12.

PROTEIN CONTENT OF SELECTED GRASSES AT DIFFERENT DATES DURING THE SECOND 12 MONTHS UNDER A TWO-MONTHLY SYSTEM OF CUTTING.

—	Protein Percentage (Dry-matter Basis).			Mean for 3 Cuts.
		SERIES 1.		
Date of cut ..	20/5/41	18/9/41	15/1/42	..
Number of cut ..	7th	9th	11th	..
Urochloa bolbodes ..	6·6	11·2	9·6	9·1
Panicum maximum var. *trichoglume* ..	8·0	10·3	3·7	7·3
Digitaria milanjiana ..	9·5	7·9	6·6	8·0
Paspalum dilatatum ..	7·2	8·4	5·8	7·1
		SERIES 2.		
Date of cut ..	30/5/41	26/9/41	28/1/42	..
Number of cut ..	7th	9th	11th	..
Hyparrhenia aucta ..	7·5	7·3	6·5	7·1
Panicum maximum var. *coloratum* ..	8·4	9·3	6·6	8·1
Brachiaria decumbens ..	7·3	6·5	7·3	7·0
Chloris gayana No. 6586 ..	8·0	7·7	3·1	6·3
		SERIES 3.		
Date of cut ..	9/6/41	7/10/41	5/2/42	..
Number of cut ..	7th	9th	11th	..
Pennisetum clandestinum ..	8·0	7·7	11·3	9·0
Panicum maximum var. *typica* ..	8·2	7·6	6·0	7·3
Chloris gayana No. 6585 ..	5·0	7·8	6·0	6·3
Melinis minutiflora ..	7·6	5·4	7·8	6·3
Mean ..	7·6	8·1	6·7	7·5

grasses have passed their peak values for protein and are on the decline due to considerably increased metabolic activity (mean 8·1 per cent.). It is of interest to note that, compared with the 7th cut, three grasses—*Urochloa bolbodes* (4·6 per cent.), *Panicum maximum* var. *trichoglume* (2·3 per cent.), and *Chloris gayana* No. 6585 (2·8 per cent.)—show fairly large increases while *Melinis minutiflora* displays a decrease.

The 11th cut (January-February), with a mean value of 6·7 per cent., corresponds to the early portion of the ''zenith'' period, and a comparison of protein figures at the 7th and 11th cuts gives useful information on the reaction of the various grasses to fertilizer application (which becomes effective from November onwards) modified by seasonal effect and cutting treatment.

It is noteworthy that the highest increases are shown by leafy grasses—*Urochloa bolbodes* and *Pennisetum clandestinum*—whereas the largest decreases recorded occur with *Panicum maximum* var. *typica* and *Chloris gayana* No. 6586, the former a moderately stemmy and the latter a very stemmy grass (see Table 13). In order to assess the above differences in protein content, account must be taken of the changes in herbage yield which occurred with the various grasses at these two cuts. The green matter yield of *Urochloa bolbodes* at the 11th cut was 325 per cent. higher than that of the 7th cut, that of *Chloris gayana* 160 per cent., and that of *Panicum maximum* var. *typica* 1189 per cent., whereas that of *Pennisetum clandestinum* was 20 per cent. less. Thus the significant fact which emerges from these comparisons is that *Chloris gayana* strain No. 6586 decreased in protein by 4·9 per cent., although yield increase was a mere 160 per cent., thus denoting a very high proportion of stem to leaf in this grass; whereas the remarkable increase in yield shown by *Panicum maximum* var. *typica* was associated with a decrease in protein of 4·3 per cent., and demonstrates the leafy nature of a large proportion of the herbage produced.

No leaf and stem analyses of grasses in this experiment were carried out at South Johnstone, but subsequently in the Brisbane area samples from four grasses were collected. All four grasses had reached the mature stage of growth, none had been cut or grazed previously in the season and harvesting was undertaken at the beginning of July.

Table 13 shows the percentage composition on a dry-matter basis of the leaf and stem portions and the respective protein contents of four grasses: *Brachiaria brizantha* (closely related to *B. decumbens*), *Chloris gayana, Cynodon plectostachyum* and *Panicum maximum* var. *typica.*

Table 13.

