The

Papua New Guinea

Agricultural Journal

Vol. 28 March, 1977 No. 1

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ERRATA

p.1 Under Introduction, 5th line, "increasing recent years" should read, "increasing in recent years"

p.7 Under Discussion, 2nd line, "supplying food" should read, "supplying feed"

p.9 Graph A has been printed upside down.

Title of graphs should read:
"*Figure 5.* — A. Dry matter yield per day for various forage species.

B. Effect of nitrogen application on production of dry matter per day."

p.10 In *Table 3*, last line should read, "348" for total growing period in days for grasses, not "34.8"

p.12 In Column 1 under *Supplementation*, paragraph 3, line 2, "Cheetham Salt C." should read, "Cheetham Salt Co.,"

p.17 Under Acknowledgements, "A. Efi and Nonisa" should read, "A. Efi and R. Nonisa"

p.19 Under Introduction, line 4 "pasture in on" should read, "pasture in one"

p.21 In Column 2, line 11, "20°C" should read, "-20°C"

p.23 In title for *Figure 2*, "3 = 5th March," should read, "3 = 5th March, 1976"

p.37 In *Table 1*, 3rd last line (2nd and 3rd columns) should read: "Silvanesan, Shaw & Brown 1976 ascospores & asci extrude"

ABSTRACTS

PERFORMANCE OF FORAGE SORGHUMS AND MILLETS UNDER REPEATED CUTTING AND FERTILIZATION IN THE MARKHAM VALLEY

P. A. Chadhokar. *Papua New Guin. agric. J.*, 28(1) : 1-10

In a comparison of four forage sorghums and two millets, the forage sorghums gave higher dry matter yield and persisted longer than millets. Millets disappeared after four (white panicum) and five (MX001) harvests but all the sorghum varieties persisted and yielded well even one year after establishment. All the sorghums responded to nitrogen application but Zulu responded most at lower level of nitrogen. Dry matter yield, nitrogen content and its yield all decreased with increasing maturity. Studies on plant characteristics (e.g. tiller number, tiller size, stem and leaf proportion) and persistence under grazing indicated that Zulu is more suitable than other sorghums under the present climatic conditions and with proper management practices it should be possible to continue harvesting for about one year without replanting. Practical implications of the results are also discussed.

EFFECTS OF A SODIUM SUPPLEMENT ON LACTATING COWS AND THEIR CALVES ON TROPICAL NATIVE PASTURES

T. F. Leche. *Papua New Guin. agric. J.*, 28(1) : 11-17

Ten milking cows with calves were given uniodized salt twice weekly for 12 weeks while another group of ten cows with calves received no supplement. They grazed together on native pasture. Liveweights were recorded weekly. Sodium and potassium levels in saliva, urine and milk of the cows and in drinking water and pasture samples were determined once. Body condition of the cows was assessed at the beginning and the end of the experiment, and pregnancy status at the end only.

On the average, supplemented cows gained 61 kg liveweight and unsupplemented cows lost 23 kg ($P < 0.001$). Calves of the former cows gained 49 kg compared with 35 kg for calves of the control group ($P < 0.05$).

After ten weeks, levels of sodium and potassium in saliva and urine were normal for the supplemented cows but were indicative of severe sodium deficiency for the control cows. The content of these elements in the milk was unaffected by supplementation.

The sodium contents of water and herbage were so low as to make it unlikely that lactating cows could satisfy their sodium requirements from these sources.

Body condition of the salt-fed cows improved ($P < 0.001$) during the period whereas it declined slightly but non-significantly for the others.

It is suggested that the condition known as "nutritional lactation stress" in the highlands of Papua New Guinea may be caused by sodium deficiency.

[*continued overleaf*]

EFFECTS OF SODIUM AND PHOSPHORUS SUPPLEMENTS FOR STEERS ON NATIVE PASTURES IN THE TROPICAL HIGHLANDS

T. F. Leche. *Papua New Guin. agric. J.*, 28(1) : 19-25

Four groups of 14 steers each were given weekly supplements of either sodium or phosphorus, both or neither for 48 weeks. They grazed together on native pasture.

Liveweight was recorded at 4 or 5-week intervals. Saliva samples were collected at 0, 30 and 48 weeks and blood samples at 0 and 30 weeks. Saliva samples were analysed for sodium and potassium. For blood samples, the concentrations of sodium, potassium, phosphorus, copper and urea in the serum were determined.

Supplementation had no effect on liveweight gain. Steers not supplemented with sodium showed large decreases in sodium, and increases in potassium, in saliva over the experiment. The levels of these elements in serum were normal and generally unaffected by the treatment. Phosphorus, copper and urea in sera were normal in all groups. Urea content of serum samples was not different among the groups but was lower than normal.

REPORT ON CONTINUING ERADICATION OF COFFEE IN TWO AREAS IN PAPUA NEW GUINEA

Dorothy E. Shaw. *Papua New Guin. agric. J.*, 28(1) : 27-32

The results of inspections of two areas in Papua from which coffee rust was eradicated in 1965 are reported for the period December, 1974 to December, 1976. Some coffee was still found, despite the prohibition on planting, and was destroyed. No coffee rust was recorded during the surveys.

The measures being taken to minimize the risk of another outbreak of coffee rust are listed, together with an assessment of the great difficulties which would be experienced should another outbreak occur on Papua New Guinea coffee, whose export value for 1976-77 is expected to exceed K115 000 000 (about $Aust. 130 000 000).

GAEUMANNOMYCES LEPTOSPORUS IN PAPUA NEW GUINEA

Dorothy E. Shaw. *Papua New Guin. agric. J.*, 28(1) : 33-38

Gaeumannomyces leptosporus Iqbal developed on submerged decayed leaves held in water culture in the laboratory. The long perithecial necks, however, protruded into the air above the water surface. On removal of the substrate into a drier atmosphere, asci were extruded in a milky droplet at the tip of each neck. The ascospores were 3-septate, with one nucleus per cell. Simple, dark brown spherical to pear-shaped appressoria developed in hanging drops from ascospores germinating within asci and as released spores. No hyphopodia developed on sterile or asterile plant surfaces when inoculated with the isolate. Although this is only the second record of the fungus in the world, the first being in England, it occurrence in two such diverse locations probably indicates that it is of worldwide distribution.

PERFORMANCE OF FORAGE SORGHUMS AND MILLETS UNDER REPEATED CUTTING AND FERTILIZATION IN THE MARKHAM VALLEY

P. A. Chadhokar*

ABSTRACT

In a comparison of four forage sorghums and two millets, the forage sorghums gave higher dry matter yield and persisted longer than millets. Millets disappeared after four (white panicum) and five (MX001) harvests but all the sorghum varieties persisted and yielded well even one year after establishment. All the sorghums responded to nitrogen application but Zulu responded most at lower level of nitrogen. Dry matter yield, nitrogen content and its yield all decreased with increasing maturity. Studies on plant characteristics (e.g. tiller number, tiller size, stem and leaf proportion) and persistence under grazing indicated that Zulu is more suitable than other sorghums under the present climatic conditions and with proper management practices it should be possible to continue harvesting for about one year without replanting. Practical implications of the results are also discussed.

INTRODUCTION

With the steady increase in the cattle population in the Markham Valley, shortages of feed are often experienced, especially during the dry season. The use of forage crops, mainly sorghums, has been increasing recent years. These supplemental forages help to maintain a high level of production during the dry when production and quality of pastures is very low.

Overseas work indicates quite encouraging results from various forage crops. In Queensland, live weight gains of 0.51 to 0.55 kg/head/day were reported from *Sorghum almum* grazed for a year (Yates *et al.* 1964; Coaldrake *et al.* 1969). A very high weight gain of 0.94 kg/head/day from *Sorghum almum* resulting in 270 kg/ha beef production over a short period of 121 grazing days was reported from Texas (Gangstad 1963). Gangstad (1959) also reported high live weight gains of 0.70 to 1.01 kg/head/day with the hybrid forage sorghum Sudax. In contrast, grain sorghum used as green fodder gave low gains of about 0.45 kg/head/day (Quinby and Marion 1960). Blunt and Fisher (1973) from Northern Australia reported that fodder sorghum grazed at 6.4 and 4.0 head/ha for 26 weeks gave a mean liveweight gain of 0.36 and 0.41 kg/head/day respectively, but ratooned grain sorghum grazed at 4.0 head/ha gave 0.35 kg/head/day and was unable to carry 6.4 head/ha. They also reported that green chopped fodder sorghum fed at the preflowering and at soft dough stage gave mean live weight gains of 0.48 and 0.37 kg/ha/day respectively over 26 weeks.

Multiple harvesting or ratooning of forage sorghum has also been reported from overseas (Plucknett and Young 1963; Parberry 1966). In Papua New Guinea, Hill (1969) compared forage sorghums and a millet at Bubia, under high rainfall conditions (2 800 mm), but these were harvested only once at a certain stage of growth, and so this trial did not give information on performance under repeated cuttings or grazing. This paper presents results on the performance of forage sorghums and millets under lower rainfall conditions with repeated cuttings. Response to nitrogenous fertilizer and plant characteristics and persistence were studied.

PROCEDURE

The trial was conducted on a heavy clay soil at Markham Farming under about 1 100 mm annual rainfall conditions. Four forage sorghums commercially known as Zulu, Sudax 11a, *Sorghum almum* (Columbus grass) and NK300F (both grain and forage type) and

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millets, hybrid MX001 and white panicum (*Echinochloa crus-galli*) were planted in November, 1973. Katherine pearl millet was chosen but failed to germinate and was replaced by white panicum. These species were planted at 5 cm spacing in rows one metre apart. Nitrogen, at 16.6 and 33.2 kg/ha as sulphate of ammonia, was applied after each harvest except the first harvest when no nitrogen was applied. Species were laid out in main plots and nitrogen levels in subplots, with four replications in randomized blocks. Nitrogen was applied after cutting the stand to 15 cm height with bush knives. In all, 11 harvests were taken at about one-month intervals.

Dry matter yield was estimated by cutting a one-metre length of row at 15 cm height and drying at 80°C for 48 hours before weighing. These samples were also used for estimating number of tillers, percentage dry matter, proportion of stem and leaves, and size of individual tillers. Samples pooled over replicates were analysed for nitrogen content for four harvests (2, 3, 4 and 5) only.

In order to study the effect of repeated grazing on persistence of the forage sorghums, small plots (10 m x 20 m) were established at Erap and were grazed every month. Observations on regrowth and persistence were taken.

Data on percentage dry matter and proportion of stem and leaf were transformed (angular) for statistical analysis.

RESULTS

Soil and Growing Season

The soil was heavy clay with moderate to high fertility which became hard during the dry weather. This land was previously used for growing grain sorghum. Although the weather was dry during the establishment period, all the species established well but the initial growth was slow. Rainfall data during the growth period are presented in *Figure* 2B.

Percentage Dry Matter

Results are presented in *Figure* 1A and 1B. Dry matter content was higher in the millets than in the sorghums, especially at later harvests as a result of the millets setting grain. On average, day matter percentage remained between 17 and 20 per cent in all the sorghums except at the second harvest when Zulu and Sudax had only 14 per cent dry matter. Dry matter appeared to have slightly increased with time but decreased with nitrogen especially during the last three harvests.

Number of Tillers

Numbers of tillers per metre length of row are given in *Figure* 2A and 2B. Tillering reduced in all the species with advance in age of the stand and appeared to have been slightly influenced by rainfall. Tillers were highest in *Sorghum almum* and lowest in NK300F and they significantly differed from Zulu and Sudax which had intermediate numbers. Of the millets, white panicum had significantly more tillers than MX001.

Application of nitrogen (*Figure* 2b) appeared to have positive effects on tillering in most of the harvests but results did not reach significant level except at the last four harvests.

Tiller Size

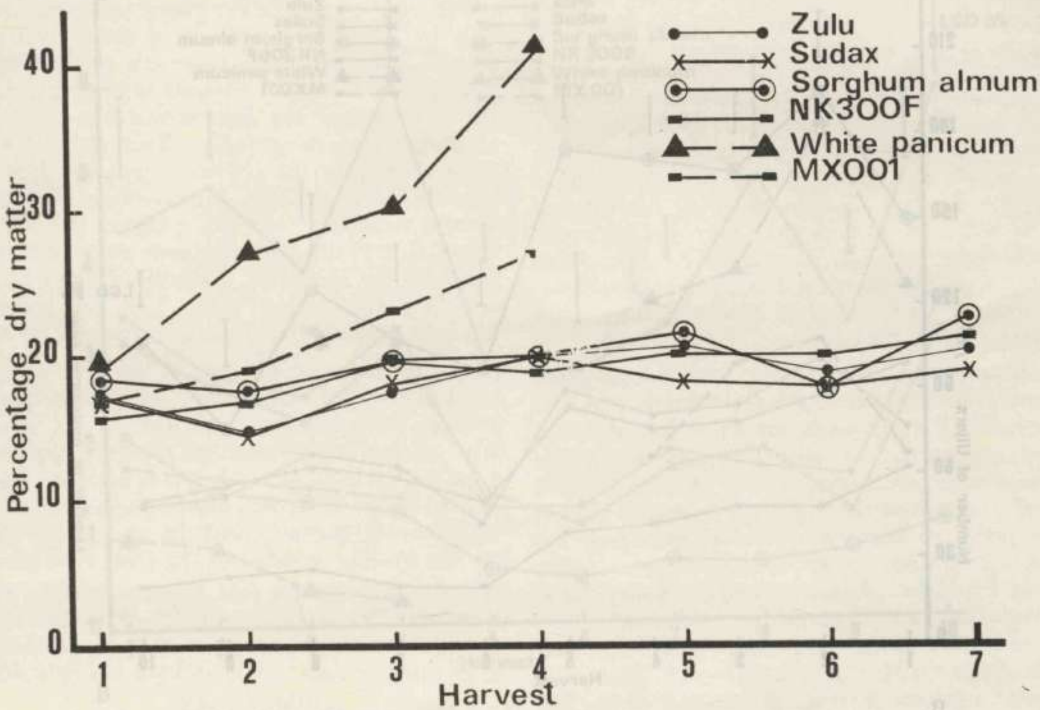
Weight of individual tillers was calculated by dividing the dry matter by the number of tillers and is presented in *Figure* 3A and 3B. Amongst the sorghums NK300F had the biggest and *Sorghum almum* the smallest tiller size and these were significantly different from Zulu and Sudax. Zulu had slightly bigger tillers than Sudax but the differences were not significant. Generally tiller size reduced with time, except at the last harvest. In the millets, white panicum had significantly smaller tillers than MX001.

