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Studies on the Influence of Nitrogen on the Productivity of Tropical Herbage Plants in Sri Lanka

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スリランカ国における熱帯性牧草の生産性に及ぼす窒素施用の影響

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INTRODUCTION

Economic circumstances and food balance

In Sri Lanka the climatic conditions and geographical features are so variedly distributed that there are infinite potentialities for agricultural production, if each of the different climatic zones is effectively utilized by the application of scientific methods. The present situation, however, is virtually the result of the agrarian revolution in Sri Lanka during the past century. This applies particularly to the large-scale production and processing of agricultural export commodities, such as tea, rubber and coconuts, which take up about two-thirds of the available agricultural land on the island and contribute 86.8 per cent of the total value of exports. In addition, people engaged in agriculture, directly or indirectly constitute more than 75 per cent of the total population, and capital for the development of agriculture as well as any industries is rather scarce (BENSH, 1965). The current world shortage of staple food items, such as rice or wheat, is likely to continue for many years. The value of Rs. 961 million according to the Annual Report of the Central Bank of Ceylon (1972), was used for the import of food. With the increasing disadvantage of tea and rubber owing to tumbling prices, it is necessary to diversify the agricultural economy of Ceylon and attain self-sufficiency in foods.

In its Third World Food Survey (1963), F.A.O. suggests that the required nutrients

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per person per day are 2550 Calories, 75 grams of total protein and 31 grams of animal protein; while these essential nutrients are consumed at low levels in Ceylon, to cite an example, 2180 Calories, 48 grams of total protein and 11 grams of animal protein in 1968. To achieve the target estimated by F.A.O., supplies of protein will have to be increased. There is no doubt that an increase of animal production will result in consuming animal protein by people in sufficient levels, and result in the improvement of unbalanced starchy diets. In recent years the actual requirement of food for domestic use are increasing, therefore the food balance seems to be improved somewhat. Milk, egg and fish production recorded an increase of 37.0, 7.3 and 16.7 per cent, respectively, in 1972. People on an average consume somewhat more milk than formerly.

Potential for animal production

The mid-country at elevations ranging from 450 to 1200 meters is now largely under tea plantation. Many agriculturists have been pointing out that grassland farming is one of the most suitable in this region, particularly on uneconomic tea plantations. The agricultural diversification of marginal tea land in the mid-country is likely to release an area of about 39,000 hectares. This vast area is capable of maintaining about 200,000 head of temperate-breed cattle on improved pasture with a milk production potential of over 400,000 kg per day, which is comparable with 620,000 kg of total milk production per day in 1972 (PERRERA, 1970). Of these potentialities, the Medium Term Plan (1972-77) will undertake to establish about 2,000 hectares of improved pasture for supporting 4,000 head of high producing stock.

It is therefore necessary to demonstrate clearly the capacity for dry matter production and the feeding value of recommended grasses and legumes in the mid-country situation.

Soil conditions

The majority of rocks in the island are ancient crystal-line rock belonging to the Archean or Pre-Cambrian Age and soils are restricted to development from siliceous parent material (JOACHIM, 1935). The mid-country soil is mostly inclined in the reddish brown lateretic soil, which merges into the red-yellow podzolic soil occurring in the up-country (MOORMAN & PANABOKKE, 1961). The mid-country soil has a low inherent fertility level with accumulating surface organic matter being low. Nitrogen and phosphorus are outstandingly deficient. As for its desirable physical properties, water infiltration is rapid and the soil responds well to fertilization, although at the same time having a low utilization rate of fertilizer applied. To achieve intensive development of pasture, nitrogen has to be applied at comparatively high levels.

Characteristics of tropical grasses

It is estimated that there are about 10,000 species of grasses (Cramineae) in the world. Of these only about forty are used in the establishment of sown pastures.

The majority of the species used in the cultivated pastures of tropical territories originated in the East African region (eight species), and in the sub-tropical South American region (four species) (HARLEY & WILLIAMS, 1956). Very few species are cultivated to any appreciable extent in tropical pasture. Many tropical grasses possess a very high potentiality in photosynthesis. According to estimates by COOPER (1970), their photosynthetic rates are over 70 mg CO_2/cm^2 per hour, equivalent to conversion rates of 5-6 % at these high light intensities, in contrast to many temperate grasses with 20-30 mg CO_2 per hour, equivalent to 2-3 %. In the actual situation, however, they rarely grow with these high potentialities because of intensive rains followed by subsequent dry seasons. Seasonal water shortage is an important factor limiting the productivity and soil fertility in tropical grasslands.

Outline of tropical legumes

According to NORRIS (1956), the original legumes are thought to have been large trees in the wet tropics. In adaptation to drought and cold, the growth forms of legumes have been progressively reduced from tree to herb, from large fleshy fruits to small pods, and from perenniality to annuality. At the present time, three tribes of sub-family Papilionatae, namely Vicieae (vetches), Trifolieae (clovers) and Loteae (birdsfoot trefoil), occur entirely in the temperate zone (ANDREW & NORRIS, 1961), wherein they contribute to high productivity and feeding value in pastures. On the other hand, tropical legumes preserve ancestral properties of being so woody or so coarse that they are of poor quality in productivity, nutritional value, and palatability as feed for cattle. The strains of Rhizobia associated with tropical legumes are also recognized as being of the ancestral type of symbiont, characterized by the slow-growing and alkali-producing types. WHYTE, *et al* (1953) point out that the utilization of tropical legumes which can nodulate and grow successfully on low fertile soil is now limited to the following genera;

Tribe	Genera
Galegeae	*Indigofera*
Hedysareae	*Alysicarpus, Desmodium, Stylosanthes*
Phaseoleae	*Dolichos, Glycine, Phaseolus, Pueraria Stizolobium, Vigna*

Legumes native to Ceylon

Perennial legumes such as *Indigofera endecaphylla* Jacoq., *Calopogonium mucunoides* Desv., *Centrosema pubescens* Benth., and *Pueraria phaseoloides* Benth , have been mostly used as cover crops in the tea, rubber or coconut plantations (MURRAY, 1931, JOACHIM, 1931 and SAMPSON, 1928). In many tropical countries, however, these legumes are being given importance in pastures because of both nutritive value and quick growth recover after defoliation. *Alysicarpus vaginalis* DC., *Desmodium triflorum* DC , *D. heterophyllum* Wall and *D. heterocarpum* DC. are commonly found in natural grasslands and have been fed to local cattle (PAUL, 1947 and ROSAYRO, 1956). At present, many species of exotic legumes have been introduced into Ceylon and some of these are under study.

Experimental

To study the influence of nitrogen on dry matter production of herbage plants, four experiments in two parts were commenced on October 2nd, 1973 and concluded on April 16th, 1974 during the main Maha season (N. E. MONSOON period) at the Department of Animal Husbandry, University of Sri Lanka, Peradeniya Campus.

PART I. THE EFFECT OF APPLYING HIGH LEVELS OF NITROGEN ON FIVE PASTURE GRASSES

Introduction

On tropical soils nitrogen supply is the principal factor limiting production so that to obtain high dry matter and protein yield, nitrogen has to be applied continually. APPADURAI (1970) concluded from recent grassland researches in Ceylon that the return of herbage dry matter per pound of nitrogen applied was approximately 30 pounds in both the Brachiaria and the Pangora pasture. It is usually observed that the quality, palatability and total yield are increased by application of elemental nitrogen. In some trials, however, high dosages of nitrogen over 400 pounds per acre reduced palatability (MCILOY, 1964) and increased the lignin content which depressed digestibility of forages (PRINE & BURTON, 1956). Another effect of nitrogenous fertilizer was reported by VINCENT-CHANDLER & FIGARELLA (1958) who stated that the application of nitrogen at the end of the rains raised the protein content of the dry-season growth, resulting in maintaining a high protein content in the standing dry fodder. Although many studies indicate the profitability of applying nitrogen, due to both the generally high cost and the temporal effects of nitrogen fertilizers, its utilization is limited to intensive dairy farming.