PROPORTION OF LEAF TO STEM OF FOUR GRASSES CUT IN THE MATURE SEEDING STAGE—EARLY JULY—TOGETHER WITH THEIR RESPECTIVE PROTEIN CONTENTS.

Grass.	Leaf : Stem	Water Free Material.	
		Protein in Leaf.	Protein in Stem.
		%	%
Brachiaria brizantha	1 : 2	6·8	4·0
Chloris gayana	1 : 2·4	8·1	4·2
Cynodon plectostachyum	1 : 2	10·8	4·6
Panicum maximum var. *typica*	1 : 1·1	7·7	5·3

The leaf in the above analyses represents the blade only—that is, the portion above the ligule—and does not include the leaf sheath (see Stapledon, 1924). *Cynodon plectostachyum* and *Brachiaria brizantha* were cut at 2 inches, *Chloris gayana* at 4 inches and *Panicum maximum* var. *typica* at 12 inches above ground level. The above figures demonstrate the very stemmy nature of Rhodes grass and the relatively high proportion of leaf in Guinea grass, even in the very mature stage of growth. The protein composition of the stem of three of the grasses shows little difference, but the Guinea grass stems are decidedly richer in protein. The leaf portion of all the grasses is much higher in protein than the stem, but there are considerable differences between species. African star grass (*Cynodon plectostachyum*) is easily the highest at 10·8 per cent. and *Brachiara brizantha* the lowest at 6·8 per cent.

A further point which indicates the fundamental importance of strain is that the later-maturing leafy strain of Rhodes grass No. 6585 showed a 10 per cent. increase in protein from the 7th to the 11th cut, although herbage yield increased during the same period by 151 per cent.

Yield of Protein.

Table 14 summarizes the yields of protein for the various grasses during the second 12 months under two-monthly cutting. As with monthly cutting, *Hyparrhenia aucta* shows a slightly higher yield at the cut taken towards the end of the "low" period than at that taken during the "rapid decrease" period, although all the other grasses show lower yields, some of which are considerably lower. The outstanding feature again is the markedly higher yield of all grasses—and particularly of *Urochloa bolbodes, Hyparrhenia aucta, Brachiaria decumbens, Panicum maximum* var. *typica* and *Melinis minutiflora*—during the "zenith" period.

Table 14.

YIELD OF PROTEIN OF SELECTED GRASSES DURING THE SECOND 12 MONTHS UNDER A SYSTEM OF TWO-MONTHLY CUTTING.

——	Yield of Protein in Lb. Per Acre			Total for 3 Cuts.
SERIES 1.				
Date of cut ..	20/5/41	18/9/41	15/1/42	..
Number of cut	7th	9th	11th	..
Urochloa bolbodes	25	23	239	287
Panicum maximum var. *trichoglume*	30	16	62	108
Digitaria milanjiana	79	5	127	211
Paspalum dilatatum	63	9	56	128
SERIES 2.				
Date of cut ..	30/5/41	26/9/41	28/1/42	..
Hyparrhenia aucta	17	20	217	254
Panicum maximum var. *coloratum*	51	15	149	215
Brachiaria decumbens	56	9	196	261
Chloris gayana No. 6586	20	17	27	64
SERIES 3.				
Date of cut ..	9/6/41	7/10/41	5/2/42	..
Pennisetum clandestinum	61	7	51	119
Panicum maximum var. *typica*	26	14	163	203
Chloris gayana No. 6585	39	10	117	166
Melinis minutiflora	44	25	169	238
Mean	43	14	131	188

GENERAL PATTERN OF PROTEIN CONTENT UNDER DIFFERENT CUTTING SYSTEMS.

The data given in Tables 12 and 14 and in Figures 1-4 all indicate the operation of a marked seasonal influence, which produces a characteristic pattern of protein content throughout the year, although there are marked differences between various species, and even between strains of the same species, in the level reached.

All three systems of cutting possess these points in common: (1) the minimum values for protein content with all grasses are reached during the "zenith" period of productivity; (2) a high level of protein occurs with all grasses in the period following establishment and during the "low" period of productivity; (3) the "rapid increase" and the "rapid decrease" periods of productivity represent, as far as protein content is concerned, transitional periods from high to low values and vice versa. In effect, the data demonstrate that a negative correlation exists between herbage dry-matter yield and protein content.