Application of nitrogen had a significant positive effect on tiller size but only in sorghums (*Figure* 3B).

Proportion of Leaf and Stem

Various parts of a forage plant have varying nutrient value and acceptability to cattle. Inflorescence with grain is the most valuable, leaf (green) next most and the stem is the least valuable. Proportion of leaf and stem are presented in *Figure* 4A and 4B. Contribution of inflorescence in sorghum species was very small and is not presented here. In sorghum species, proportion of leaves increased with decrease in stem. Highest leaf proportion was in NK300F in the beginning but *Sorghum almum* dominated at later stages. However amongst the sorghums Zulu had the lowest proportions of leaves. In the millets, inflorescence was a major contribution to yield and white panicum had the lowest proportion of both leaf and stem as compared to MX001.

A



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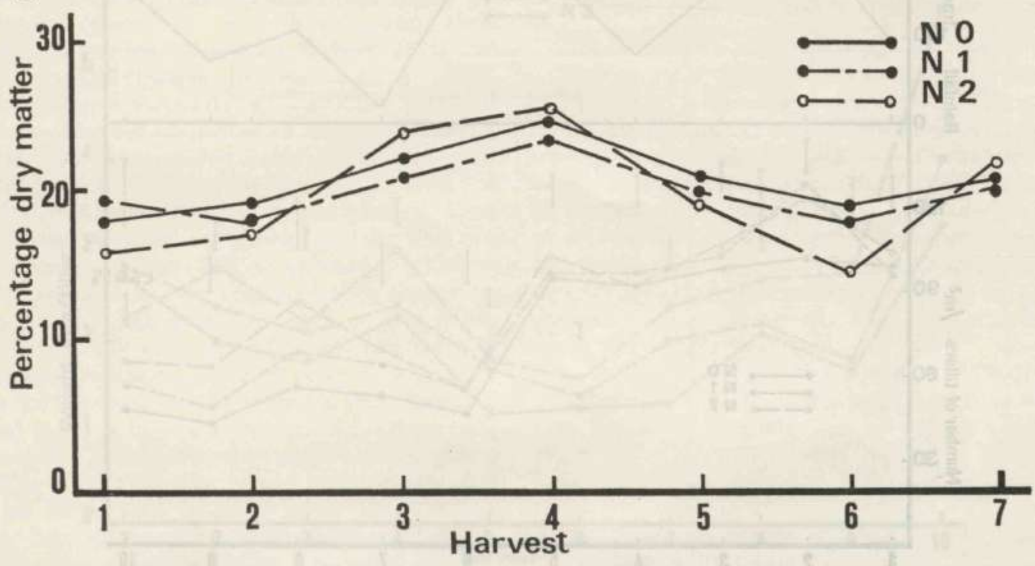

Figure 1.—A. Percentage dry matter in various forage crops (averaged over nitrogen application rates)
B. Effect of nitrogen on percentage dry matter (averaged over forage species)

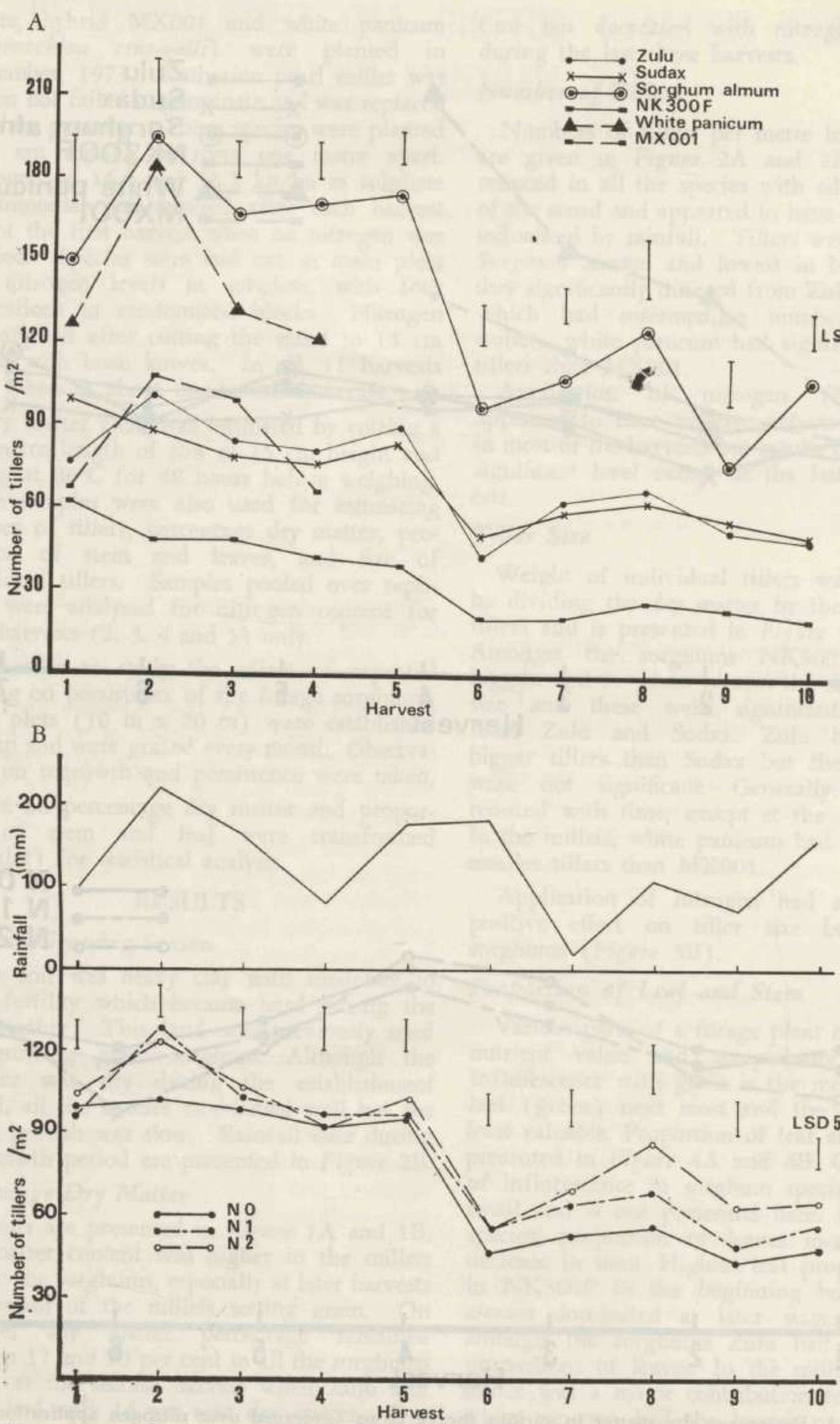

Figure 2.—A. Number of tillers/m² in various species at various harvests. B. Number of tillers/m² as affected by nitrogen application

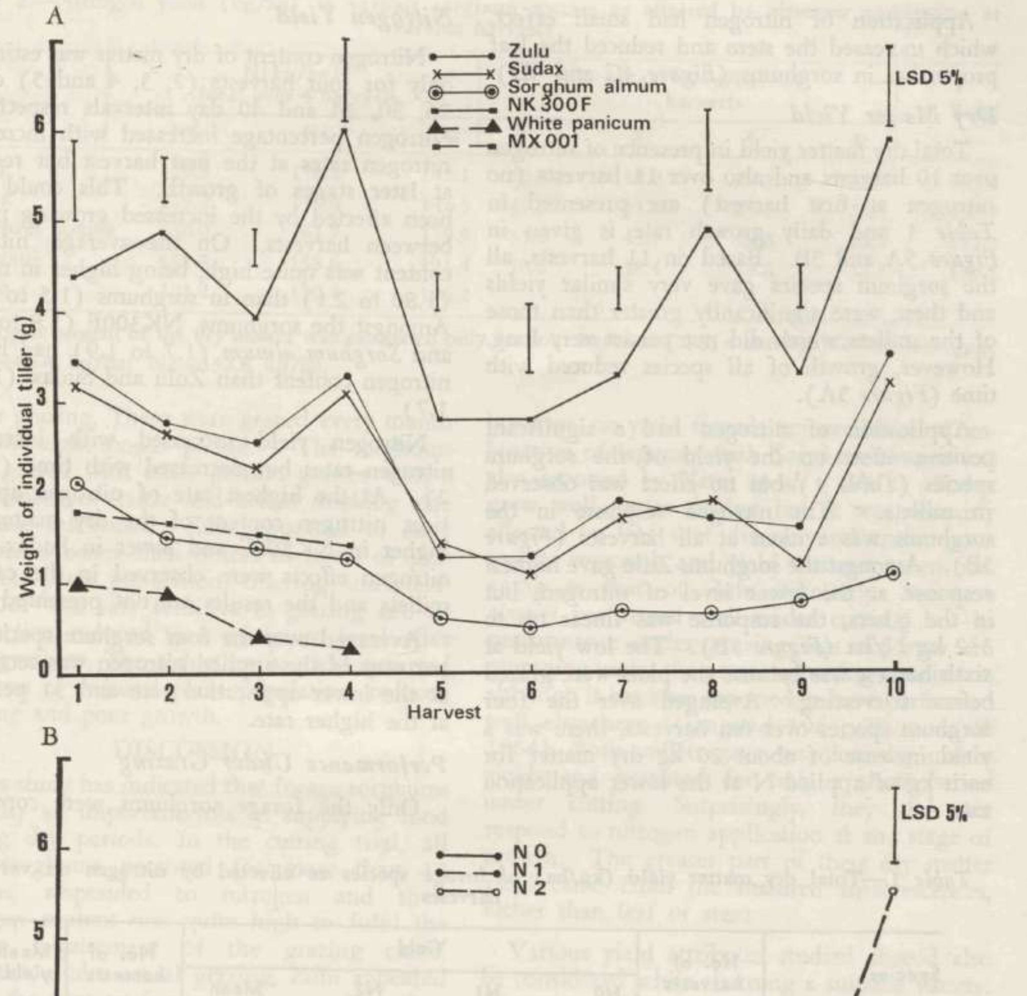

Figure 3.—A. Individual tiller weight of forage species at various harvests. B. Effect of nitrogen application on individual tiller weight at various harvests

Application of nitrogen had small effect, which increased the stem and reduced the leaf proportion in sorghums (*Figure* 4C and 4D).

Dry Matter Yield

Total dry matter yield in presence of nitrogen over 10 harvests and also over 11 harvests (no nitrogen at first harvest) are presented in *Table* 1 and daily growth rate is given in *Figure* 5A and 5B. Based on 11 harvests, all the sorghum species gave very similar yields and these were significantly greater than those of the millets which did not persist very long. However, growth of all species reduced with time (*Figure* 5A).

Application of nitrogen had a significant positive effect on the yield of the sorghum species (*Table* 1) but no effect was observed in millets. The nitrogen response in the sorghums was evident at all harvests (*Figure* 5B). Amongst the sorghums Zulu gave highest response at the lower level of nitrogen, but in the others, the response was linear up to 332 kg N/ha (*Figure* 5B). The low yield at sixth harvest was because the plots were grazed before harvesting. Averaged over the four sorghum species over ten harvests, there was a yield increase of about 20 kg dry matter for each kg of applied N at the lower application rate.

Nitrogen Yield

Nitrogen content of dry matter was estimated only for four harvests (2, 3, 4 and 5) cut at 26, 30, 34 and 40 day intervals respectively. Nitrogen percentage increased with increasing nitrogen rates at the first harvest but reduced at later stages of growth. This could have been affected by the increased growing period between harvests. On the average, nitrogen content was quite high, being higher in millets (1.80 to 2.1) than in sorghums (1.5 to 1.9). Amongst the sorghums, NK300F (1.8 to 2.0) and *Sorghum almum* (1.7 to 1.9) had higher nitrogen content than Zulu and Sudax (1.5 to 1.7).

Nitrogen yield increased with increasing nitrogen rates but decreased with time (*Table* 2). At the highest rate of nitrogen application, nitrogen content of the dry matter was higher in NK300F and lower in Sudax. No nitrogen effects were observed in the case of millets and the results are not presented here.

Averaged over the four sorghum species, 38 per cent of the applied nitrogen was recovered at the lower application rate and 31 per cent at the higher rate.

Performance Under Grazing

Only the forage sorghums were compared

Table 1.—Total dry matter yield (kg/ha) of forage species as affected by nitrogen on various harvests

Species	No. of harvests	Yield				No. of harvests	Mean yield*
		N0	N1	N2	Mean		
Forage sorghums—							
Zulu	10	13 777	18 374	19 187	17 113	11	18 579
Sudax	10	13 298	15 585	18 188	15 691	11	18 320
Sorghum almum	10	12 494	15 617	18 466	15 526	11	17 787
NK300F	10	12 961	15 746	18 266	15 658	11	18 935
Mean		13 123	16 370	18 527			
Millets—							
White panicum	4	3 659	3 590	4 057	3 769		
MX001	4	5 691	5 748	5 147	5 529	5	7 832
Mean		4 675	4 670	4 602			

N0—no nitrogen;

N1—166 kg/ha;

N2—332 kg/ha.

* Nitrogen was not applied at first harvest in the case of 11 harvests.

Table 2.—Nitrogen yield (kg/ha) in various sorghum species as affected by nitrogen application at various harvests

Species	N(kg/ha)* total over 4 harvests			Mean N(kg/ha) at harvests				Total
	N0	N1	N2	2	3	4	5	
Zulu	119.3	170.1	147.1	50.0	38.0	29.8	28.0	145.8
Sudax	129.7	131.0	146.3	49.2	35.1	23.3	28.1	135.7
Sorghum almum	130.0	161.7	179.9	55.6	43.7	29.8	28.1	157.0
NK300F	121.7	138.6	191.4	50.8	38.4	29.8	31.5	150.5
Mean	125.2	150.4	166.2					

*Nitrogen content of the dry matter was estimated only for four harvests (2, 3, 4 and 5). N0—no nitrogen; N1—66.4 kg/ha; N2—132.8 kg/ha.

under grazing. These were grazed every month over an eight-month period. The sorghums were grazed with other pasture grasses with a set number of cattle and actual stocking rate was not calculated. Zulu appeared to have performed better than others in terms of persistence, plant population, tillering and yield. NK300F was very sensitive to grazing and its production reduced to a minimum level after four grazings. The reduction in yield occurred in terms of reduced plant population, reduced tillering and poor growth.