The present experiment was conducted to evaluate the dry matter yields of five pasture grasses under high nitrogen application. The five pasture grasses used were Paspalum (*Paspalum plicatulum* Michx.), Coastal Bermuda grass (*Cynodon dactylon* Pers. & Linn.), Ruzi grass (*Brachiaria ruziziencis* Germain & Everard), Para grass (*B. mutica* Stapf. & Forsk.), and Signal grass (*B. brizantha* Stapf. & Hochst.).

Materials and methods

A randomized block design was used on setting plots. Fifteen treatments comprising five species of grasses at three levels of nitrogen application were replicated four times. The size of each plot was 15×15 feet. The pastures were established in the field in May, about five months prior to the commencement of the trial. Plants were evenly spaced at a distance of 6×6 inch in each plot. All plots were fertilized uniformly with a basal application of 100 lb K_2O and 50 lb P_2O_5 per acre. Nitrogen fertilizer as urea was applied at the rate of 75, 150 and 225 lb per acre for six months at monthly intervals.

The swards were defoliated to within one inch of the soil surface by the "Allen Cut" mowing machine. Yields were estimated from sample harvestd in a swath 15×3 feet. To estimate the leaf/stem ratio, sub-sample of 4 to 10 ounces (100–250 grams) were taken and separated to leaf and stem. Yield estimates were based on sample from regular harvests at monthly intervals throughout the experimental period.

The entire samples of herbage were then dried in a unitherm drying oven at 100°C for six hours. A representative sub-sample from the first harvest was used for the estimation of crude protein. Total nitrogen was determined by Kjeldahl's method. The crude protein content was estimated by multiplying the total nitrogen content by 6.25.

Result

Fig. I shows the mean monthly temperature and monthly total rainfall in the

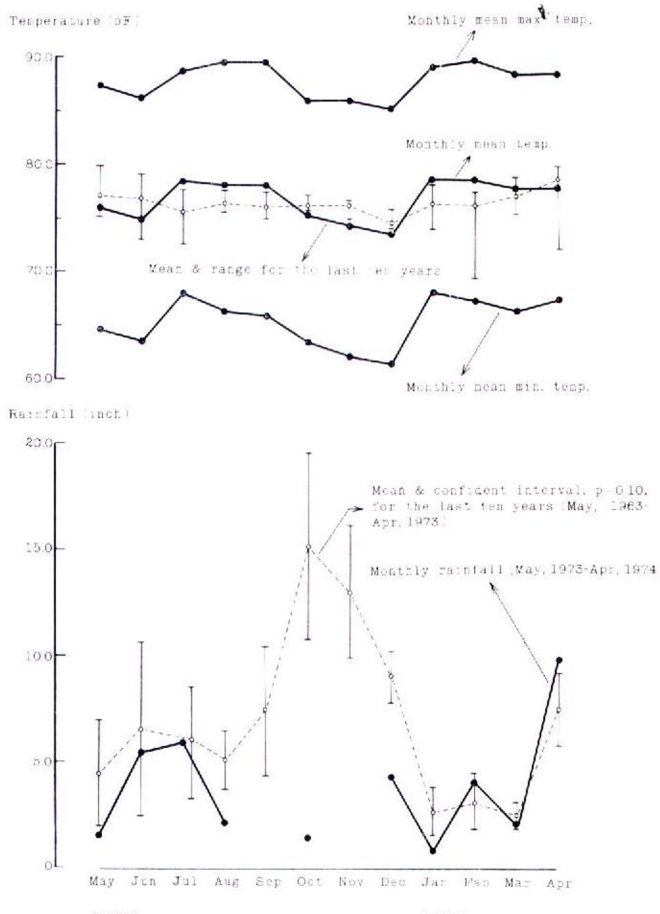
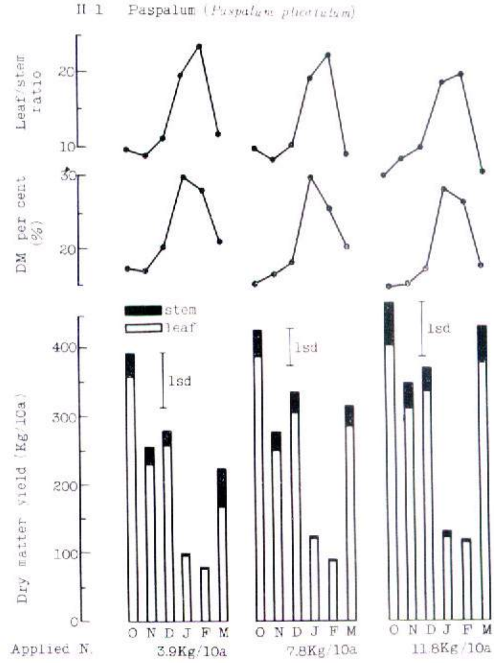


Fig. I Rainfall and temperature

period of the experiment and during the last ten years. In September and November, 1973, no rain was recorded. This period is usually called the Maha season with marked seasonal concentrations of rainfall, separated by a dry period, in February March before the onset of the next rainy season called the Yala. The abnormal pattern of rainfall was clearly recognized by comparision with the mean value and its confidence intervals ($p=0.10$) for the last ten years. The annual rainfall in 1973 was extremely low with the value of 26.12 inches as against 90 inches for the last ten years.

Fig. II-1, 2, 3, 4, 5 gives the monthly variation of dry matter yield, dry matter percentage and leaf/stem ratio. The same pattern of herbage production was observed in all five grasses. Peak production occurred at the first sampling, except in Para grass at the highest nitrogen application. In spite of persistent drought, residual moisture was apparently sufficient for plant growth to continue for the first three months. During the months of January and February, herbage production was considerably depressed, at the mean decreasing rate of 80 to 90 per cent. The lack of moisture appeared to disturb normal plant growth. With the advent of rain, grass yields increased. In all plots under the highest nitrogen application (225 lb/acre), dry matter yield at the sixth harvest was as high as of the first. Rich rain appeared to have accelerated the effect of nitrogen on herbage production. Only Coastal Bermuda grass produced a low yield. This was due to slow vegetative gowth after defoliation, resulted in weed growth.

II 1 Paspalum (*Paspalum plicatulum*)