Cartmill (1944), working under coastal conditions in northern Queensland, observed a similar rhythm of protein content in the three grasses examined. He pointed out that the highest protein content occurred in the "late-wet" period (June-July), which corresponds to the end of the "rapid decrease" and the beginning of the "low" period of productivity, whereas the lowest protein content was associated with the "pre-wet" period (December-January), which represents the end of the "rapid decrease" and the commencement of the "zenith" period of productivity. Paterson (1933) in Trinidad, has pointed out that with elephant grass "the protein content is lowest when the productivity of the crop is at a maximum."

Summer conditions in coastal northern Queensland bear no resemblance to any climatic conditions in the temperate zone, nor can the winter climate of coastal northern Queensland be compared to the English summer. Nevertheless it is apparent that, under temperate and tropical conditions alike, when herbage production is at a maximum protein content is at a minimum, and as herbage productivity decreases protein content increases (the application of nitrogenous fertilizer, however, increases yield and protein content). The fundamental cause of this negative correlation between dry-matter yield and protein content would appear to be the ratio of leaf to stem, which is conditioned essentially by the influence of meterological factors. It may be stated that the high yields of herbage obtained in the "rapid increase" and "zenith" periods of productivity are due, in large measure, to a higher proportion of stem which depresses the protein content. In fact, mention has already been made (Schofield, 1944) that *free* inflorescence emergence marks a period of *high* "yield" with some grasses, whereas in the "rapid decrease" and "low" periods stem production is at a minimum and the herbage tends to be richer in protein.

The negative correlation which exists between yield and protein content is shown by the following figures in this experiment: *Panicum maximum* var. *coloratum* showed an increase of 435 per cent. during the "zenith" as compared with the "low" period of productivity in the first 12 months under monthly cutting, and the crude protein dropped from 13·3 per cent. (5-7-40) to 5·3 per cent. (30-1-41). In the second 12 months, the increase in productivity rose 41 times (vide Schofield, 1944) and the protein dropped from 13·4 per cent. (29-7-41) when fertilizer was not effective to 12·0 per cent. (28-1-42) when fertilizer effect was strongly in evidence.

With respect to the profound importance of the proportion of leaf to stem relative to crude-protein content, it is of interest to note that Fagan and Davies (1937) quote for *Lolium italicum* a nitrogen value of 3·16 per cent. (leaf) and 1·85 per cent. (stem) at four weeks and 1·74 per cent. (leaf) and 1·01 per cent. (stem) at eight weeks of age; figures in this experiment with a leafy grass, *Pennisetum clandestinum* (including leaf and stem), during the period following establishment in the first year at four and eight weeks respectively were 2·93 per cent., and 2·21 per cent., whereas a stemmy grass, *Chloris gayana* No. 6586 (including leaf and stem) for the same periods gave 1.79 per cent. and 0·98 per cent.

To summarize, the chief points relating to the pattern of protein composition of grasses under different cutting systems are as follows:—

(1) A negative correlation between dry-matter yield and protein content is apparent with all grasses in each of the four periods of seasonal productivity.

(2) The grasses with the highest protein content throughout each 12 months are the leafy grasses, and the lowest protein is found in the stemmy grasses, thereby demonstrating the marked influence of the leaf to stem ratio on protein content.