DISCUSSION

This study has indicated that forage sorghums can play an important role in supplying food during dry periods. In the cutting trial, all four sorghums persisted for more than 12 months, responded to nitrogen and their nitrogen content was quite high to fulfil the protein requirement of the grazing cattle. However, under actual grazing, Zulu appeared to be the best performer in terms of production and persistence. Zulu variety also gave the highest response at the lower level of nitrogen under cutting. Superiority of Zulu was also reported in Queensland, by Fletcher, Henzell and Moor (1965). Although NK300F did not persist long under grazing, it can be useful as a dual purpose variety, so that it can be grown for grain and then ratooned for subsequent grazing. Already quite a large area in the Markham Valley is under grain sorghum and planting of a slow-establishing legume such as stylo (*Stylosanthes guyanensis*) could give a high quality forage after grain harvesting. This stand could be either grazed or harvested for hay. Stylo grown with sorghum on some properties appeared to have no adverse effect either on grain yield or on harvesting of grain; however, no yield records are available. Combination of legumes with *Sorghum almum* was also reported by Yates *et al.* (1971). Sudax grew well under cutting but it was seriously affected by leaf spot disease, and under grazing its regrowth and yield was not as encouraging as that of Zulu. Similarly, *Sorghum almum* performed well under cutting, but its performance under grazing was not very encouraging under the present growing conditions, although it has been reported to have performed well elsewhere (Gangstad 1963; Yates *et al.* 1964). Both millets gave very low dry matter yields and persisted for only a short period under cutting. Surprisingly, they did not respond to nitrogen application at any stage of growth. The greater part of their dry matter yield came from the matured inflorescences, rather than leaf or stem.

Various yield attributes studied should also be considered while choosing a suitable variety. Given preference, cattle will eat the inflorescence, leaves and top portion of the stem which is soft. Zulu, although it appeared to be the best under grazing, had a low proportion of leaves, which means cattle would have less acceptable feed. A variety with high tillering capacity and high leaf percentage would be an obvious choice. However, under dry conditions, persistence and high dry matter yield may need to be given first preference. Under grazing, it was noted that plants broken from near the roots by cattle did not grow. This effect was further intensified when the plants were allowed to grow too high. It was also noted that tillering after grazing had increased if the plant was slashed at about 15 cm high. For maximum utilization these sorghums should be grazed when they are about 60 to 70 cm high as they have been reported to be safe then from cyanide poisoning (Vincent pers. comm.). This height will be achieved within 2 to 3 weeks, depending on the prevailing growing conditions and this will also encourage maximum utilization, as the plant would be soft and tender at that age.

Although no direct comparison was made to show whether forage sorghums were superior to pasture grasses under similar conditions, results from a nearby trial on grass species evaluation can be compared approximately for the same growing period. The results are presented in *Table* 3. Figures for the grasses are averaged over eight species, with 25 kg of nitrogen applied per hectare at each harvest and compared with average figures of sorghum species treated with 16.6 kg N/ha at each harvest.

Although the dry matter yield (kg/ha/day) reduced with time in sorghum species, it was always higher than that of grass species. The low yield of sorghums at the sixth harvest was because the plots were grazed by the cattle

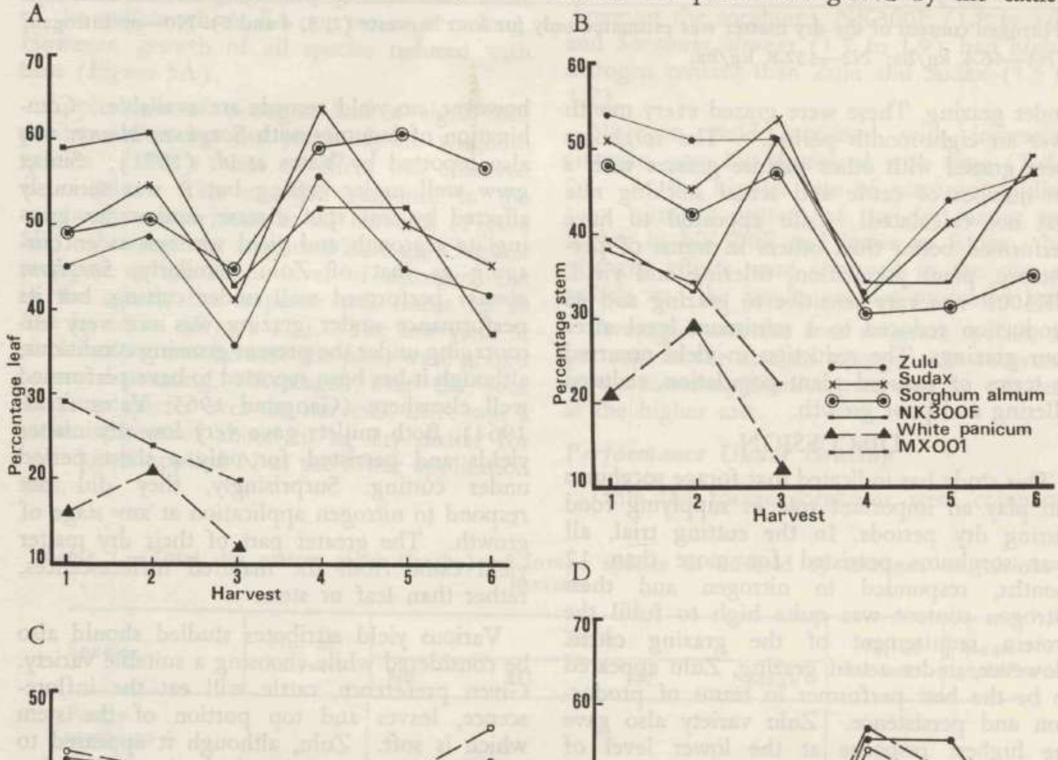

Figure 4.—a. Percentage leaf in the dry matter of various forage species. b. Percentage of stem in the dry matter in various forage crops. c. Percentage stem in the dry matter as affected by nitrogen application. d. Percentage leaves in the dry matter as affected by nitrogen application.

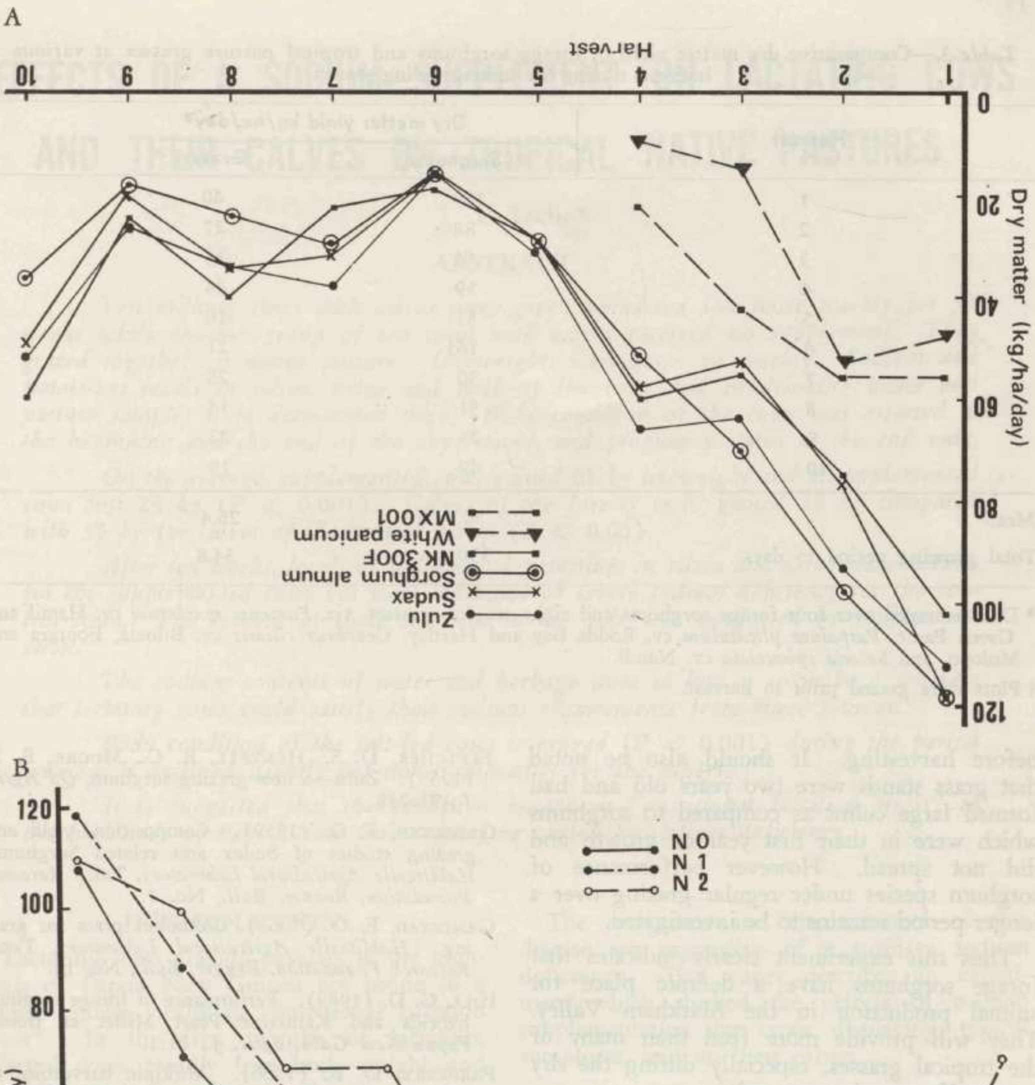

Table 3.—Comparative dry matter yield of farge sorghums and tropical pasture grasses at various harvests during the same growing season

Table 3.—Comparative dry matter yield of forage sorghums and tropical pasture grasses at various harvests during the same growing season

Harvest	Dry matter yield kg/ha/day*	
	Sorghums	Grasses
1	119	40
2	88	27
3	63	33
4	59	44
5	31	16
6	16†	21
7	30	28
8	31	14
9	23	22
10	49	19
Mean	50.9	26.4
Total growing period in days	330	34.8

* Data averaged over four forage sorghums and eight tropical grasses, viz, *Panicum maximum* cv. Hamil and Green Panic, *Paspalum plicatulum* cv. Rodds Bay and Hartley, *Cenchrus ciliaris* cv. Biloela, Boorara and Molopo, and *Setaria sphacelata* cv. Nandi.

† Plots were grazed prior to harvest.

before harvesting. It should also be noted that grass stands were two years old and had formed large culms as compared to sorghums which were in their first year of growth and did not spread. However performance of sorghum species under regular grazing over a longer period remains to be investigated.

Thus this experiment clearly indicates that forage sorghums have a definite place for animal production in the Markham Valley. They will provide more feed than many of the tropical grasses, especially during the dry season, if properly managed.

ACKNOWLEDGMENTS

The author is grateful to Mr S. Meara for assistance, to the Chief Chemist for nitrogen analysis and to Mr A. E. Charles for helpful criticisms of the manuscript.

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(Accepted for publication October, 1976.)

EFFECTS OF A SODIUM SUPPLEMENT ON LACTATING COWS AND THEIR CALVES ON TROPICAL NATIVE PASTURES

T. F. Leche*

ABSTRACT

Ten milking cows with calves were given uniodized salt twice weekly for 12 *weeks while another group of ten cows with calves received no supplement. They grazed together on native pasture. Liveweights were recorded weekly. Sodium and potassium levels in saliva, urine and milk of the cows and in drinking water and pasture samples were determined once. Body condition of the cows was assessed at the beginning and the end of the experiment, and pregnancy status at the end only.*

On the average, supplemented cows gained 61 *kg liveweight and unsupplemented cows lost* 23 *kg* ($P < 0.001$). *Calves of the former cows gained* 49 *kg compared with* 35 *kg for calves of the control group* ($P < 0.05$).

After ten weeks, levels of sodium and potassium in saliva and urine were normal for the supplemented cows but were indicative of severe sodium deficiency for the control cows. The content of these elements in the milk was unaffected by supplementation.

The sodium contents of water and herbage were so low as to make it unlikely that lactating cows could satisfy their sodium requirements from these sources.

Body condition of the salt-fed cows improved ($P < 0.001$) *during the period whereas it declined slightly but non-significantly for the others.*

It is suggested that the condition known as "nutritional lactation stress" in the highlands of Papua New Guinea may be caused by sodium deficiency.

INTRODUCTION

Lactating cows grazing pastures in the highlands of Papua New Guinea are prone to a disease known locally as "nutritional lactation stress". In the first months of lactation, affected cows rapidly lose both weight and condition, and often die. By this time emaciation is extreme and the coat is dull, rough and sparse. Dehydration is evident.

The disease affects only lactating cows but not all of them. Other stock grazing with them usually appear healthy and productive. It occurs very frequently on some farms and on others not at all.

The calf remains in good condition until the cow dies. The effect of the disease on growth rate of the calf while the cow lives is not known.

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The symptoms and circumstances of this disease are suggestive of a primary sodium deficiency. This paper describes an experiment which studied the effects of sodium supplementation on cows displaying typical symptoms, and on their calves.

MATERIALS AND METHODS

Location

The experiment was conducted on the Highlands Beef Research Unit, 10 km south of Goroka, Eastern Highlands Province (6°05' S., 145°25' E.).

The altitude is 1 600 m above sea level.

Mean annual rainfall is 1 675 mm. An average of 650 mm falls between 1st January and 1st April, but in 1976 only 475 mm fell in this period.

Experimental Period

The experiment ran for 12 weeks from 9th January to 2nd April, 1976.

Statistical Design and Methods

A completely randomized design with two treatments was used. The cows, with calves, were randomly assigned to either of two groups of ten cows each.

Weight gains for female calves were adjusted upward by 10 per cent before statistical analysis, to account for the known influence of sex on pre-weaning growth rate (National Beef Recording Scheme 1972).

Treatment effects were tested by Student's 't' test for unpaired observations with equal variances (Steel and Torrie 1960).

Animals

Twenty lactating cows were selected from a herd of Brahman crossbreds, from which all mineral supplements had been withheld for three years.

The cows had given birth to an average of 3.8 calves each by the start of the experiment. Only one was primiparous.

In December, 1975 the cows but not their calves were treated for helminths with 1-tetramisole (Nilverm, I.C.I., Lae).

At the beginning of the experiment, the age of the calves varied from 3 to 27 weeks, with a mean (± standard error) of 18 ± 1.6 weeks. There were 8 male and 2 female calves in the supplemented group and 4 male and 6 female calves in the other group.

Supplementation

One group of cows, with their calves, was given sodium chloride (salt supplemented, SS) whereas the other group (unsupplemented, US) was not.

On Tuesday and Friday mornings the SS cows and calves were placed in a 0.25 ha enclosure, with water available from an earthen dam. At the same time the US animals were grazed nearby, also with water from an earthen dam.