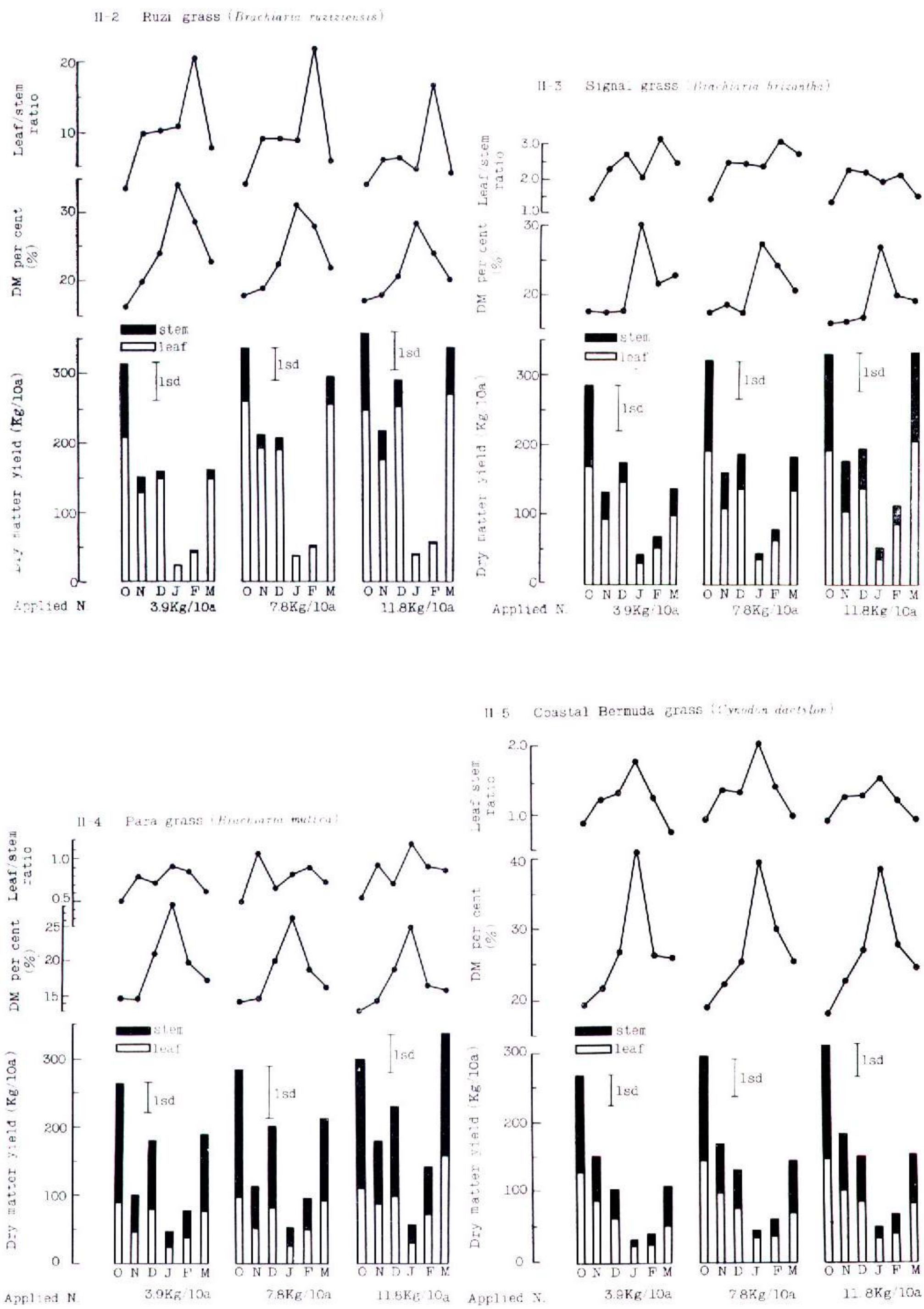


Fig. II Pattern of dry matter yield, DM per cent, and leaf/stem ratio of five pasture grasses during the Maha season (Oct. 1973–Mar. 1974)

Dry matter percentage was correlated negatively with dry matter yield in all five grasses. Nitrogen application tended to depress dry matter percentage.

A leaf/stem ratio of Paspalum and Ruzi grass was fairly variable within the wide range of 6 to 23 and 2 to 22, respectively (Table I). The highest value was observed at the lowest herbage production at the fifth harvest. On the other hand, Signal grass, Para grass and Coastal Bermuda grass maintained constant values of 3 to 1, 1 to 0.5 and 2 to 1, respectively. In the later three grasses which possess a prostrate habit of growth, the leaf/stem ratio was less influenced by the water stress. The grand mean during the whole period is shown in Table I. It was evident that the leaf/stem ratio of the former two grasses decreased linearly up to 75, 150 and 225 lb nitrogen fertilizer, respectively. On the other hand, there was no significant difference between the three levels of nitrogen application in the latter three grasses.

The mean total herbage production from six harvests was significantly increased by nitrogen application (Table II). With respect to nitrogen efficiency, Paspalum showed little evidence of advantage over the other grasses. Coastal Bermuda grass appeared to be unresponsive to nitrogen application.

The percentage of crude protein in the dry matter is shown in Table III. It was clear that high dressings of nitrogen increased crude protein content. There were fair variations between grass species. Paspalum and Ruzi grass, which yielded high dry matter, tended to maintain low values of the percentage of crude protein, from 10 to 11 per cent. On the other hand, Signal grass, Para grass and Coastal Bermuda grass, which yielded comparatively low herbage, maintained high values from 13 to 16 per cent.

There was a high correlation between crude protein yield and applied nitrogen. Paspalum was superior to the other grasses with respect to the mean value of crude protein yield, but at the highest application of nitrogen (225 lb/acre), Signal grass and Para grass were a little higher than Paspalum. This difference was due to nitrogen

Table I. Mean leaf/stem ratio estimated from six monthly harvests of five pasture grasses during the Maha season (Oct. 1973–Mar. 1974)

Pasture grass	Urea levels per acre applied during six months of the trial						Mean
	75 lb/ac (3.9 kg-N/10a)		150 lb/ac (7.8 kg-N/10a)		225 lb/ac (11.7 kg-N/10a)		
	Mean	Confidence limits	Mean	Confidence limits	Mean	Confidence limits	
Paspalum	13.6	11–16*	12.0	9–15	11.3	8–14	12.3
Ruzi grass	10.1	7–13	9.1	6–12	6.7	6–9	8.7
Signal grass	2.5	2.0–3.0	2.5	2.1–2.9	2.2	1.8–2.6	2.4
Para grass	0.7	0.6–0.8	0.8	0.7–0.9	0.9	0.8–1.0	0.8
C. Bermuda grass	1.2	1.0–1.4	1.3	1.1–1.5	1.3	1.0–1.6	1.2

* The figure shows the confidence limits at $P=0.05$

Table II. Yield estimates from six monthly harvests of five pasture grasses during the Maha season

Pasture grass	N-levels applied dur. 6 mon. (X)	Fresh herb. yield in 1,000 Kg/10a	Dry matter yield (Y) Mean (kg/10a)	Linear equat.
Paspalum	3.9 kg	6.6	1,250	
	7.8	8.2	1,430	Y=56 X+1020
	11.7	10.2	1,690	r=0.83
	Mean	8.3	1,460	
Ruzi grass	3.9 kg	4.1	810	
	7.8	5.4	1,100	Y=54 X+620
	11.7	6.5	1,230	r=0.85
	Mean	5.3	1,050	
Signal grass	3.9 kg	4.4	820	
	7.8	5.0	940	Y=41 X+650
	11.7	6.6	1,140	r=0.91
	Mean	5.3	970	
Para grass	3.9 kg	4.6	800	
	7.8	5.2	890	Y=50 X+560
	11.7	7.4	1,190	r=0.80
	Mean	5.7	960	
Coastal Bermuda grass	3.9 kg	3.1	680	
	7.8	3.7	830	Y=22 X+620
	11.7	3.9	860	r=0.67
	Mean	3.6	790	
		CV=10.2%	CV=10.6%	
		LSD=0.83	LSD=158	

Table III. C. Protein per cent and yields estimated from six monthly harvests of five pasture grasses during the Maha season (Oct. 1973–Mar. 1974)

Pasture grass	N-levels applied dur. 6 mon. (X)	C. P. per cent Mean (%)	C. P. per cent Range	C. P. yield (Y) Mean (kg/10a)	C. P. yield (Y) Linear equat.
Paspalum	3.9 kg	9.9	9–10	124	
	7.8	10.2	9–11	147	Y=6.4 X+98
	11.7	10.3	10–11	174	r=0.87
	Mean	10.1		148	
Ruzi grass	3.9 kg	10.6	10–12	86	
	7.8	11.0	9–13	121	Y=7.2 X+60
	11.7	11.7	10–14	142	r=0.88
	Mean	11.1		116	
Signal grass	3.9 kg	14.2	13–17	104	
	7.8	14.7	14–17	138	Y=10.1 X+63
	11.7	16.0	15–18	181	r=0.92
	Mean	14.7		141	
Para grass	3.9 kg	11.5	10–13	92	
	7.8	12.6	12–14	112	Y=10.8 X+43
	11.7	14.8	14–16	177	r=0.87
	Mean	13.0		127	
Coastal Bermuda grass	3.9 kg	12.6	12–14	86	
	7.8	14.0	12–16	115	Y=5.0 X+69
	11.7	14.6	13–16	125	r=0.78
	Mean	13.7		108	
		CV=7.9%		CV=11.7%	
		LSD=1.42		LSD=21.3	

efficiency. Coastal Bermuda grass showed the lowest value of crude protein yield and nitrogen efficiency.