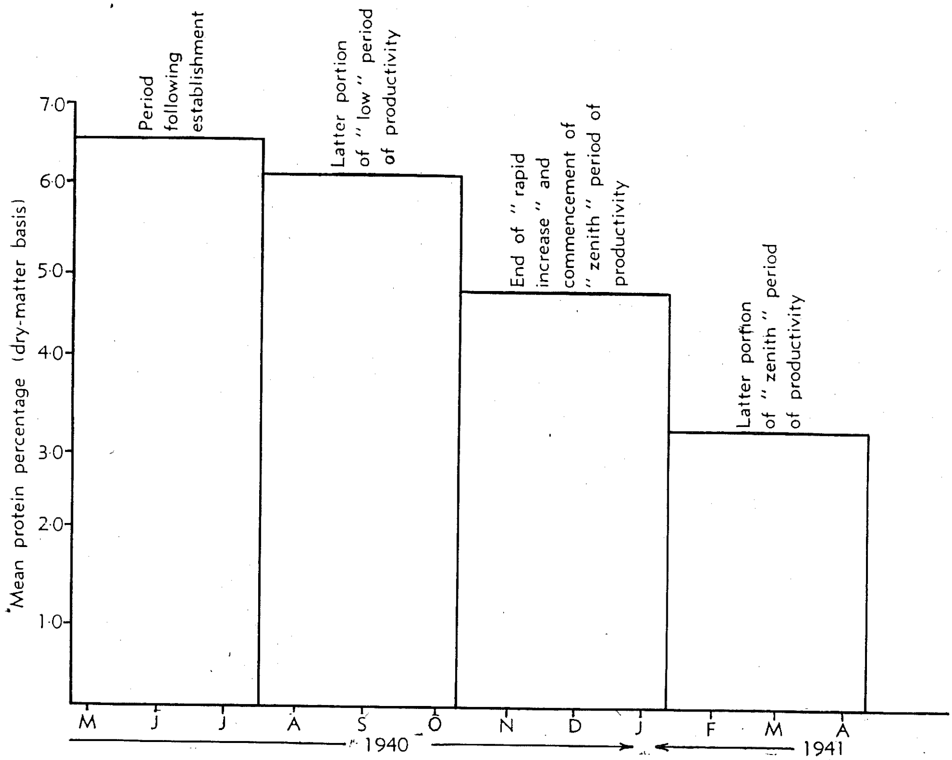

Figure 5.

Showing the seasonal variation in the mean protein percentage of 19 grasses under a system of three-monthly cutting during the first 12 months.

Figure 5 shows in the form of a histogram the characteristic pattern of protein composition during the first 12 months under a system of three-monthly cutting.

AN EXCEPTION TO THE GENERAL PATTERN OF PROTEIN YIELD.

The effect of the meteorological conditions on herbage yield and on protein content throughout the year, under coastal conditions in northern Queensland, involves two contrasting and reciprocal phenomena: summer rainfall conditions promoting herbage yield but limiting protein production, and dry winter influences inhibiting herbage growth but stimulating protein formation. The individual reactions of the various grasses to these seasonal effects have been discussed, and it now remains to determine the general pattern of protein yield, and any exception which may occur among the grasses studied. The figures in Table 7 show the effect of season on protein yield under a system of three-monthly cutting, and Figure 6 demonstrates the marked variation which occurs in yield in each productivity period. The variation applies to 17 out of 19 grasses—*Panicum maximum* No. 1200 was excluded because no yield figure was available for one cut and *Hyparrhenia aucta* because of its exceptional behaviour.