Uniodized common salt (Mermaid Butter Salt, Cheetham Salt C., Victoria) was provided *ad libitum* to the SS group for at least one hour on these days. Disappearance of salt was measured as the difference between air-dry weights of the steel containers, with salt, before and after the cattle had access to them. No other mineral supplement was available to any of the cattle, during the experiment.

Pasture Management

Both groups grazed together with other cattle in the herd on natural pasture of *Imperata cylindrica, Themeda australis, Heteropogon* spp. and other species of grasses and weeds. The stocking rate varied between 1.0 and 0.5 beasts/ha depending upon the number of head in the remainder of the herd.

Weighing

On Fridays the cows and calves were weighed before the supplementation treatments were applied.

Assessment of Body Condition

Body condition of the cows was assessed subjectively by the author on 9th January and 2nd April, 1976 on a scale of six levels: 1 = very poor; 2 = poor; 3 = fair; 4 = fairly good; 5 = good; 6 = very good. Plate I shows two cows judged to be in very poor (1) and in good condition (5), respectively.

Pregnancy Status

At the end of the experimental period, an experienced veterinarian estimated pregnancy status in the cows by rectal palpation.

Chemical Analyses

Samples of pasture herbage, cut at 15 cm above ground level, were collected from 1 m^2 quadrats of ungrazed pasture adjacent to the experimental paddock. Two such samples were taken from each of three sites, representing hilltop, valley bottom and intermediate grassland. Herbage was dried at 70°C.

Samples of water were taken from earthen dams used by the cattle. Samples of saliva, urine and milk were collected from cows of both groups at the end of the tenth week.

The contents of sodium and potassium in these samples were determined by direct flame photometry.

RESULTS

Liveweight Changes

Mean liveweights of the cows, and of the calves, at weekly intervals are plotted in *Figure* 1.

The mean (± standard error) increase in liveweight of the SS cows was 61 ± 6.6 kg whereas the US cows lost an average of 23 ± 7.4 kg ($P < 0.001$). The supplemented group gained about 40 kg in the first week of supplementation and thereafter their rate of

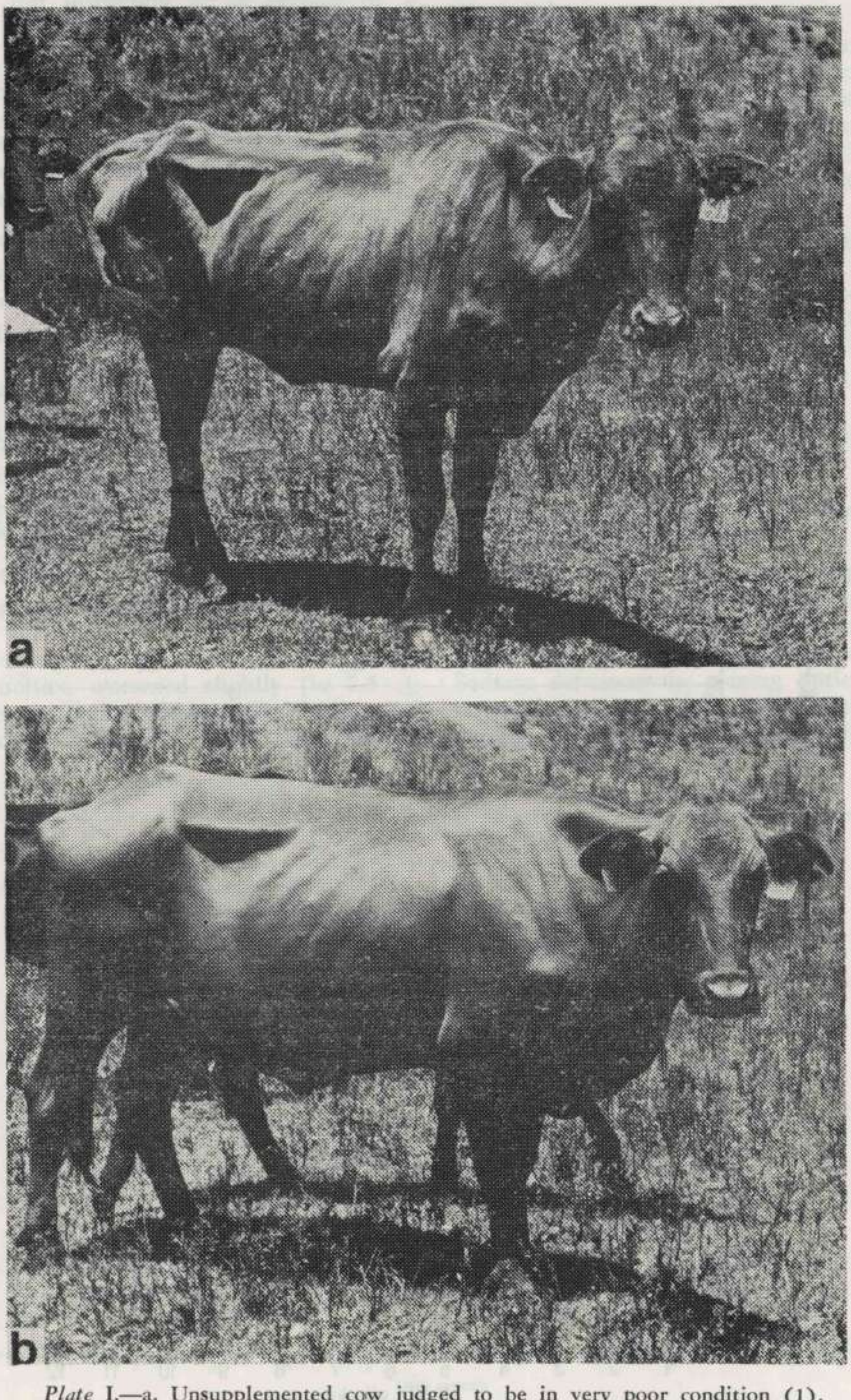

Plate I.—a. Unsupplemented cow judged to be in very poor condition (1).
b. Supplemented cow judged to be in good condition (5)

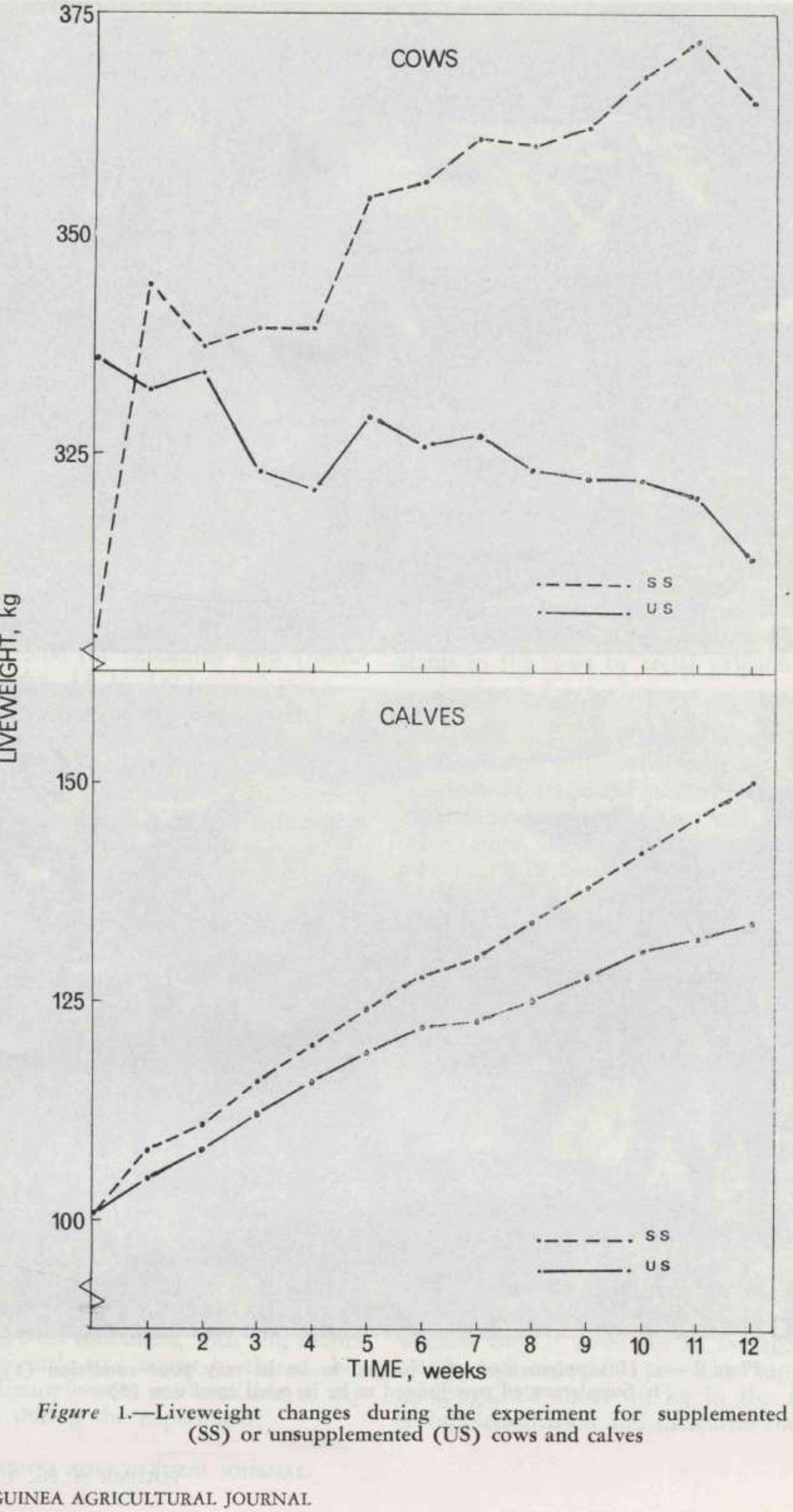

Figure 1.—Liveweight changes during the experiment for supplemented (SS) or unsupplemented (US) cows and calves gain averaged 2 kg/week. The US cows in contrast, lost liveweight at an average of 2 kg/week throughout.

Calves of SS cows gained 49 ± 2.5 kg, compared with 35 ± 5.0 kg for the US calves ($P < 0.05$). Growth of the latter calves was slower but steady until the sixth week when the growth rate fell to 60 per cent of its earlier value.

Salt Consumption

Consumption of salt by the SS group during the experiment is illustrated in *Figure* 2.

Initially, salt was consumed at a very high rate but after the third supplementation day, consumption fell to a mean of 314 ± 29 g per cow per week. The SS cows ate most of the salt but their calves were seen to eat a little.

Each supplementation day, the cattle showed almost no interest in the salt after one hour, and preferred to graze or drink.

Body Condition

Both groups started in low body condition (2.6 ± 0.2 and 2.9 ± 0.4 for the SS and US cows respectively). For the US group, body condition worsened slightly (to 2.5 ± 0.4) over the period, whereas the condition of the SS cows was judged to have improved (to 4.0 ± 0.3: $P < 0.001$).

Mortalities

In the US group, one cow died in the fifth week and another died in the eleventh week. Both were first found recumbent and unable to stand even with assistance. Post-mortem examinations were not performed but death appeared to have been related to extreme emaciation.

Data for these cows and for their calves have been ignored in calculations. One calf was male and one was female, leaving three male and five female calves in the US group.

Pregnancy Status

Three of ten SS cows were detectably pregnant (1.5, 1.5 and 6 months) compared with one of eight cows in the US group (5 months).

Sodium and Potassium in Pasture, Water, Saliva, Urine and Milk

Pasture herbage contained only a trace (< 0.5 m-equiv/kg dry matter) of sodium. The sodium content of pasture plants usually lies in the range 20 to 350 m-equiv/kg dry matter. Sodium deficiency in grazing cattle has been reported from Australia with pastures containing 3.5 to 8.3 m-equiv/kg (Murphy and

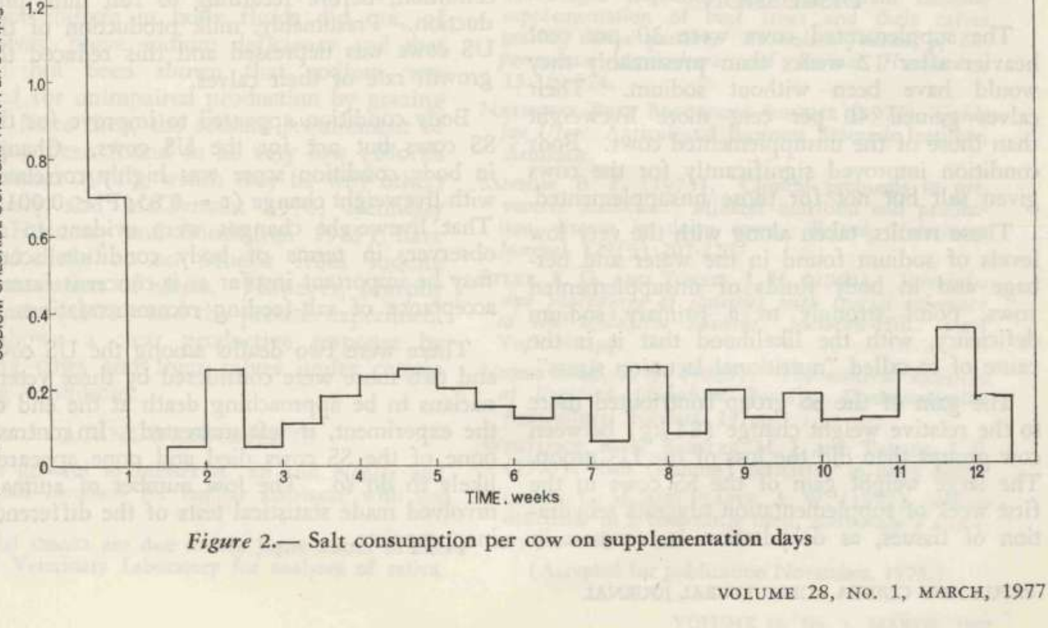

Figure 2.— **Salt consumption per cow on supplementation days**

Plasto 1973) and 2.6 to 6.1 m-equiv/kg (Hennessy and Sundstrom 1975) of sodium in the dry matter.

The mean content of potassium in the pasture samples was found to be 182 m-equiv/kg.

Drinking water samples contained an average of 0.42 m-equiv/l of sodium and 0.5 m-equiv/l of potassium. The sodium content is extremely low (Murphy and Plasto 1972).