Discussion

The experiment was conducted in order to ascertain the performance of herbage production of five pasture grasses. In terms of ability to survive and to spread by vegetative methods, Signal grass, Para grass and Coastal Bermuda grass are classfied as being of the prostrate ecotype which is advantageous in covering the soil surface completely. Paspalum and Ruzi grass send active runners and are likely to form a dense mass. In the experiment, this difference in ecotype that directly relates to systems in the soil contributed to the differnces observed in leaf/stem ratios. Prostrate grasses were not always influenced by high dressings of nitrogen. It has been shown by many workers that in pasture grasses the percentage of crude protein and digestible crude protein are very much higher in the leaves than in the whole plant. However, in Paspalum and Ruzi grass having a high leaf/stem ratio comparatively low values were observed with respect to the percentage of crude protein. The important factor in the relation between the leaf/stem ratio and the percentage of crude protein remains to be considered. However, based on actual observations, this would seem to be due to the differences with response to individual species to applied nitrogen.

From the stand point of total yield and yield contribution, it would appear that Paspalum is outstanding; the three species of *Brachiaria* followed. Coastal Bermuda grass is considered to be unsuitable for the mid-country situation because of both slow recovery after defoliation and poor resistence to drought.

The response to fertilizer nitrogen was 56, 54, 41, 50, and 22 kg of dry matter per kg of nitrogen applied in a pure stand of Paspalum, Ruzi grass, Signal grass, Para grass, and Coastal Bermuda grass, respectively. In the case of Signal grass, the same value of nitrogen efficiency has been reported previously by SIVALINGAM (1964). Nitrogen efficiency appeared to be governed by soil moisture. The factor which probably contributed to this interaction was the inactivity of applied nitrogen, which was less absorbed by plants under these conditions. Nitrogen remaining on the soil surface would be lost by ammonia volatilization or as nitrogen gas. With the advent of rain, herbage production responded increasingly to the nitrogen applied.

The response per kg of nitrogen applied in terms of crude protein was 5–10 kg of crude protein in the grasses. A similar value was observed by SEMPLE (1970).

PART II. THE NITROGEN REPLACEMENT VALUE OF LEGUME GROWN IN ASSOCIATION WITH GRASS

Introduction

It is well known that legumes are advantageous in obtaining nitrogen through the activity of symbiotic root nodule bacteria, and also in improving the quality of feed due to the relatively high contents of crude protein, calcium and fat in most legumes. The early experiments in the dry zone of Ceylon (FERNANDO, 1961) indicated that dry matter yields in the grass/legume mixture were significantly superior to those of grass in pure stand. The average daily live-weight gains of yearling steers were also higher on legume-containing pastures than on those without legumes (Van KENSEN & HEINEMANN, 1958). Particularly at the present time owing to the comparatively high cost of nitrogen fertilizer and the economic condition of Ceylon, the possible supply of nitrogen by legumes becomes a matter of great importance.

In spite of enormous efforts to maintain satisfactory grass/legume mixture, there has been little success in incorporating and sustaining legumes into pastures. The growth habits of tropical grasses and the ecological nature of tropical grasslands appear to hinder the survival of legumes.

Unfortunately, there is little exact information on the associated growth of grass and legume under Ceylon conditions. More research is required into the grass/legume relationship in swards and the nitrogen replacement value by legumes.

To estimate the associated growth in mixtures, four exotic legumes, viz, Green-leaf (*Desmodium intortum* Urb.), Siratro (*Phaseolus atropurpureus* Moc. & Sesse.), Perennial Soybean (*Glycine javanica* Linn.) and Silver-leaf (*Desmodium uncinatum* DC.) were grown in association with two popular grasses namely, Setaria (*Setaria sphacelata shumac.* Stapf & Hubbard, var. Nandi) and Guinea grass (*Panicum maximum* Jaqnin).

Materials and methods

Experiment 1: To estimate the associated growth in mixture, three exotic legumes, namely, Green-leaf, Siratro, and perennial soybean in all combinations were mixed with Setaria and Guinea grass. The eighteen treatments comprising inter actions of six grass/legume mixtures at three levels of nitrogen (75, 150 and 225 lb/acre during six months) were replicated four times

Experiment 2: To estimate the nitrogen replacement value of a nodulating legume with respect to the nitrogen requirement of the associated grass, a Setaria/Siratro mixture was compared with a pure stand of Setaria, at three levels of nitrogen (nil, 25 and 50 lb/acre during six months). The four treatments were replicated three times.

Experiment 3: Guinea grass was mixed with Silver-leaf. The other treatments were the same as in Experiment 2.

In each experiment, the size of plot was 4×10 feet. The 2×3×3 factorials in complete randomized block design was used on setting plots. Legume seeds were sown earlier in May 1973, approximately two months prior to the planting of grass. Legume was seeded in a row between two parallel rows of grass. In June, the fodder grasses were established in the field evenly and carried ten plants in each plot.

Prior to the commencement of the trial, all plots were cut uniformly to a height of 6 inches above ground level by a hand-cut. All plots fertilized equally with a basal application of 100 lb K_2O and 50 lb P_2O_5 per acre. Nitrogen was applied in 6 split doses at monthly intervals. Yield estimates were based on samples from regular harvests of a whole plot at monthly intervals. The yields of grasses were estimated directly by harvesting the entire plot, and then converting to yields per acre. The yields of legumes, however, were adjusted using a factor of 2, because one row of legume was planted in each plot against two rows of grass.

Results

Experiment 1: Fig. III shows the monthly variation in dry matter yields and dry matter percentage. Mean monthly dry matter yields varied with rainfall. During the first three months, dry matter yields in Setaria/legume mixtures continued to decline to a certain extent. On the other hand, Guinea/legume mixtures produced more dry matter at the second harest than the first. This was probably due to the difference in ability to withstand drought between Setaria and Guinea grass. The fourth harvest in February showed extremely low figures in all mixtures. With the advent of rain, grass components in mixtures recovered vigorous growth, whereas legume components in the Guinea/legume sward were retarded in growth more than in the Setaria/legume mixtures.

The percentage of dry matter in all plants had a wide range of variation which was well correlated with dry matter yields. Its peak coincided with the lowest yield of dry matter, with increasing rates of 16 % to 27 % in Guinea grass, 12 % to 19 % in Setaria, 19 % to 29 % in Green-leaf, 21 % to 28 % in Glycine and 16 % to 25 % in Siratro.

The mean total herbage production for the whole period is shown in Table IV. There were significant differences in yield between the Guinea/ and Setaria/legume mixtures. On the other hand, Setaria/legume mixtures produced a little more than Guinea/lequme mixtures with respect to fresh herbage production. The dry matter yield in the Guinea/Glycine and Setaria/Green-leaf had a wide variation between the four replications, so that mean value gave a reduction of yield with the higher rates of nitrogen application. The grass/Green-leaf mixtures had the highest and the grass/Siratro mixtures had the lowest proportion of legume in terms of dry matter yield. The highest rates of nitrogen application decreased the proportion of legume in the mixtures, although there was no significant reduction in grass/Glycine mixtures.