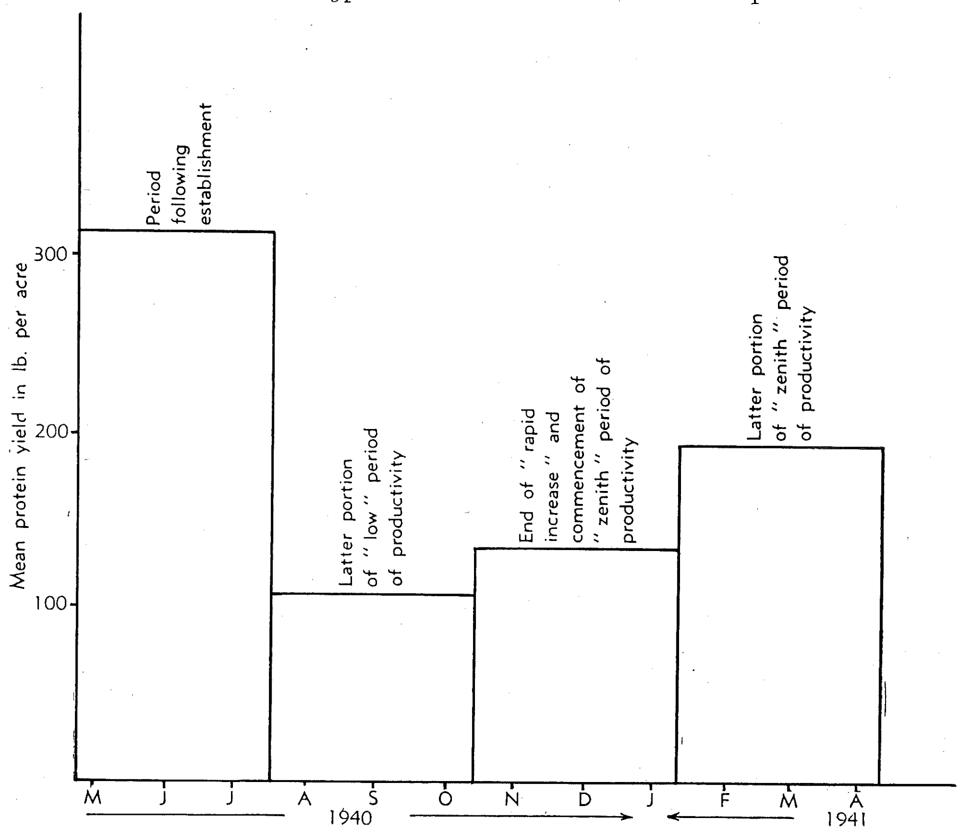

Figure 6.

Showing the seasonal variation in the mean protein yield of 17 grasses under a system of three-monthly cutting during the first 12 months.

This yield pattern is common to each cutting rotation, subject to the differences in herbage yield and protein content resulting under the different cutting systems which have already been examined. In general, it will be observed that the grasses which produced the highest herbage yields also produced the highest yields of protein per acre, but there are a number of exceptions. However, it is not total yield which is now being examined, but the pattern of protein yield, and the figures show that one grass, *Hyparrhenia aucta,* is quite different in this respect. The explanation of this exceptional behaviour is to be found in the different growth periodicity characteristic of this grass (Schofield, 1944). Figure 7 contrasts the yield of protein in pounds per acre from *H. aucta* with that from *Pennisetum clandestinum, Panicum maximum* var. *typica,* and *Cynodon plectostachyum* under three-monthly cutting during the first 12 months. It will be observed that, from July to January, the trend of protein yield from *H. aucta* is practically the reverse of that from *Panicum maximum* var. *typica.* From July to October, the yield of protein with *Hyparrhenia aucta* rises to a maximum, whereas with *Panicum maximum* var. *typica* it falls to a minimum;