Saliva samples from the SS cows, with 147.7 $\pm$ 6.2 m-equiv/l of sodium and 6.1 $\pm$ 1.5 m-equiv/l of potassium, were normal. In contrast, the levels for the control cows were indicative of acute sodium deficiency: 32.3 $\pm$ 6.6 m-equiv/l of sodium and 70.0 $\pm$ 5.0 m-equiv/l of potassium. These differences are significant for both elements ($P < 0.001$).

The level of sodium in the urine of the US cows was markedly depressed in relation to that of the SS cows (0.76 $\pm$ 0.11 versus 60.7 $\pm$ 11.5 m-equiv/l; $P < 0.01$). The potassium content was lower in the US cows but not significantly (178.1 $\pm$ 24 versus 222.6 $\pm$ 27 m-equiv/l).

There were no significant differences between groups in the sodium and potassium levels in milk. For the US cows the concentrations of sodium and potassium were 15.5 $\pm$ 1.6 and 32.2 $\pm$ 3.2 m-equiv/l and the corresponding values for the SS cows were 14.8 $\pm$ 0.5 and 35.2 $\pm$ 0.7 m-equiv/l.

DISCUSSION

The supplemented cows were 30 per cent heavier after 12 weeks than presumably they would have been without sodium. Their calves gained 40 per cent more liveweight than those of the unsupplemented cows. Body condition improved significantly for the cows given salt but not for those unsupplemented.

These results, taken along with the very low levels of sodium found in the water and herbage and in body fluids of unsupplemented cows, point strongly to a primary sodium deficiency, with the likelihood that it is the cause of so-called "nutritional lactation stress".

The gain of the SS group contributed more to the relative weight change (84 kg) between cow groups than did the loss of the US group. The large weight gain of the SS cows in the first week of supplementation suggests rehydration of tissues, as dehydration is common in severe sodium depletion. Reduced feed intake is another symptom reported in sodium deficiency (Morris and Gartner 1971) and so, greater gut fill, resulting from sodium repletion, may have added to the large weight increase. Whitlock *et al.* (1975) reported a similar sudden weight gain (76.4 kg in 12 days) in a sodium-depleted cow after salt was given. The gradual liveweight increase of SS cows in the last ten weeks of the present work, along with apparent improvement in body condition, is suggestive of real tissue deposition.

The more rapid growth of the SS calves probably was due to increased milk production by their dams rather than to a direct effect of sodium supplementation on the calves. The level of sodium in milk is maintained until depletion is severe (Gunther 1970; Murphy and Plasto 1973; this experiment) and even milk production is unaffected in the early stages (Underwood 1966; Gunther 1970). Indeed this is why the milking cow is more likely to become sodium-deficient compared with dry cows and male cattle.

Calves of both groups grew slower (0.58 and 0.42 kg/day for the SS and US calves, respectively) than the mean pre-weaning growth rate of calves (0.73 kg/day) from similar, salt supplemented herds on this station (Leche, unpublished data). For the SS calves, this may have been because their dams diverted some nutrients to restoration of their own body condition, before returning to full milk production. Presumably, milk production of the US cows was depressed and this reduced the growth rate of their calves.

Body condition appeared to improve for the SS cows but not for the US cows. Change in body condition score was highly correlated with liveweight change ($r = 0.85$; $P < 0.001$). That liveweight changes were evident to an observer, in terms of body condition score, may be important insofar as it concerns farmer acceptance of salt-feeding recommendations.

There were two deaths among the US cows and two more were considered by three veterinarians to be approaching death at the end of the experiment, if left untreated. In contrast, none of the SS cows died and none appeared likely to do so. The low number of animals involved made statistical tests of the difference inappropriate.

For the same reason, results of the pregnancy diagnosis were not tested. However, they favoured the SS group in that three of the ten SS cows were pregnant compared with one of eight US cows. Further, two of three pregnant SS cows had conceived since supplementation began. It can be shown that a random sample from a fertile herd in these conditions should show about 40 to 45 per cent pregnancy at any time. Therefore, the pregnancy rate for each group was poor and specially so for the US group.

The daily dietary sodium requirement of a 500 kg cow producing 7 kg milk/day has been estimated at about 10 g for maintenance and 6 g for the milk (Gunther 1970; Sansom 1973; Aitken 1976). From the levels of sodium in the water and herbage, the cows of this experiment would not likely have received more than 5 per cent of this requirement from these sources. Unsupplemented lactating cows in these conditions could be in deficit about 15 g sodium/day. As the mobilizable reserves of sodium in a cow are about 200 g (Gunther 1970), it is clear that these reserves could be depleted within several weeks after calving. The levels of sodium and potassium in saliva and urine of the US cows are typical of severe sodium deficiency (Murphy and Connell 1970; Murphy and Plasto 1973; and Whitlock *et al.* 1975) and it seems probable that the sodium reserves of these cows were nearly exhausted.

In 1968, McDonald rightly noted that low levels of sodium in body fluids did not, of themselves, prove sodium deficiency and that it had not been shown that sodium was required for unimpaired production by grazing cattle. Since then, the sodium requirement of steers has been found to be very low (Morris and Gartner 1971), which may be why others (Hennessy and McClymont 1970; Hennessy 1971; Hennessy and Sundstrom 1975) have reported little or no benefit from sodium supplementation of steers. However, Murphy and Plasto (1973) and the present experiment have shown a clear productive response by lactating cows and their calves under certain grazing conditions.

ACKNOWLEDGMENTS

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(Accepted for publication November, 1976.)

EFFECTS OF SODIUM AND PHOSPHORUS SUPPLEMENTS FOR STEERS ON NATIVE PASTURES IN THE TROPICAL HIGHLANDS

T. F. Leche*

ABSTRACT

Four groups of 14 steers each were given weekly supplements of either sodium or phosphorus, both or neither for 48 weeks. They grazed together on native pasture.

Liveweight was recorded at 4- or 5-week intervals. Saliva samples were collected at 0, 30 and 48 weeks and blood samples at 0 and 30 weeks. Saliva samples were analysed for sodium and potassium. For blood samples, the concentrations of sodium, potassium, phosphorus, copper and urea in the serum were determined.

Supplementation had no effect on liveweight gain. Steers not supplemented with sodium showed large decreases in sodium, and increases in potassium, in saliva over the experiment. The levels of these elements in serum were normal and generally unaffected by the treatment. Phosphorus, copper, and urea in sera were normal in all groups. Urea content of serum samples was not different among the groups but was lower than normal.

INTRODUCTION

The beef cattle industry in the highlands of Papua New Guinea relies heavily on unimproved native grasslands. Another paper (Leche 1977) showed that native pasture in on area contained inadequate sodium for lactating cows and their calves. In addition, soils of the region generally are phosphorus-deficiant.

This paper describes an experiment which examined the effects of supplementation with sodium or phosphorus on steers grazing native pasture in the highlands.

MATERIALS AND METHODS

Location

The site was the Highlands Beef Research Unit, 10 km south of Goroka, Eastern Highlands Province (6°05' S., 142°25' E.) at 1 600 m above sea level.

Mean annual rainfall is 1 675 mm, most of which falls in the summer monsoon season between October and April.

Experimental Period

The experiment was carried out between 4th April, 1975 and 5th March, 1976, a period of 48 weeks.

The experiment was designed to study sodium and phosphorus supplementation in a 2 x 2 factorial design. However, death of some experimental animals left groups unbalanced and so, in the absence of obvious significant interactions, the effects were tested by analyses of variance with unequal subgroup numbers in a completely randomized design.

Animals

Fifty-six Brahman crossbred steers aged 18.8 ± 3.3 months (mean ± standard error) and 272 ± 5.4 kg liveweight were randomly allocated to four groups of 14 each. One steer which died in the first week was replaced immediately by a comparable animal.

For the previous year these animals grazed native pasture of the type described below. A mineral supplement provided for the first six months was withdrawn for the latter six months. The composition of the supplement was ground limestone (38.8 per cent) bonemeal (38.8 per cent), salt (19.4 per cent), copper sulphate (1 per cent), cobalt chloride (1 per cent) and iodine (0.03 per cent).

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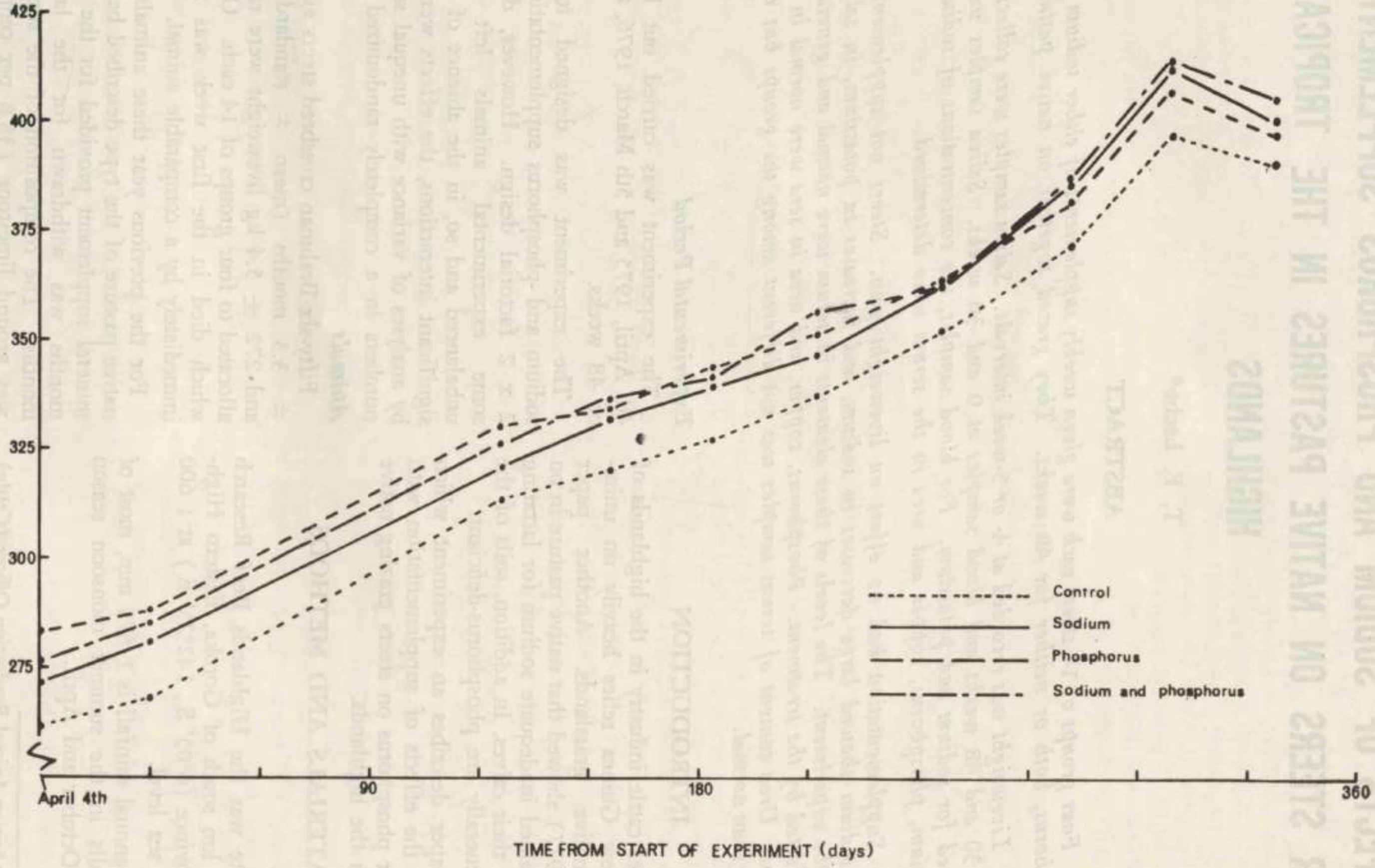

Figure 1.—Plots of mean liveweight for experimental groups at intervals during the experiment

Treatment for Helminths

All steers were drenched for helminths with 1-tetramisole (Nilverm, I.C.I., Lae) on 23rd June, 1975.

Pastures and their Management

The steers were grazed as one group in rotation around three paddocks of 26, 32 and 32 ha, at a mean stocking rate of 0.62 steers per ha.

The pasture was composed of native species, viz, *Imperata cylindrica, Themeda australis, Heteropogon* spp., along with other grasses and weeds in minor proportions.

Supplementation

At the beginning of the experiment, all steers were given the following supplements—

(1) 120 mg copper as a subcutaneous injection of copper glycinate (Coprin, Glaxovet, North Ryde, N.S.W.);

(2) One cattle-sized cobalt bullet (Siroco, 60 per cent cobaltic oxide, 40 per cent comminuted iron). This and an iron grinder were introduced into the rumen by the mouth.

(3) 1 ml of 40 per cent iodine preparation (iodized ethyl esters of the fatty acids of poppy seed oil) by intramuscular injection.

The four experimental treatments were sodium only, phosphorus only, both together or neither. The control group did not receive a placebo treatment.

The supplements were given weekly on Fridays. A length (500 mm approx.) of rigid polythene tubing (30 mm I.D.) was placed medially in the mouth to protect a softer rubber stomach tube (12 mm I.D.) which was put down the oesophagus. The supplements were administered as solutions which were poured down the stomach tube with the aid of a funnel.

Sodium was given as 0.5 l of 2.4 N NaCl which supplied 28 g Na per head per week, and phosphorus was given as 1 l of 4.34 N KH_2PO_4 which provided 45 g P per head per week.

Measurements and Sample Collection

Liveweight was recorded at 4 - or 5-week intervals. Data for the second and third weighings after the initial weighing were discarded later as the weighing machine was found to be faulty.

Saliva samples were collected by a modification of the method of Murphy and Connell (1970) on 3rd April and 31st October, 1975 and on 5th March, 1976.

Blood samples (c. 10 ml) were taken by tail bleeding on 3rd April and 31st October, 1975. Serum was separated by centrifugation and frozen at 20°C.

The levels of sodium and potassium in the saliva and serum samples were determined by direct flame photometry.

Urea content of serum was determined by the phenol-alkaline hypochlorite method (Henry 1966).

The concentration of copper in serum was determined only on the samples collected on 31st October, 1975, by atomic absorption spectrophotometry after precipitation of protein with 8 per cent trichloracetic acid.

RESULTS

Liveweight Gain

Growth curves of the groups are shown in *Figure* 1. The mean daily liveweight gains for the entire experimental period appear in *Table* 1.

The phosphorus-only grew more slowly but this difference was not significant. Growth rates of the other groups were very similar and are typical for steers on this type of pasture (Leche, unpublished data).

Sodium and Potassium Concentrations in Saliva

The levels of sodium and potassium in saliva collected at the three samplings are illustrated in *Figure* 2. The corresponding means with standard errors are presented in *Table* 2.