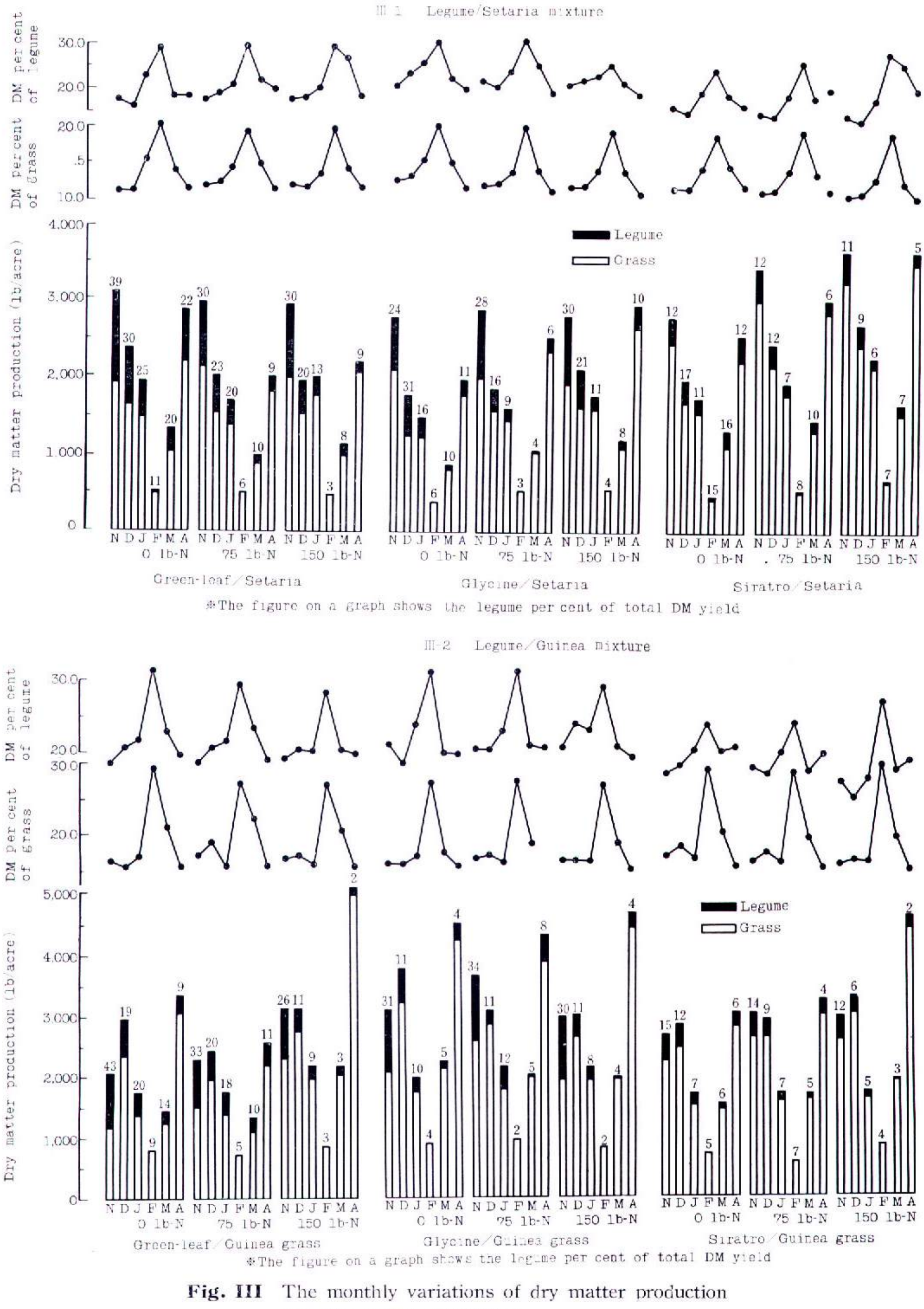


Fig. III The monthly variations of dry matter production and dry matter percentage.

Table IV Yield estimates of fresh and dry matter from six harvests of grass/legume mixtures in 1,000 lb/acre during the Maha season.

N levels per acre applied during 6 months of the trial	Fresh yield	DM yield mean (%)	DM yield Legume. compo.	Fresh yield	DM yield mean (%)	DM yield Legume compo.	Fresh yiedl	DM yield mean (%)	DM yield Legume compo.	Fresh yield	DM yield mean (%)	DM yield Legume compo.
	Guinea/Green-leaf			Guinea/Glycine			Guinea/Siratro			Mean		
75 lb−N	79	12.2	19	98	16.1	11	77	12.5	9	85	13.6	13
150 lb−N	60	10.8	18	94	16.2	12	79	13.2	8	78	13.4	13
225 lb−N	99	16.7	9	94	15.5	11	95	15.4	5	96	15.8	9
Mean	79	13.2	15	95	15.9	12	84	13.7	7	86	14.3	11
	Setaria/Green-leaf			Setaria/Glycine			Setaria/Siratro			Mean		
75 lb−N	91	12.2	27	67	9.1	16	88	11.0	13	82	10.8	19
150 lb−N	78	10.4	19	80	10.4	14	102	13.0	9	87	11.3	14
225 lb−N	81	10.8	17	87	11.4	16	128	14.7	7	99	12.3	13
Mean	83	11.1	21	78	10.3	15	106	12.9	10	89	11.5	15

CV in DM yield = 23.1%, CV in legume proportion = 36.8%
LSD in DM yield = 4.23, LSD in legume proportion = 5.3

Table V. Percentage of crude protein estimated from the first harvest of grass/legume mixture

N levels per acre applied duing 6 months of the trial	Guinea/ Green-leaf	Guinea/ Glycine	Guinea/ Siratro	Mean	Setaria/ Green-leaf	Setaria/ Glycine	Setaria/ Siratro	Mean
		Grass				Grass		
75 lb−N	14.6	14.3	12.5	13.8	17.3	16.4	14.6	16.1
150 lb−N	13.3	14.2	13.9	13.8	16.5	14.8	16.4	15.9
225 lb−N	15.4	14.3	13.6	14.4	17.0	16.4	16.9	16.8
Mean	14.4	14.3	13.3	14.0	16.9	15.9	16.0	16.3
				CV = 10.9%,	LSD = 2.35 per cent.			
		Legume				Legume		
75 lb−N	19.8	20.5	20.8	20.4	19.7	19.7	23.8	21.1
150 lb−N	20.6	20.5	19.4	20.1	19.7	20.5	22.4	20.9
225 lb−N	19.9	21.2	20.4	20.5	20.4	21.1	23.5	21.7
Mean	20.1	20.7	20.2	20.3	19.9	20.4	23.2	21.2
				CV = 6.6%,	LSD = 1.97 per cent.			

With respect to the percentage of crude protein of grass in the dry matter, significant differences were obtained between Guinea grass and Setaria (TableV). At harvest time, there was 100 per cent flowering in Guinea grass and 25 per cent flowering in Setaria. In the percentage of crude protein of legumes, F ratio for the grass treatment, legume treatment and grass/legume interaction from the analysis of variance showed a significant difference. There was no evidence of effect of nitrogen application on the percentage of crude protein in any of the grasses and legumes.

The grass/legume interaction with respect to the crude protein yield was also significant (Tabl VI). The effect of nitrogen application did not cause a significant increase in crude protein yields in any of the grass/legume combinations. The

Table VI. Yield estimates of crude protein from six harvests of grass/legume mixtures during the Maha season.

N levels per acre applied during 6 months of the trial	CP yield in 1,000 lb/acre	Legume propo. (%)	CP yield in 1,000 lb/acre	Legume propo. (%)	CP yield in 1,000 lb/acre	Legume propo. (%)	CP yield in 1,000 lb/acre	Legume propo. (%)
	Guinea/Green-leaf		Guinea/Glycine		Guinea/Siratro		Mean	
75 lb−N	1.9	24	2.4	16	1.7	14	2.0	18
150 lb−N	1.6	25	2.5	17	1.9	11	2.0	18
225 lb−N	2.6	12	2.3	16	2.2	7	2.4	12
Mean	2.0	20	2.4	16	1.9	11	2.1	16
	Setaria/Greeen-leaf		Setaria/Glycine		Setaria/Siratro		Mean	
75 lb−N	2.2	30	1.6	18	1.8	20	1.9	23
150 lb−N	1.8	22	1.7	18	2.2	12	1.9	17
225 lb−N	1.9	20	1.9	17	2.6	10	2.1	16
Mean	2.0	24	1.7	18	2.2	14	2.0	22

CV in CP yield=25.5%, CV in legume proportion=36%
LSD in CP yield=0.74, LSD in legume proportion=8.9

proportion of legume with respect to crude protein yield was similar to that with respect to dry matter yield, but there was no evidence of the difference between Guinea/ and Setaria/ legume mixtures.