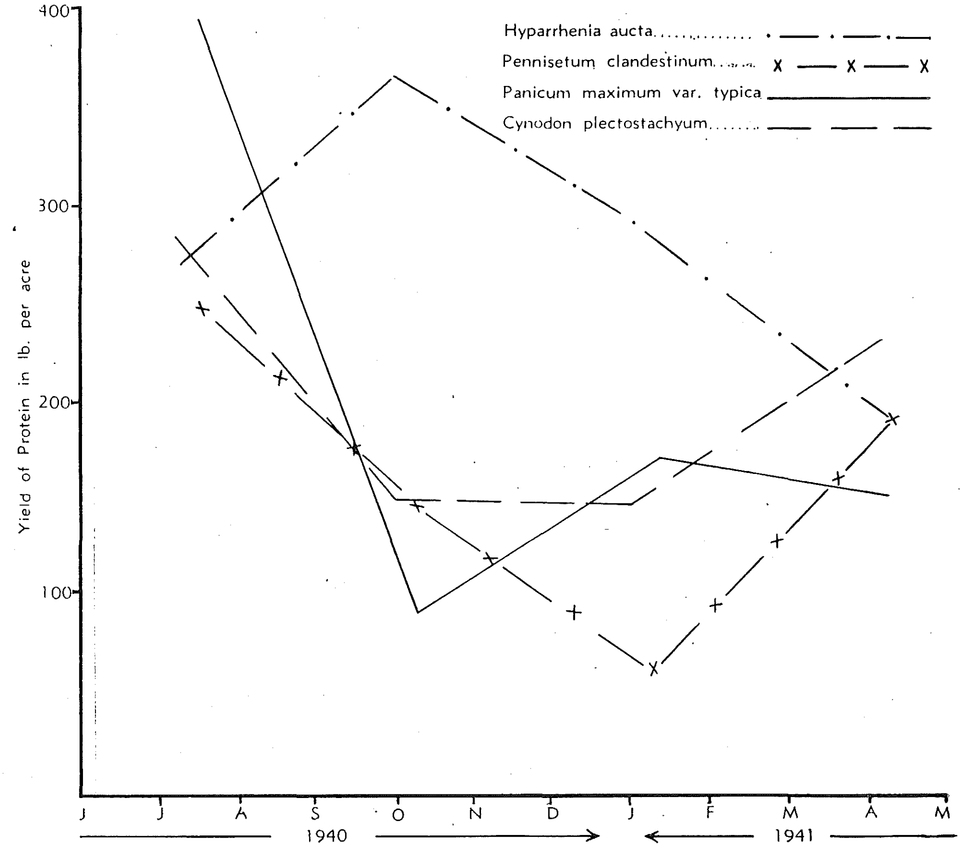

Figure 7.

Contrasting the variation in protein yield of four grasses under a system of three-monthly cutting.

and from October to January the protein yield of *Hyparrhenia aucta* falls and that of *Panicum maximum* var. *typica* increases. *Cynodon plectostachyum*, although it possesses the general pattern of protein yield, differs in not falling below 151 lb. per acre during the "rapid increase" period of productivity, and *Pennisetum clandestinum* is characterized by reaching its minimum value in early January and then increasing rapidly in protein during the "zenith" period.

The exceptional behaviour of *Hyparrhenia aucta* is important, because, if a similar form of crude-protein yield curve could be obtained with a palatable, aggressive, persistent species, it may facilitate solution of a serious problem of animal husbandry in Queensland—the acute seasonal shortage of protein in grass herbage from April until good summer rainfall conditions occur.

RELATIONSHIP BETWEEN PROTEIN AND FIBRE CONTENT.

Table 15 shows the fibre and protein percentages of a number of grasses at various periods under different systems of cutting.

The chief points of interest in these figures may be summarized as follows:—

1. Fibre percentage decreases with increase of intensity in the cutting system. Thus under a system of two-monthly cutting for the period May-June the mean fibre percentage shows an increase of 3·7 per cent. over the corresponding figure obtained with a system of monthly cutting. The mean for a system of three-monthly cutting during the period June-July exceeded that under the monthly system (May-June) by 7·1 per cent.

2. In the "low" period of productivity, when inflorescence emergence is very restricted, the proportion of stem to leaf tends to be at a minimum for most grasses, which results in a low fibre content. Thus for the period of September-October (latter part of "low" period) under a system of two-monthly cutting the mean fibre decreased by 4·5 per cent. compared to the May-June cut; similarly under a system of three-monthly cutting the mean fibre for September-October was 30·5 per cent., whereas in June-July the mean was 32·7 per cent. It is of interest to observe that under a system of two-monthly cutting the three grasses—*Hyparrhenia aucta* and *Chloris gayana* Nos. 6586 and 6585—which possess a fibre percentage exceeding 30 per cent. (September-October) are grasses which show inflorescence emergence at that period.

3. Fibre percentage tends to reach a maximum in the "zenith" period of productivity—the time of maximum inflorescence emergence—and under a system of three-monthly cutting the mean for eight grasses exceeded 40·0 per cent.

4. There is an inverse relationship between the protein and fibre contents of the various grasses under all systems of cutting, a fact which has been observed by many workers, e.g., Evans (1931), and Fagan and Milton (1931) at Aberystwyth, Archibald and associates (1932) in Massachusetts and Du Toit and associates (1935) in South Africa.

DISCUSSION.

The two main conclusions which can be drawn from this investigation refer to:—(1) the effect of seasonal productivity on the protein production

Table 15.

FIBRE AND PROTEIN PERCENTAGES (MOISTURE FREE BASIS) OF A NUMBER OF GRASSES AT VARIOUS PERIODS UNDER DIFFERENT SYSTEMS OF CUTTING.