There were no significant differences among groups in concentration of sodium or potassium in saliva at the start of the experiment. Therefore, the treatment effects on these concentrations were tested by analysis of variance using the changes in concentration between first and last samplings for individual steers (*Table* 2).

At the beginning, sodium was lower and potassium higher than is normal, for all groups (Murphy and Plasto 1973). This probably

Table 1.—Mean liveweight gain per day of steers over the experimental period

Treatment group	Number of steers	Mean liveweight gain per day (± s.e.), kg*
Control	14	0.378 ± 0.012
Sodium	12	0.372 ± 0.017
Phosphorus	13	0.338 ± 0.022
Sodium + phosphorus	12	0.378 ± 0.019

* No significant differences.

results from the extremely low sodium content of these pastures (Leche 1977) and the six-month period before the experiment when the steers were denied a mineral supplement.

By the second sampling the sodium level had increased and the potassium decreased to more normal values for the two groups being given sodium. There was no significant change for the phosphorus-only group but in the control group the sodium concentration had fallen 17.1 m-equiv/l and potassium had risen by 1.4 m-equiv/l). These changes in the control group are indicative of developing sodium deficiency.

Between the second and third samplings, the control group suffered a further decrease of 25.3 m-equiv/l for sodium and an increase of 18.8 m-equiv/l for potassium. Even greater changes in the same directions were experienced by the phosphorus-only group; sodium fell 32.0 and potassium rose 20.3 m-equiv/l. For the two groups receiving sodium, with or without phosphorus, sodium concentration fell and potassium increased but the actual values were still within the normal range.

By the end of the experimental period, the provision of sodium resulted in average saliva sodium levels 47.2 m-equiv/l higher and potassium levels 37.5 m-equiv/l lower, than for the groups not receiving it ($P < 0.01$).

Serum Composition

(1) Sodium and Potassium

The sodium content of serum samples was normal and not significantly different among groups at either sampling (*Table* 3).

This was the case also for potassium at the first collection. However, at the second sampling, the mean for the control group was normal but higher than for the sodium-only group ($P < 0.05$).

(2) Phosphorus

The mean levels of phosphorus in serum samples taken on two occasions were not significantly different among groups or between samplings and the pooled mean (± standard error) was 6.18 ± 0.20 mg/dl. All samples had concentrations of phosphorus within the normal range.

(3) Copper

The concentration of copper in serum was normal and not significantly different among the groups. The overall mean (± standard error) was 67.5 (± 0.97) mg/dl.

(4) Urea

There were no significant differences in concentration of urea in serum samples at either sampling. The mean (± standard error) pooled over all groups and both samplings was 7.43 ± 0.28 mg/dl.

Mortality

Six steers died during the experiment: three from accidental drowning while being drenched, and three from throat infections probably arising from injury during drenching. All but one occurred in the first seven weeks, indicating that the difficulty was due mainly to inexperience with the technique. The throat injuries were likely caused by abrasive marks on the polythene tube, which were made by the teeth of the steers.

Near the end of the period, the polythene tubing was replaced by a smooth steel pipe and no more trouble of this sort occured.

The technique of giving mineral solutions to individual steers proved very useful in this experiment. By allowing all the animals to be run together it eliminated differences in pasture quality in various paddocks as a potentially important source of variation. It also ensured that the intake of supplement was known and constant for all animals within a group.

The mortality rate was regrettably high but after initial difficulties were overcome, the technique was simple and effective.

DISCUSSION

Supplementation with sodium or phosphorus or both did not affect growth rate of the steers in this experiment. This is in contrast to the effect that sodium supplementation had on lactating cows and their calves on the same pasture (Leche 1977) but agrees with results for steers on native pasture in northern New South Wales (Hennessy 1971). However, provision of sodium did prevent large changes in saliva composition which usually indicate sodium deficiency.

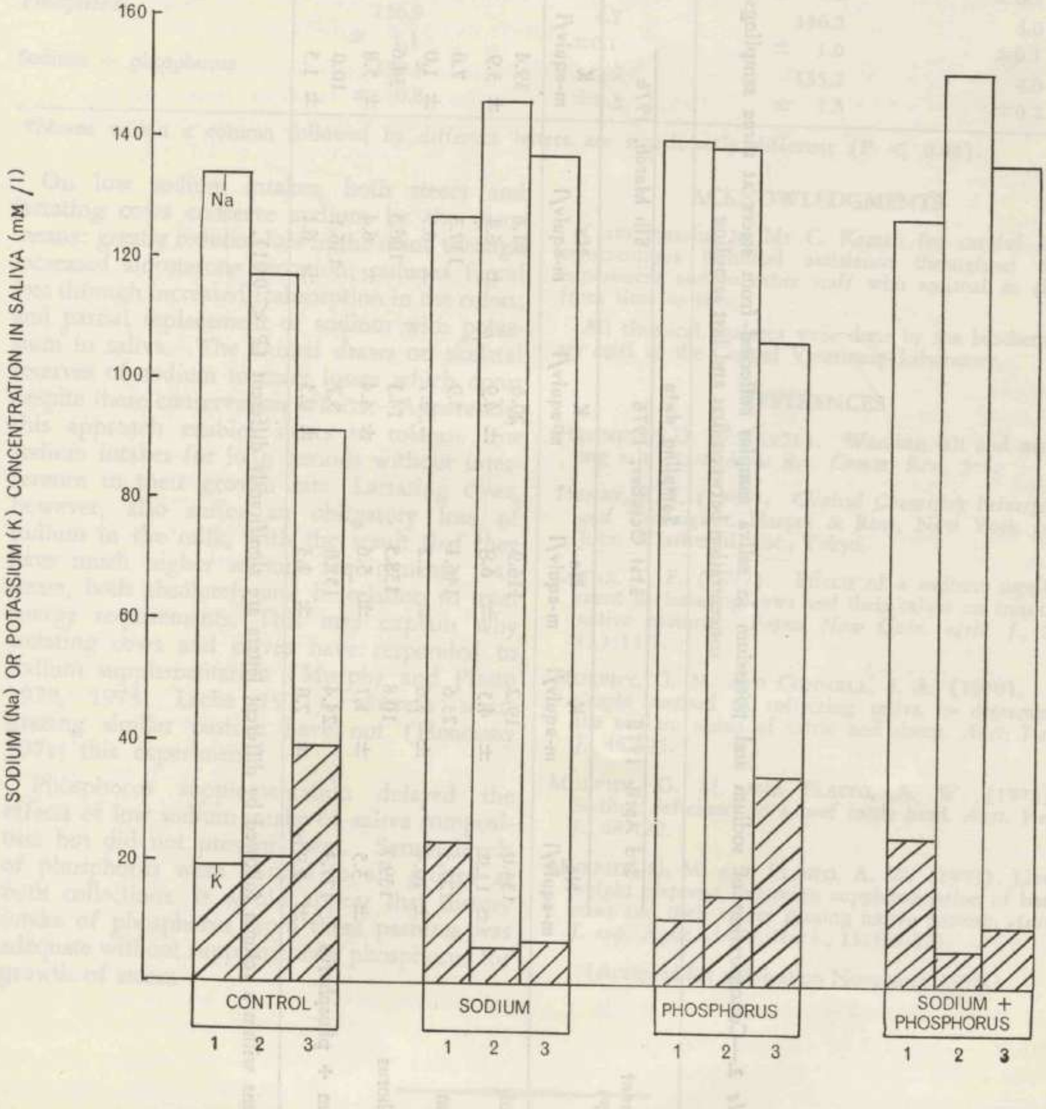

Figure 2.—Histogram showing concentration of sodium and potassium in saliva samples from four treatment groups at three samplings (1 = 3rd April, 1975; 2 = 31st October, 1975; 3 = 5th March, *Table* 2.—Concentration of sodium and potassium in saliva samples collected from steers at three samplings and mean differences in concentration between first and last sampling

Treatment groups	Sampling date						Change between 3rd April, 1975 and 5th March, 1976*	
	3rd April, 1975		31st October, 1975		5th March, 1976			
	Na m-equiv/l	K m-equiv/l	Na m-equiv/l	K m-equiv/l	Na m-equiv/l	K m-equiv/l	Na m-equiv/l	K m-equiv/l
Control	134.0 ± 11.9	19.2 ± 4.5	116.9 ± 6.8	20.6 ± 4.9	91.6 ± 6.4	39.4 ± 3.9	-42.4 a ± 12.0	20.2 a ± 6.0
Sodium	127.3 ± 10.4	23.6 ± 7.6	146.1 ± 2.2	5.9 ± 0.7	137.3 ± 6.7	7.0 ± 1.0	10.0 b ± 9.5	—16.6 b ± 7.5
Phosphorus	139.7 ± 3.5	10.8 ± 1.7	138.5 ± 5.6	14.3 ± 4.4	106.5 ± 6.4	34.6 ± 5.8	—33.3 a ± 5.2	23.8 a ± 5.1
Sodium + phosphorus	127.3 ± 7.9	24.4 ± 7.0	151.8 ± 1.3	5.7 ± 0.5	136.1 ± 6.1	10.0 ± 1.5	8.8 b ± 8.1	—14.4 b ± 6.7

* Means within a column followed by different letters are significantly different ($P < 0.01$).

Table 3.—Concentration of sodium and potassium in serum samples collected from steers on two occasions

Treatment group	Sampling date			
	3rd April, 1975		31st October, 1975	
	Na m-equiv/l	K m-equiv/l	Na m-equiv/l	K * m-equiv/l
Control	137.6 ± 0.9	5.0 ±0.3	137.6 ± 1.1	4.5 a ±0.2
Sodium	137.9 ± 1.1	5.0 ±0.2	137.0 ± 1.1	3.8 b ±0.1
Phosphorus	136.9 ± 1.1	4.7 ±0.1	136.2 ± 1.0	4.0 ab ±0.1
Sodium + phosphorus	138.8 ± 0.8	5.2 ±0.3	135.2 ± 1.5	4.0 ab ±0.2

*Means within a column followed by different letters are significantly different ($P < 0.05$).

On low sodium intakes, both steers and lactating cows conserve sodium by the same means: greatly reduced loss in the urine through increased aldosterone secretion; reduced faecal loss through increased reabsorption in the colon; and partial replacement of sodium with potassium in saliva. The animal draws on skeletal reserves of sodium to meet losses which occur despite these conservation efforts. Apparently, this approach enables steers to tolerate low sodium intakes for long periods without interference to their growth rate. Lactating cows, however, also suffer an obligatory loss of sodium in the milk, with the result that they have much higher sodium requirements than steers, both absolutely and in relation to total energy requirements. This may explain why lactating cows and calves have responded to sodium supplementation (Murphy and Plasto 1972, 1973; Leche 1977) whereas steers grazing similar pasture have not (Hennessy 1971; this experiment).

Phosphorus supplementation delayed the effects of low sodium intake on saliva composition but did not prevent them. Serum levels of phosphorus were normal in all groups at both collections. It would appear that dietary intake of phosphorus from these pastures was adequate without supplementary phosphorus for growth of steers.

ACKNOWLEDGMENTS

I am grateful to Mr C. Kamen for careful and conscientious technical assistance throughout this experiment and to other staff who assisted so ably from time to time.

All chemical analyses were done by the biochemistry staff of the Central Veterinary Laboratory.

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(Accepted for publication November, 1976.)

REPORT ON CONTINUING ERADICATION OF COFFEE IN TWO AREAS IN PAPUA NEW GUINEA

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ABSTRACT

The results of inspections of two areas in Papua from which coffee rust was eradicated in 1965 *are reported for the period December,* 1974 *to December,* 1976. *Some coffee was still found, despite the prohibition on planting, and was destroyed. No coffee rust was recorded during the surveys.*

The measures being taken to minimize the risk of another outbreak of coffee rust are listed, together with an assessment of the great difficulties which would be experienced should another outbreak occur on Papua New Guinea coffee, whose export value for 1976-77 *is expected to exceed* K115 000 000 (*about* $*A*130 000 000).

INTRODUCTION

One probable and two confirmed outbreaks of coffee rust, caused by *Hemileia vastatrix*, occurred in Papua New Guinea in 1892-3, 1903 and 1965. The outbreaks and the successful eradication campaign of 1965 were described in detail by Shaw (1968).

After the 1965 eradication it was decided to keep a large region, comprising the area around the main Port of Entry (Port Moresby) and the previously coffee rust infected areas, free from coffee. If this were done, it would mean that should viable coffee rust spores reach the country again through the main port or the international airport, there would be no host available for infection or build-up of the fungus. It was realized, of course, that eradication of coffee in this region surrounding Port Moresby would be of no use if the fungus broke out first in the main coffee growing areas of the country, after the arrival of viable spores either wind-borne from overseas, or carried on international travellers or on goods or on seed or other plants from infected countries, despite fungicide pretreatment of plants and seeds at source and on arrival.

The results of regular inspections of the area being kept as free from coffee as possible, were reported by Shaw (1970, 1975).

The present paper records the results of the surveys carried out in the prohibited coffee growing areas since December, 1974 to December, 1976.

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THE SURVEYS

The area of prohibited coffee growing, comprising the immediate environs of Port Moresby, the Sogeri Plateau and the Rigo hinterland, was described and figured by Shaw (1968, 1970).

During the last two year period, foot patrols only were available for the surveys. Despite the prohibition on coffee growing in the area, coffee was found at many sites, either being grown in claimed ignorance of the prohibition, or originating from previously missed, or incompletely dug out bushes, and perhaps in some cases from bird distributed berries.

The number of seedlings and regrowth found at each site was recorded by the survey teams, and an endeavour was made to trace the source of seed, if seedlings were found. Any coffee found was checked for coffee rust, and any queried symptoms forwarded to the Chief Plant Pathologist for checking. All seedlings and regrowth were destroyed by burning.

The main results of the surveys during 1975 and 1976 are summarized in *Table* 1.

From the *Table* it will be seen that—

(*a*) No rust was recorded on any coffee found in either area, indicating the efficiency of the disease eradication campaign carried out in 1965, as is also evidenced by the fact that over

Table 1.—Results of inspections for coffee and coffee rust in a previously eradicated area from December, 1974 to December, 1976

Area	Date of inspection	Number of sites: Inspected	Number of sites: Recorded free from coffee	Recorded with coffee: Seedlings and/or regrowth: 1·99 plants	Recorded with coffee: Seedlings and/or regrowth: 100-999 pants	Recorded with coffee: Seedlings and/or regrowth: More than 1000 plants	Recorded with coffee: With coffee rust
Sogeri Plateau	April, 1975	14	3	8	3	0	0
	Nov., 1975	15	7	7	1	0	0
	June, 1976	7	1	1	5	0	0
	Nov., 1976	20	5	9	5	1	0
Rigo hinterland	Oct., 1975	2	0	0	2	0	0

K200 000 000 (about $A227 000 000) has been exported since 1965 up till June, 1976—if rust had reached the main coffee areas the whole industry would have been seriously affected.