Discussions

At each sampling, there were considerable variations in the yields of the different plots under the same treatment. It was not clear whether this variation was due to the suitability of the size of plot, to differences in the characters of plants or, as pointed by RUSSELL (1966), to differences in the propertion of the deeper sub-soil and plant-root penetrations.

It was observed that the growth pattern of legume was very different from those of grasses. As a result, legume plants in the mixture tended to decline in the face of the wet-dry-wet spells. Suppression of legumes was probably due to the effect of shading by the grass, especially by Guinea grass, and to increased competition for rooting space, nutrients and soil moisture. In addition, nitrogen fixation appears to have sensitively responded to climatic condition such as high temperature and the intensity of light.

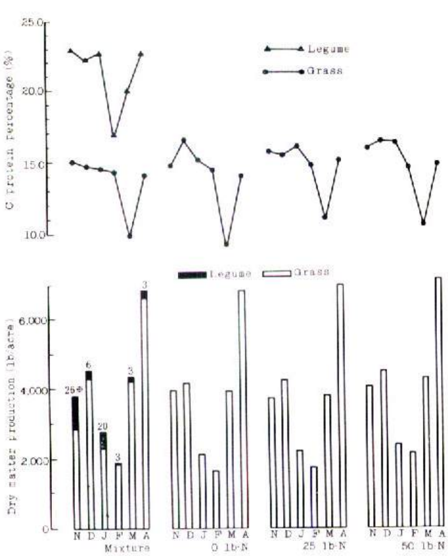
From the standpoint of the mean total dry matter yields, Glycine and Siratro were superior to Green-leaf. On the other hand, the proportion of legumes in the grass/Green-leaf sward was highest. The main factor causing this would probably have been the differences in the ecotype of the legume component which excercised an influence on the compatibility of the legume with grass in a mixed sward. Green-leaf is a semi-erect and stoloniferous bush, and apparently competes well with grasses for light, while Glycine and Siratro are prostrate trailing herbs, their growth governed by the extension of grass leaves.

It is well known that the higher rates of nitrogen application reduce the legume content in a grass/legume sward. In the experiment, the same tendency was generally observed. Only in the grass/Glycine mixtures, however, did heavy nitrogen dressings not cause a significant reduction in the proportion of legumes. It seems that Glycine hardly depressed the growth of grass stimulated by nitrogen application, at the same time, Glycine may have responded well to nitrogen application up to 225 lb/acre. There was a clear tendency towards a decrease in the percentage of crude protein at the nitrogen application of 150 as against 75 and 225 lb/acre for six months. This may have been due to many factors, one of which could be the influence of stage of growth of plants.

Although differences were observed between grasses, legumes and nitrogen application, there was only a very slight difference in the mean crude protein yield. On an average, the reduction in the quality of crude protein contributed by the legume was compensated by the increasing nitrogen fertilizer.

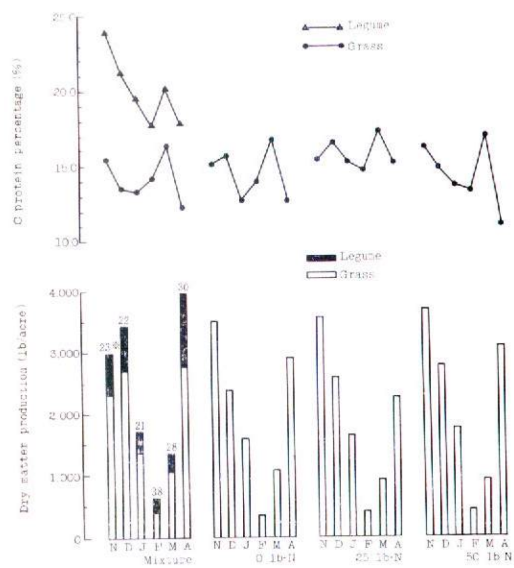
Experiments 2 and 3: Fig. IV and V show the monthly variations in the dry matter yield and the percentage of crude prtien in a mixture and a pure stand of grass. The monthly dry matter yields were markedly influenced by rainfall. The Setaria/Siratro mixture produced monthly from 1380 to 3980 lb/acre and the pure stand of Setaria produced from 360 to 3720 lb/acre. The Guinea/Silver-leaf mixture produced from 1870 to 6890 lb/acre and the pure stand of Guinea produced from 1660 to 6850 lb/acre.

Setaria/Siratro mixture maintained a high proportion of legume. On the other hand, the Guinea/Silver-leaf mixture reduced it after the fourth harvest with a figure



*The figure on a graph shows a legume per cent of total DM

Eig. IV Guinea-grass/Silver-leaf mixture



*The figure on a graph shows a legume per cent of total DM.

Fig. V Setaria/Siratro mixture

of 3 per cent.

With respect to the pattern of the percentage of crude protein, there was a marked difference between Setaria and Guinea. At the fourth harvest in May, Setaria gave the highest value with an increasing rate of about 3 per cent, as against Guinea which had the lowest value with a decreasing rate of 4 per cent of the percentage of crude prtein. That of legumes also varied from 18 to 24 and 17 to 23 per cent in Siratro and Silver-leaf, respectively.

The grass/legume mixtures were superior to the pure stand of grasses in dry matter yield during the whole peiiod (Table VII and VIII). In spite of 11 and 6 per cent reduction in the grass content in the grass/legume mixture cmpared with the

Table VII. Yield estimates of dry matter from six harvests of a Guinea/Silver-leaf mixture and a pure stand of Guinea during the Maha season

Treatment		Dry matter yield	
	Nitrogen levels applied during 6 months per acre (X)	Mean in lb/acre (Y)	Linear equation
Pure stand of Guinea	0 lb-N	23,000	
	25 lb N	23,000	$Y = 22,750 + 32X$, $r = 0.40$
	50 lb-N	24,600	
	Mean	23,500	
Guinea/Silver-leaf mixure		24,600 (100%)	
	Grass proportion	22,100 (90%)	
	Legume proportion	2,500 (10%)	

CV = 9.0%
LSD = 4,290 lb/acre

Table VIII. Yield estimates of dry matter from six harvests of a Setaria/Siratro mixture and a pure stand of Setaria during the Maha season.

Treatment		Dry matter yield	
	Nitrogen levels applied during 6 months per acre (X)	Mean in lb/acre (Y)	Linear equation
Pure stand of Setaria	0 lb-N	12,000	
	25 lb-N	11,800	$Y = 11,900 + 8X$, $r = 0.19$
	50 lb-N	12,400	
	Mean	12,100	
Setaria/Siratro mixture		14,300 (100%)	
	Grass component	10,700 (75%)	
	Legume component	3,600 (25%)	

CV = 7.5%
LSD = 1,900 lb/acre

Table IX. Percentage and yield of crude protein estimated from the first harvest of a Guinea/Silver-leaf mixture and a pure stand of Guinea.

	Treatment Nitrogen levels applied during 6 months per acre	Crude protein per cent Mean	Crude protein per cent Range	Crude protein yield in 1,000 lb/acre
Pure stand of Guinea	0 lb−N	14.0	9−17	3.20
	25 lb−N	14.9	10−16	3.36
	50 lb−N	14.7	9−17	3.60
	Mean	14.5	−	3.39
Guinea/Silver-leaf mixture		−	−	3.48 (100%)
	Grass proportion	13.7	8−15	2.98 (86%)
	Legume proportion	21.3	16−24	0.58 (14%)

CV=7.4%
LSD=0.50

Table X. Percentage and yield of crude protein estimated from the first harvest of a Setaria/Siratro mixture and a pure stand of Setaria

	Treatment Nitrogen levels applied during 6 months per acre	Crude protein per cent Mean	Crude protein per cent Range	Crude protein yield in 1,000 lb/acre
Pure stand of Setaria	0 lb−N	14.4	13−17	1.72
	25 lb−N	15.5	14−17	1.77
	50 lb−N	14.2	11−17	1.75
	Mean	14.7		1.75
Setaria/Siratro mixture		−		2.19 (100%)
	Grass proportion	14.1	12−16	1.46 (67%)
	Legume proportion	20.1	18−24	0.73 (33%)

CV=10.9%
LSD=0.41

pure stand of grass, the legume content compensated for the loss, resulting in the increase of 18 and 5 per cent dry matter yield in Setaria/Siratro and Guinea/ Silver-leaf mixture, respectinely.