Grass.	Monthly Cut.				Two-monthly Cut.				Three-monthly Cut.					
	2nd (May-June)		13th (April-May)		1st (May-June)		3rd (Sept.-Oct.)		1st (June-July)		2nd (Sept.-Oct.).		4th (March-April).	
	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.
							SERIES 1.							
Urochloa bolbodes	28·1	13·2	33·0	9·0	33·1	10·8	25·2	10·3	33·8	7·6	25·1	9·3	..	..
Digitaria milanjiana	26·4	16·7	36·1	8·9	31·0	11·4	27·5	10·3	31·5	10·1	28·1	8·8	..	..
Paspalum dilatatum	34·1	13·6	33·5	8·9	33·2	10·5	27·1	8·3	35·1	8·0	28·3	7·4	..	..
							SERIES 2.							
Hyparrhenia aucta	31·6	13·6	39·9	8·6	34·6	9·3	36·5	7·4	38·7	6·4	36·4	6·7	44·6	3·4
Panicum maximum var. *coloratum*	29·8	15·7	31·8	8·7	35·2	8·7	26·3	7·2	37·2	7·0	29·4	5·9	45·4	3·0
Brachiaria decumbens ..	28·4	12·0	26·0	7·6	34·0	7·6	28·3	5·6	38·7	5·4	29·3	5·4	39·8	1·9
Chloris gayana No. 6586 ..	34·9	10·1	33·9	8·4	39·2	6·1	34·1	4·4	38·1	5·0	35·0	3·8	40·6	2·7
							SERIES 3.							
Pennisetum clandestinum ..	22·6	17·9	30·8	11·0	26·0	13·8	27·5	8·8	34·3	8·6	28·1	8·1	34·6	5·3
Panicum maximum var. *typica*	27·9	15·3	29·9	9·9	36·0	7·7	26·2	7·2	40·6	4·9	28·0	6·7	42·3	2·7
Chloris gayana No. 6585 ..	37·9	7·4	38·5	7·4	37·2	10·3	34·1	4·7	43·5	4·3	35·0	3·5	42·2	3·0
Melinis minutiflora	29·3	13·6	30·8	8·4	32·3	10·7	29·2	7·1	37·8	7·5	32·4	6·1	38·1	3·6
Mean	30·1	13·6	33·1	8·8	33·8	9·7	29·3	7·4	37·2	6·8	30·5	6·5	40·9	3·2

potential of the various grasses, and (2) the significance, under the same soil-climatic conditions, of particular species relative to their efficiency of elaboration of protein throughout the year.

The results demonstrate that the protein content of the grasses follows a marked seasonal pattern, there being a negative correlation between herbage dry-matter yield and protein content. An inverse relationship between fibre and protein content also exists under each system of cutting. There is a serious deficiency of protein throughout the "rapid decrease" and "low" periods of herbage productivity—comprising autumn, winter and early spring—under conditions in coastal northern Queensland. The obvious line of approach towards a solution lies in the introduction of suitable legumes into pastures, and establishment of areas under satisfactory species—representing a phase of legume dominance—including summer-growing types such as species of *Centrosema, Pueraria* and *Stylosanthes* and selected strains of *Cajanus cajan*, and possibly winter-growing legumes. Another line of research is also opened up by the exceptional behaviour of *Hyparrhenia aucta* in this experiment relative to protein yield, namely the use of perennial grasses which possess the characteristic of high-protein yield during the cooler months. Such grasses require to be palatable, aggressive and persistent, but unfortunately *Hyparrhenia aucta* is not palatable.

The marked differences in protein content and in protein yield between the various species is another outstanding feature of the results. It is apparent that, under the same soil-climatic conditions, certain species possess ability to make more effective use than others of soil nutrients in the elaboration of protein. Notable among these protein-rich grasses are the leafy species: *Urochloa bolbodes, Digitaria milanjiana* and *Pennisetum clandestinum*. Of the three, only the last-named represents a species which is sufficiently aggressive and persistent to be of value under certain conditions in coastal Queensland. At the opposite extreme is a number of stemmy grasses which are protein-poor. Table 6 shows that there is no significant difference under three-monthly cutting between 10 of these grasses. The fact that *Chloris gayana* (Rhodes grass) consistently shows the smallest protein content is a feature of the results. Edwards and Goff (1935) in Hawaii found that Rhodes grass contained the lowest protein content of the five grasses examined: they also found that paspalum was slightly higher in protein than Kikuyu grass.

Perhaps the most important conclusion from this experiment, however, is that the same fundamentals of pasture growth—as, for example, the relationship between dry-matter herbage yield and protein content, fibre and protein content, and the influence of seasonal productivity on the relative proportion of leaf to stem—are operative not only in the temperate zone, but also under tropical conditions.

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