(*b*) Coffee bushes, seedlings and regrowth contnued to be found in both areas, despite the previous surveys and eradicaton of coffee since 1965;

(*c*) When compared with the surveys reported previously (Shaw 1970, 1975), it was obvious that in one area at least, the surveys during this two year period were more limited in the number of sites covered.

As stated by Shaw (1975), and as has become increasingly evident, changes in personnel and reductions in the number of trained field staff and supervisory officers, finance for helicopter transport and availability of helicopters, has greatly limited the number and extent of inspections possible and the efficiency of the operations.

As mentioned in the previous report the persistence of coffee in the area, despite its prohibition and the eradication patrols, indicates the difficulty which would be experienced in maintaining a coffee-free zone, i.e., a "cordon sanitaire", of any worthwhile extent in respect of coffee rust, should the need for such arise in the future, unless ample staff and transport were available for continuous patrols.

COFFEE RUST RISK IN THE FUTURE

In order to minimize the risk of another outbreak of coffee rust, the following measures continue, or are proposed:

(*a*) The import of all parts of the coffee plant is completely prohibited;

(*b*) The import of plant material from coffee rust infected countries (see (*Figure* 1) is greatly restricted, and imports which are permitted have to be treated with fungicide at source, and again on arrival, and all packagings burnt;

(*c*) The writer has recommended, although this has not been adopted as yet, that the import of all vegetative plant material from coffee rust countries be prohibited, and if material is imported despite the prohibition, it be destroyed on arrival without opening, inspection or treatment.

The main vegetative species imported from such countries are orchids for the gardens of private citizens and some firms and institutions. If the recommendation of (*c*) above is adopted, most of these species could probably still be imported as seedlings in sterile agar cultures, or obtained from non-coffee rust infected countries.

(*d*) A publicity campaign, involving coloured slides* and posters showing coffee rust, is to be promulgated throughout the country, especially through agricultural colleges, agricultural experiment stations and Rural Development Offices, and at the international airport and airstrips throughout the main coffee growing areas.

(*e*) Coffee rust is still a notifiable disease throughout Papua New Guinea, under the *Plant Disease and Control Ordinance* 1953-1968.

The likelihood of another outbreak of coffee rust in Papua New Guinea is even more probable now than at the times of previous warnings (Shaw 1962, 1975) for the following reasons:

(*a*) The coffee catch crop area for windborne spores has extended to an estimated 50 000 ha (about 123 500 acres);

(*b*) Air services from other countries with coffee rust have greatly increased to the ports of entry;

(*c*) Internal feeder services within the country from the main port and international airport have greatly increased, although in the last year some curtailment has occurred;

(*d*) There is no adequate way known to prevent the passive carriage of viable spores on travellers or on goods from other countries with coffee rust;

*The originals of the 25 mm colour transparencies used were kindly made available through the courtesy of Dr J. W. Waller, ODM Liaision Officer, Commonwealth Mycological Institute, England, and were not imported direct from coffee-rust countries.

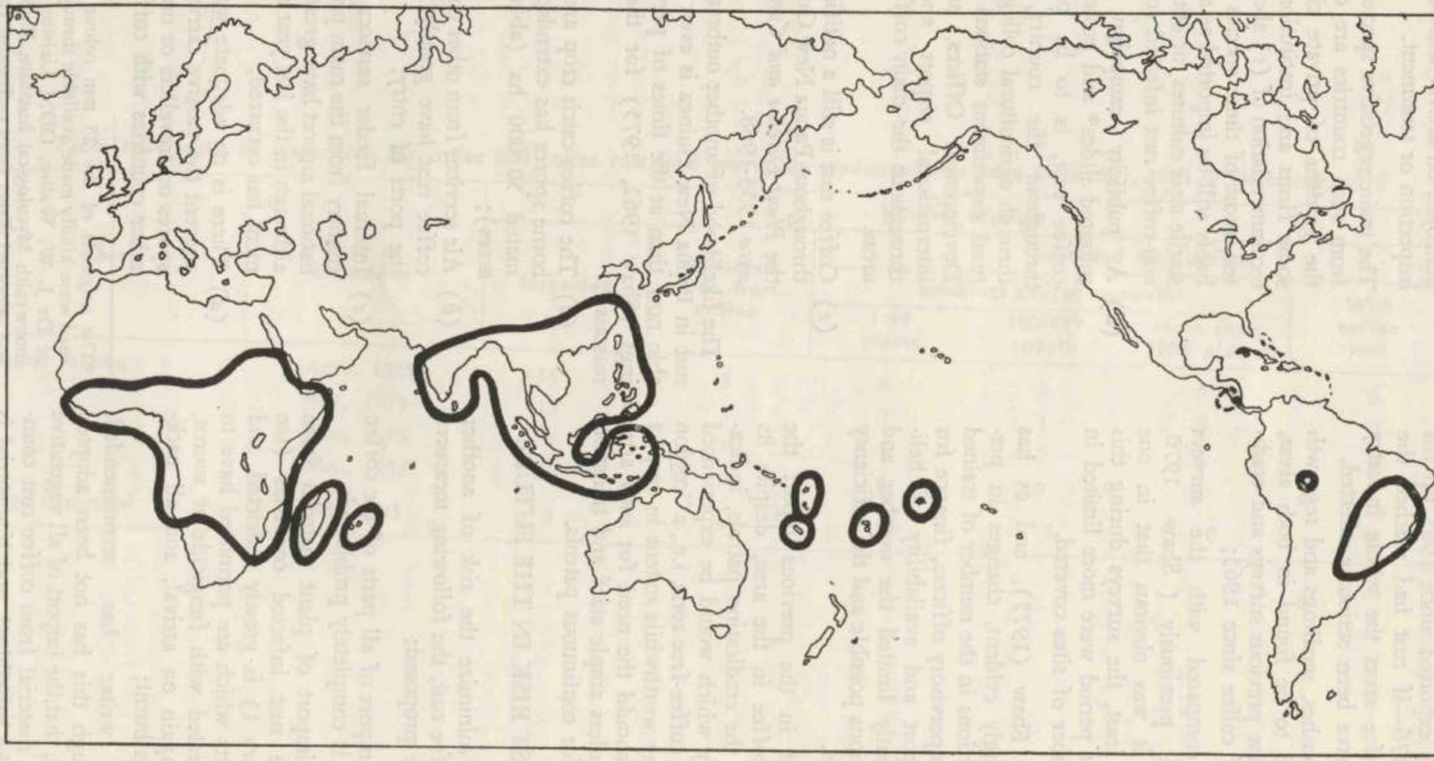

Figure 1.—Coffee rust infected countries of the world (circled in heavy black line). Adapted from CMI Map No. 5 Edition 5 of Distribution Maps of Plant Diseases for *Hemileia vastatrix*. Recent outbreak in Nicaragua circled with dotted line (*e*) Some unscrupulous people may still succeed in surreptitiously bringing in high coffee rust risk material despite quarantine prohibitions and surveillance;

(*f*) The reduction in trained and responsible agricultural staff throughout the country means less regular and less efficient patrols of routine inspection throughout the coffee growing areas, so that if coffee rust should break out again, it may escape notice for some time, and thereby reach non-eradicable proportions before detection;

(*g*) The position in (*f*) above is compounded by the increasing lack of managerial and maintenance skill displayed by individual coffee growing owners, which again means that any future outbreak may be undetected for such time that eradication, when detected, would be impossible.

A new outbreak of coffee rust, if the quarantine barrier is again breached, could have a most serious affect on the industry. As Shaw (1975) pointed out, although some control is possible by the use of fungicides, the cost of these and spraying equipment, and the cost and difficulties which would be involved in transporting materials and equipment to, and especially within, Papua New Guinea, would be high. Also, many national growers, who are responsible for about 80 per cent of the coffee acreage, are still not technically knowledgeable, and the number of trained officers capable of supervising large scale fungicide control measures is still very limited. Also, with an annual rainfall mainly between 1 880 and 2 745 mm (about 74 to 108 inches) in the coffee areas, a continuous epiphytotic could be expected, probably necessitating an increase in number of applications for effective fungicidal control, with concomitant increase in cost.

In 1960 the Department first began importing coffee varieties resistant to certain races of coffee rust, as these varieties became available through the Centro de Investigacao das Ferrugens do Cafeeiro, Oeiras, Portugal and the Instituto Interamericano de Ciencias Agricolas, Turrialba, Costa Rica. Thirty-two races of coffee rust have been designated (Rodrigues *et al.* 1975), but as these workers point out, not a single cultivar or selection of *Coffee arabica* has ever been found with total resistance to the known races of *Hemileia vastatrix*, the coffee rust fungus. This means that the "resistant" varieties available are in fact only resistant to certain races or groups of races. As it is not known in advance, of course, which race may arrive, should an outbreak occur again, it is not known in advance which varieties, selections or cultivars would be needed for the unknown race or races.

Of the three collections of coffee rust of the 1965 outbreak sent from Papua New Guinea to Oeiras, Portugal, for race identification, two were Race II and one was Race I (Rodrigues *et al.* 1975).

Also, as Schieber (1975) has pointed out, although Race II was the invading race in Brazil in 1970, the appearance of new races of the rust in Brazil has been almost continuous since that time, so that by 1974 four races had been recorded, namely, II, XV, III and I.

Martinez *et al.* (1975) trapped coffee rust spores over Brazil at altitudes as high as 1 000 m, and found that the spores were spread by wind over long distances, even up to 700 km from the main focus of rust. They further found that these spores were brought back from the air to the ground by rain water. Therefore, should coffee rust again reach Papua New Guinea, the spread of the rust over all the coffee growing areas by wind, as well as on people and on vehicles and goods, would probably be very rapid.

For the reasons given above, an outbreak of coffee rust in Papua New Guinea in the future could be catastrophic for the coffee growers and also for the economy of the country as a whole, as coffee exports for the year 1976-77 are expected to reach a value of K115 000 000 (about $A 130 000 000).

Arabica and robusta coffee growers, rural development officers, all members of the agricultural community (whether coffee growers or not), citizens of Papua New Guinea returning from visits to overseas countries with coffee rust, tourists from such countries, the Customs and Quarantine Services, and in fact every member of the general public in Papua New Guinea, should be aware of what another outbreak of coffee rust could do to the economy of this country, and practise the utmost vigilance at all times.

ACKNOWLEDGMENTS

The work of the inspection teams and the rural development officers, especially Mr P. Tuitalele, on the Sogeri Plateau and in the Rigo hinterland, is gratefully acknowledged, as on them fell the main burden of the eradication patrols. The Director of the Commonwealth Mycological Institute, Kew, kindly gave permission for the adaptation of CMI Map No. 5 Edition 5 of Distribution Maps of Plant Diseases for *H. vastatrix*.

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(Accepted for publication January, 1977.)

GAEUMANNOMYCES LEPTOSPORUS IN PAPUA NEW GUINEA

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ABSTRACT

Gaeumannomyces leptosporus *Iqbal developed on submerged decayed leaves held in water culture in the laboratory. The long perithecial necks, however, protruded into the air above the water surface. On removal of the substrate into a drier atmosphere, asci were extruded in a milky droplet at the tip of each neck. The ascospores were 3-septate, with one nucleus per cell. Simple, dark brown spherical to pear-shaped appressoria developed in hanging drops from ascospores germinating within asci and as released spores. No hyphopodia developed on sterile or asterile plant surfaces when inoculated with the isolate. Although this is only the second record of the fungus in the world, the first being in England, its occurrence in two such diverse locations probably indicates that it is of worldwide distribution.*

INTRODUCTION

Iqbal (1972) described *Gaeumannomyces leptosporus* as a new aquatic ascomycete occurring with immature perithecia on decaying submerged umbelliferous branches in the River Creedy, England. Mature ascospores developed after three weeks when the branches were incubated in plastic bags at 15° C. The present paper reports the occurrence of this fungus in Papua New Guinea.

Papua New Guinea Record

In March, 1976 this species (PNG 10147; IMI 202624) was found on brown, decaying unidentified leaves of a broad-leaved species, held for several weeks in water culture in Petri dishes in the laboratory, having been originally collected as brown submerged leaves from a stream at about 457 m altitude, about 24 km from Port Moresby.

Although the perithecia occurred on the submerged leaves in Petri dishes, the perithecial necks extended above the water surface. Perithecial necks of *Gnomonia papuana* reported recently by Sivanesan and Shaw (1976) did likewise in a similar situation. Also, as with *Gn. papuana*, when the leaf material was removed from the water culture into a dry Petri dish base, a white milky globule formed at the perithecial tip within about 15 minutes, the globule containing extruded asci. Later the globule became honey-coloured, adhering to the perithecial tip and resisting pressure with a needle, and at that stage contained ascospores (*Plate* I E).

Asci from the milky terminal globules when streaked on to potato dextrose agar (PDA) plates germinated slowly, mainly from both ends of the enclosed ascospores (*Plate* I D). Cultures established from single asci were at first white and began to produce long-necked perithecia after three weeks, as reported by Iqbal, mainly at the inoculum site; later perithecia were produced over the whole surface of the medium in cultures with a bacterial contaminant. Necks were up to 2.4 mm long, mainly at right angles to the medium surface, and appeared to show no geotrophic effect. Purified cultures later became grey, with an appressed growth which became slightly crust-like after about five weeks so that it could be lifted without much difficulty from the surface of the agar; perithecia did not form in the purified cultures on this medium.

As mentioned above, asci from the original substrate germinated very slowly. Asci from culture also germinated slowly in water in hanging drops, but the ascospores were even slower. No germination occurred in 24 hours, but by 69 hours, while only 7 out of 44 ascospores examined had germinated, 60 out of 62 asci examined had produced germ tubes. Whether the slow germination of asci and ascospores has some significance as a survival factor is not known.

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After 69 hours in the hanging drop, two of the asci had each produced a brown appressorium, while another had produced one hyaline and one brown appressoria. A few days later, in two traverses 3 out of 13 ascospores had germinated, one with an appressorium, while 11 out of 15 asci had produced appressoria, some with up to four, all dark brown.