There was no significant increase in the dry matter yield in a pure stand of grasses with increasing rates of nitrogen application.

With respect to crude protein yield, reductions of 19 and 12 per cent in the grass content in the grass/legume mixture were observed, with increases of 25 and 3 per cent in the total in the Setaria/Siratro and Guinea/Silver-leaf mixture, respectively (Table IX and X).

Discussions

On an average, Guinea produced two times the dry matter produced by Setaria.

Especially, Guinea was advantageous in recovering vigorous with the advent of rain. However, Guinea was not very compatible with Silver-leaf. The proportion of legume in the Guinea/Silver-leaf mixture maintained extremely low figure of 3 per cent of the total dry matter yield. It appears to be difficult to maintain a satisfactory combination in the Guinea/Silver-leaf mixture, because Guinea would completely depress Silvef-leaf in competition for light. In addition, the suppression of Silver-leaf would be due to the lack of drought resistence which is directly influenced by the shallow rooting system of Silver-leaf (WHYTE, *et al*, 1953). The production of grass in the Setaria/Siratro mixture was the same as in the pure stand of Setaria, so that the mixture was advantageous in that the legume component added to the total herbage production.

Although there was no significant correlation between dry matter yield and the increasing rates of nitrogen application, the apparent estimate of nitrogen fixation by legume was 58 lb/acre in Guinea/Silver Silver-leaf mixture. In the case of Setaria/Siratro mixture, it was impossible to estimate nitrogen fixation because of extremely low correlation coefficiency ($r=0.19$).

The wide variation and characteristic changing pattern of the percentage of crude protein have to be considered. It is realised that these are due either to the interaction of grass and legume, or to environmental factors, although more researches on these complicated factors is necessary. It has been previously reported that wet weather raised the percentage of protein of the sward of *Brachiaria brizantha* (FERNANDO, 1958) and Guinea grass and Setaria (APPADURAI and GOONEWARDENE, 1971).

SUMMARY

The authors carried out the experiment on the effect of the nitrogen fertilizer application and legumes grown in association with grasses on the productivity of tropical herbage plants in Sri Lanka. The results are summarized as follows.

Part I; To study the response to nitrogen applied, five pasture grasses, viz., Paspalum (*Paspalum plicatulum* Michx.), Coastal Bermuda grass (*Cynodon dactylon* Pers. & Linn.), Ruzi grass (*Brachiaria ruziziensis* Germain & Ever.), Para grass (*B. mutica* Stapf. & Forsk.), and Signal grass (*B. brizantha* Stapf. & Hochst.), were used in a mid-country area of Sri Lanka.

The persistent drought depressed dry matter production, at the mean decreasing rate of 80 to 90 per cent.

Leaf/stem ratio and crude protein percentage were significantly different between growth habits of grasses; the prostrate types, viz. Signal grass, Para grass and Coastal Bermuda grass, maintained constant value of 0.5 to 3 in leaf/stem ratio and 12 to 18 per cent in crude protein, while the bunch type, viz. Paspalum and Ruzi grass was variable within the wide range of 6 to 23 and 9 to 14 per cent, respectively.

Nitrogen fertilizer produced a linear response with respect to both yield and

quality in all five grasses studied. Some grasses with high dry matter production had a tendency to have low crude protein percentage.

Total dry matter production at the highest nitrogen application was 1460, 1050, 970, 960 and 790 kg/10a for six months in Paspalun, Ruzi grass, Signal grass, Para grass, and Coastal Bermuda grass, respectively.

Part II. To estimate the associated growth in mixtures, four legumes, viz., Green-leaf (*Desmodium intortum* Urb.), Siratro (*Phaseolus atropurpureus* Moc. & Sesse.), Perennial Soybean (*Glycine Javanica* Linn.), and Silver-leaf (*Desmodium uncinatum* DC.) were grown in association with two popular grasses, namely Setaria (*Setaria sphacelata shumac.* Stapf & Hubbard, var. *Nandi*) and Guinea grass (*Panicum maximum Jaquin.*),

Monthly dry matter productions and dry matter percentages varied widely in all herbage plants due to a lack of moisture in the soil. Legumes in the mixture tended to decline at each monthly harvest.

Legume/Guinea grass mixture were superior to legume/Setaria mixture with respect to total dry matter production, but legume percentage in the former was lower than in the latter. The higher rates of nitrogen application reduced legume contents in all grass/legume mixtures.

Green-leaf, erect and stoloniferous bush, was able to compete with grasses, while Glicine and Siratro, prostrate and trailing herb, appeared to be hindered in the extension of their leaves by associated grasses.

Dry matter production in a Guinea grass/Silver leaf mixture was equivalent to that in a pure stand of Guinea grass at 50 lb urea per acre (2.6 Kg-nitrogen/10a) application. Setaria/Siratro mixture produced more dry matter than at the application of 50 lb urea per acre in a pure stand of Setaria.

Acknowlegements

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摘　　要

この研究はスリランカ国における熱帯性牧草の生産に及ぼす窒素施用の影響について実施したものであるが，この研究は2部に区分される。

第1部：スリランカ国の中部地帯で5草種のイネ科牧草，パスパルム，コースタルバーミューダグラス，ルーズィグラス，パラグラス，シグナルグラスが供試された。一般に永続する旱魃は乾物生産を80～90％に低減させた。

葉茎比および粗蛋白質含量は牧草の生育型と有意差があった。たとえば匍匐型のシグナルグラス，パラグラスおよびコースタルバーミューダグラスは葉茎比が0.5～3，粗蛋白質含量が12～18％であったが，叢状型のパスパルムおよびルーズィグラスは葉茎比が6～23，粗蛋質含量が6～14％であった。

今回の研究に用いたイネ科牧草の5草種の収量に及ぼす窒素施用の影響は直線的な感応を

示し，高い乾物生産の草種は低い粗蛋白質含量であった。最高の窒素施用量を行った6カ月のイネ科牧草草種の乾物収量 (Kg/10a) はパスパルムで 1460, ルーズィグラスで 1050, シグナルグラス 970 で，パラグラスで 960, コースタルバーミューダグラスで 790 であった。

第2部： 土壌水分の欠乏が供試牧草の月別乾物収量および乾物率に及ぼす変化は大きかった。特に混播におけるマメ科牧草では，乾物収量が減少する傾向を示した。総乾物生産ではギニアグラス混播がセタリア混播よりも勝っていたが，前者のマメ科率は後者のそれよりも低かった。窒素施用量が多いと混播草種のマメ科牧草率を低下させた。緑葉，直立型の灌木がイネ科牧草の生育と競合し，匍匐型の雑草であるグリシンおよびシラトロは混生する牧草の葉の伸長を妨げるようである。乾物生産はギニアグラス，シルバーリーフ混播では，尿素の 2.6 Kg/10a 施用においてギニアグラスの単播と同じであったが，セタリア，シラトロ混播ではセタリア単播よりも窒素の同量の施用で高かった。

No. of photographs

1. Experimental plots for five pasture grasses
2. Coastal Bermuda grass
3. Paspalum
4. Para grass
5. Ruzi grass
6. Signal grass
7. Experimental plots for grass/legume mixtures
8. Setaria
9. Guinea grass
10. Siratro
11. Green-leaf desmodium
12. Silver-leaf desmodium