The appressoria were simple and non-lobed, circular to pear shaped with a truncate base at the septum, 3.5 to 4.5 um wide and mainly 7.5 to 10.5 um long, at first hyaline, later dark brown, occasionally with a second intercalary appressorium immediately adjacent to the terminal one which formed first. In most cases the appressoria appeared at the tips of germ tubes which were 4.5 to 31.5 um long, mainly from the end cells, occasionally from the sides, of the ascus. In a few cases, the appressoria appeared sessile or nearly sessile on the ascus or ascospore (*Plate* II E, F).

No hyphopodia were noted when pieces of culture were inoculated on to live coleoptiles produced from surface sterilized germinating grains of wheat, oats, maize, rice and Triticale in Petri dishes lined with wet filter paper, or on leaves of *Auracaria hunsteinii* on detached shoots maintained alive in a humid atmosphere, or on sterile grass pieces on water agar in Petri dishes. In all these cases the hyphae radiated sparsely over the surface of the tissue around the inoculum piece without forming hyphopodia.

The fungus agrees well with Iqbal's description, with perithecial necks up to 2.4 mm long by up to 39 um wide (*Plate* I A), asci 75 to 90 x 4.5 to 5.8 um (*Plate* I B), and with a refractive body in the ascus tip 1.8 x 1.2 um in size, with median canal and slightly flattened base (*Plate* I C) and ascospores 66 to 81 x 1.0 to 1.5 um (*Plate* II A). The number of septa in the spores could not be distinguished in mounts of water, cotton blue lactophenol, lactic fuchsin or Lugol's solution. Ascospores mounted in a small drop of water, then allowed to air-dry on the slide, exhibited what appeared to be a slight thickening of the walls at three places along the spore (*Plate* II B), probably indicating the position of septa.

Asci and ascospores air-dried on slides and stained with Giemsa after acid hydrolysis in N HCI at 60° showed one nucleus per cell, that is, four nuclei per spore. The two centre groups of nuclei in the ascospores still retained in the asci were mainly stained deep purple, and each nucleus was more compact than the nuclei at each end of the spore. These latter were more reddish purple, more diffuse and more elongated than those in the two centre groups (*Plate* II C). In released ascospores the four nuclei were usually elongated (*Plate* II B). In most ascospores a small area at the tip of the spore was tinged red, but did not give a positive purple reaction. While many ascospores were lost during the staining and washing procedures, all the asci adhered firmly to the slides, perhaps indicating that some fluid from the extrusion globule had remained on the asci and was acting as a cementing agent.

No asexual state was found in the cultures on PDA, and none formed when pieces of these cultures were floated on water in Petri dishes, or when the isolate was subcultured on to sterile dead stems of *Barleria cristata* (a substrate often used in this laboratory) and no perithecia formed on the dead stems. Small very slightly coloured spherical knots of hyphae formed on some of the floating pieces of culture, but no further development took place.

DISCUSSION

Iqbal's collection consisted of immature perithecia on submerged decaying branches, and mature perithecia developed when the material was held in plastic bags, but whether this entailed a humid atmosphere only, or immersion in water in the bags, was not stated. In culture, Iqbal obtained perithecia without flooding, as did the present author.

Perithecia in the present collection formed on the submerged substrate, and were apparently mature, as asci were extruded within a short time when the material was removed from the water culture and allowed to air-dry.

It should be noted that these mature asci were not extruded until drying occurred, even though the tips of the perithecial necks protruded above the water surface into the air.

Whether the fungus colonized the leaves before immersion, or whether the submerged substrate was colonized by propagules from the stream, is not known. It is also not known whether asci and ascospores will mature if the substrate remains totally submerged, and

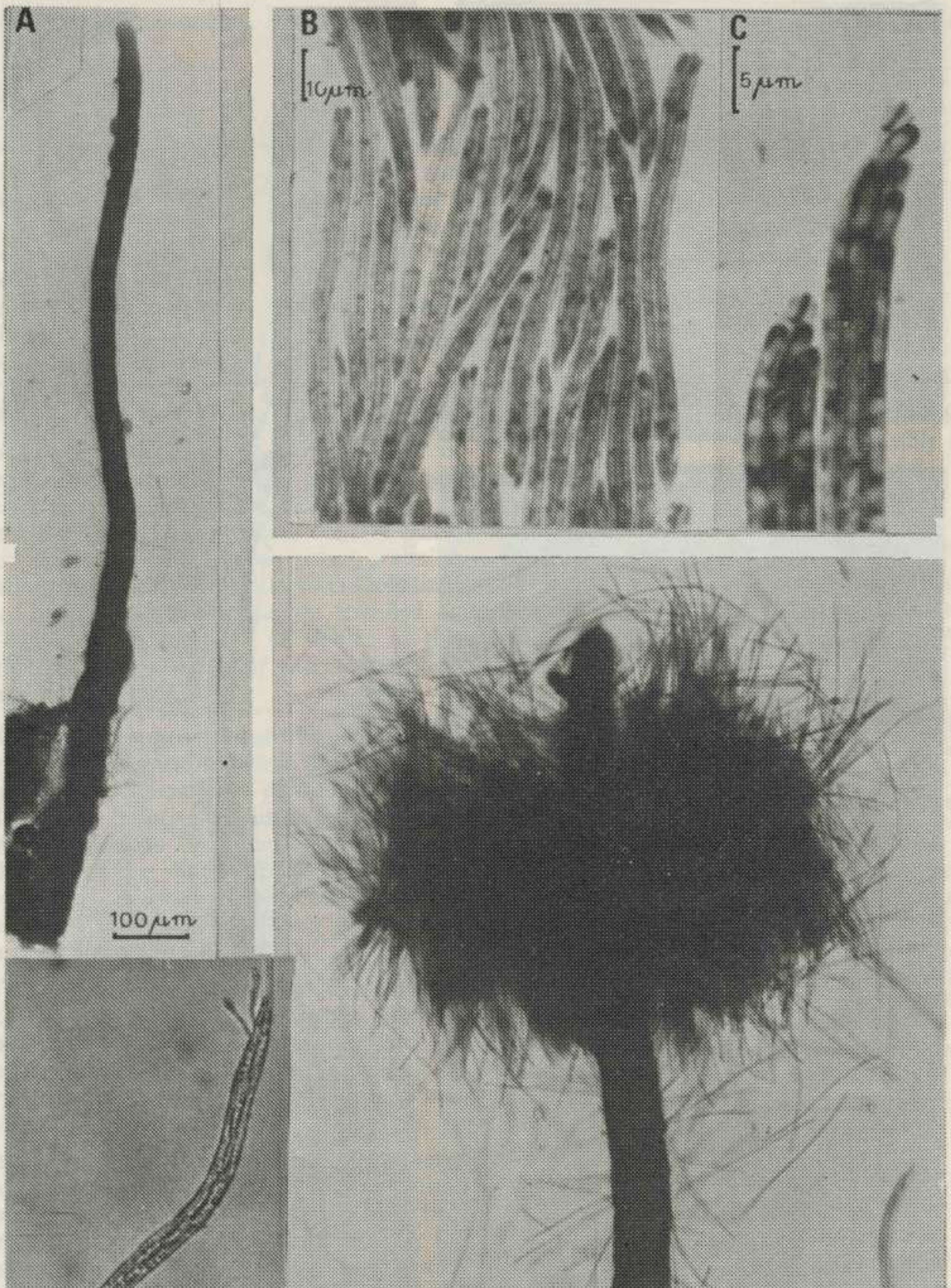

Plate I.— A. Perithecial neck from original substrate. B. Asci extruded in globule from neck tip in drier atmosphete; stained lactic fuchsin. C. Two ascus tips showing median canal in apical ring; stained cotton blue lactophenol. D. Extruded ascus with ascospores germinating at both ends; unstained. E. Ascospores in terminal globule some time after extrusion; only a few asci still remaining; stained lactic fuchsin

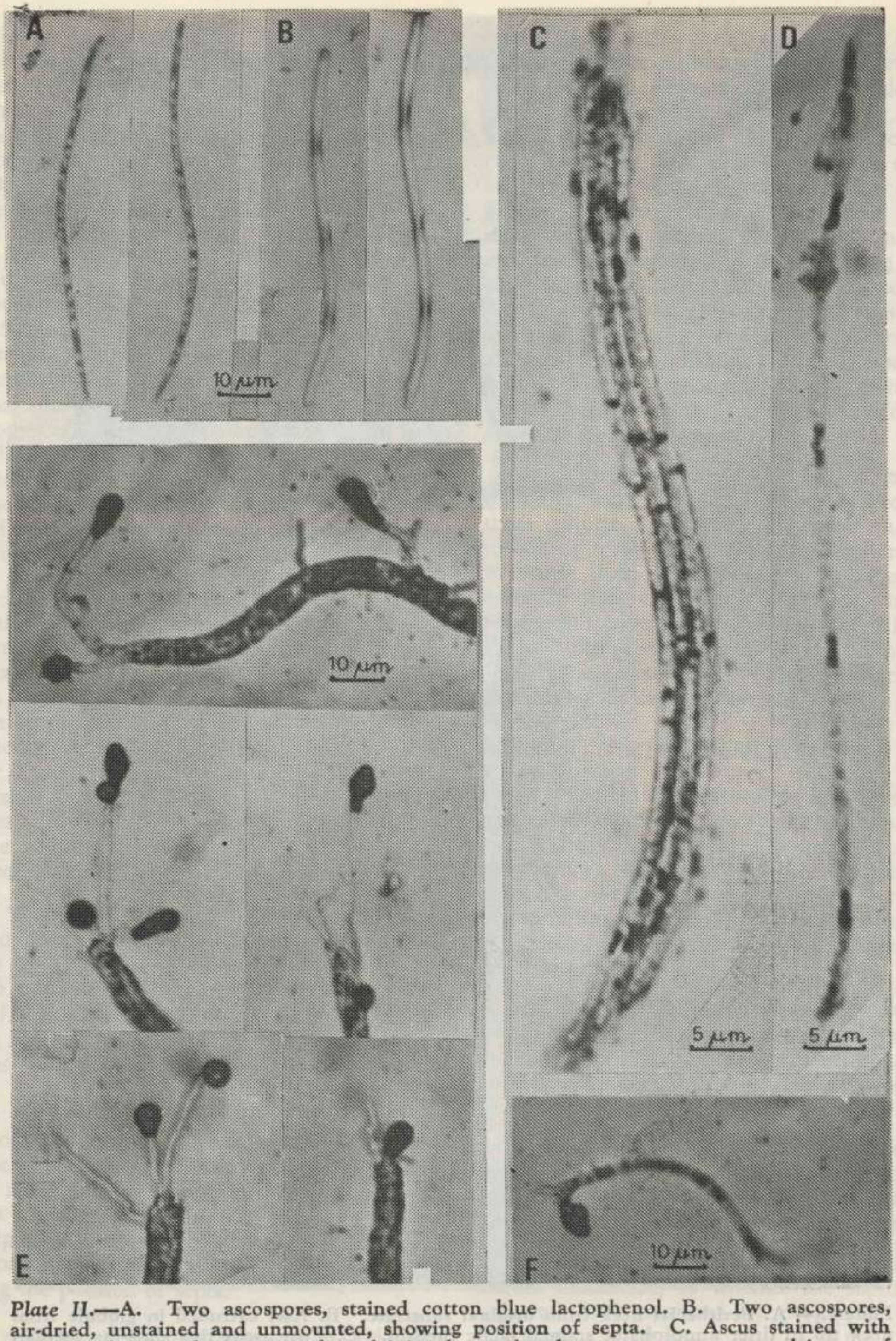

Plate II.—A. Two ascospores, stained cotton blue lactophenol. B. Two ascospores, air-dried, unstained and unmounted, showing position of septa. C. Ascus stained with Giemsa, showing four areas of nuclei in the enclosed ascospores; some nuclei out of focus. D. Ascospore stained with Giemsa showing four elongated nuclei per spore. E. Various appressoria from ascospores germinating within asci in hanging drops; unstained. F. Appressorium produced on germinating ascospore in hanging drop; unstained

Table 1.—Ascomycetes recorded as ejecting or extruding asci or ascospores when placed in a condition of lower humidity

Sordaria fimicola	Ingold & Mashall 1962*	ascospores ejected
S. fimicola	Austin 1968*	" "
Nectria galligena	Lortie & Kuntze 1963*	" "
Wetted lichen fruit bodies	Ahmadjian 1967*	" "
Anthostomella cylindrospora	Booth & Shaw 1967	" extruded
A. cylindrospora	Shaw & Booth 1967	" "
Claviceps purpurea	Hadley 1968*	" ejected
Calonectria crotalariae	Rowe & Beute 1975	" "
Leiosphaerella longispora	Sivanesan, Shaw & Brown 1976	& asci extruded
Gnomonia papuana	Sivanesan & Shaw 1976	asci "
Gaeumannomyces leptosporus	Shaw (herein)	" "

* Cited by Ingold (1971)

whether, if maturation does occur, asci or ascospores are extruded below the water surface. Although extrusion in the present case occurred in the laboratory when the leaf pieces were removed to a drier atmosphere, a similar situation could occur in nature when colonized leaves or branches in streams are stranded on the banks, or on rocks, or on debris, as this would constitute a relatively drier atmosphere than the submerged state.

While it is apparent that this fungus can survive in an aquatic situation, it may not be fully aquatic, especially as perithecia are able to develop to maturity on nutrient agar without immersion, and as the perithecial necks protruded above the water surface in the water cultures, and as asci were extruded in the air when the substrate with perithecia was removed to a drier atmosphere.

The occurrence reported here adds another species to the number of ascomycetes (such as those listed in *Table* 1) whose asci or ascospores have been reported as ejected or extruded when the perithecia were placed in a condition of lower humidity.

It is not known as yet whether *G. leptosporus* produces hyphopodia on its substrates in nature. However, the fact that it did not produce them in several tests in the laboratory, although the germinating ascospores formed appressoria in hanging drops, may indicate that this species is somewhat different (apart from the smaller size of the asci and ascospores already noted by Iqbal) from *G. graminis*, which produces abundant hyphopodia.

The fact that this fungus has now been reported from two such diverse locations as about 51° N. latitude in England and about 9° S. latitude in Papua New Guinea probably indicates that it is of worldwide distribution.

ACKNOWLEDGMENTS

Grateful thanks are extended to Dr A. Sivanesan of the Commonwealth Mycological Institute, Kew who confirmed the identity of the fungus, and to Mr J. Walker, Department of Agriculture, Rydalmere, NSW, for general discussion on the genus *Gaeumannomyces*.

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(Accepted for publication October, 1976.)

Printed and Published by E. C. Awo, Papua New Guinea Government Printer,
Port Moresby—6043/1 500.—7.77.