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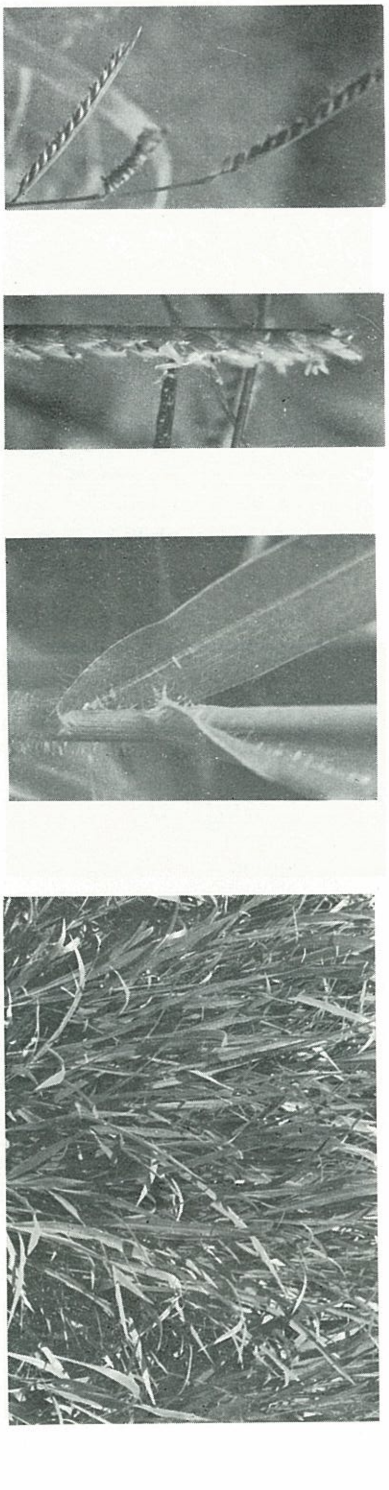

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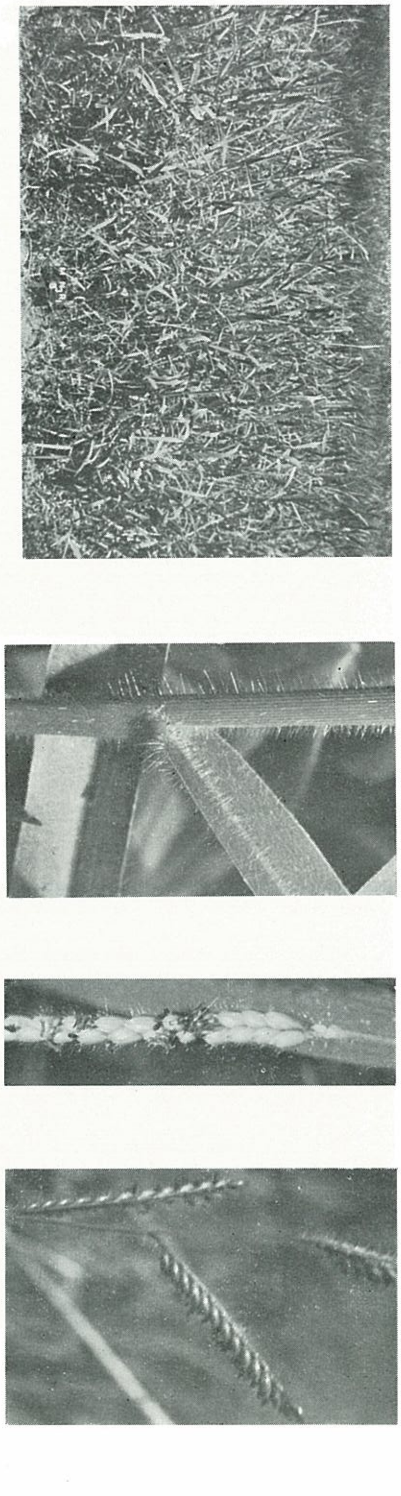

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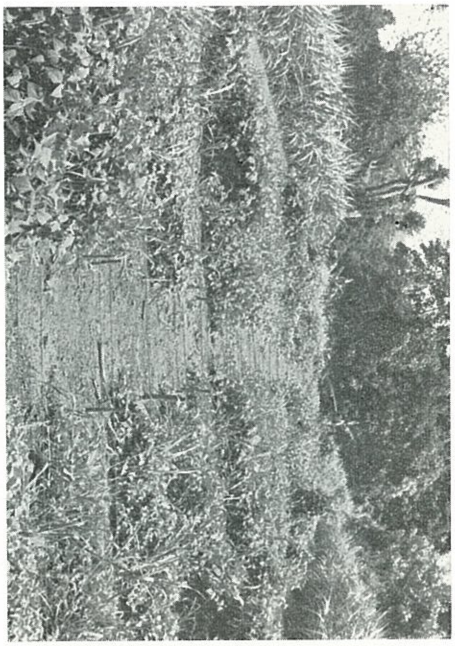

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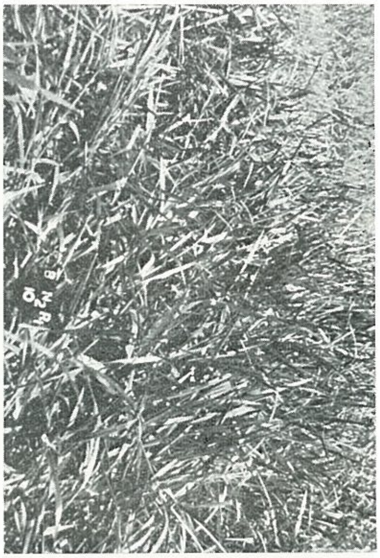

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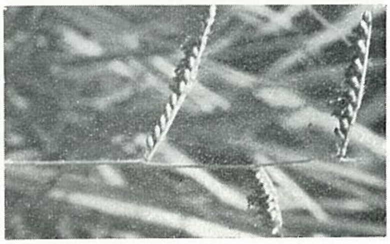

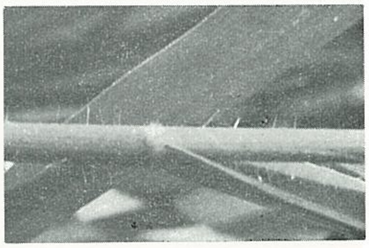

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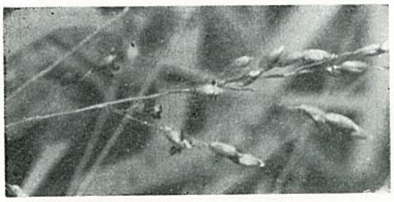

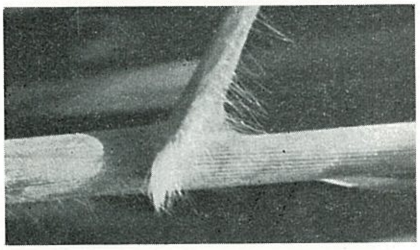

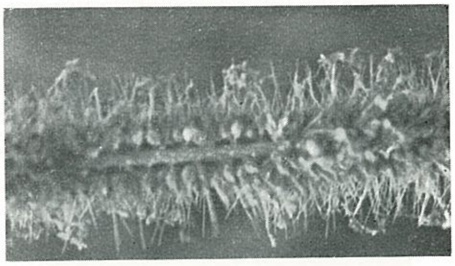

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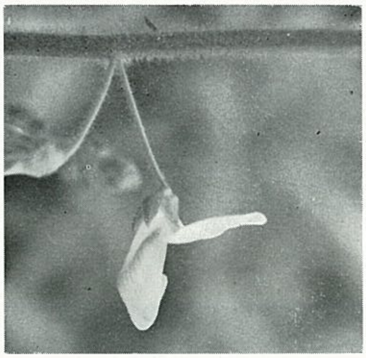

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