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Response of Digitaria setivalva *to nitrogen, phosphorus, potassium, magnesium and calcium on Ebini sandy loam, Guyana. I—Effect on yield, tissue composition and nutrient uptake*

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A field experiment was conducted in Guyana to determine the response of the grass *Digitaria setivalva* on Ebini sandy loam, a highly leached infertile soil, to N, P, K, Mg and Ca. Application of N and P caused very significant increases in dry matter production of the order of 8000 and 4000 kg/ha respectively. Ca, K and Mg had no effect on yield. It was shown that adequate moisture was necessary for optimum dry matter production. The application of N, P and K generally increased the tissue content of the respective nutrient. The P content of non-phosphorus fertilized grass was deficient for grazing cattle. The percentage recoveries of fertilizer N, P and K were low and the possible reasons for this are discussed.

INTRODUCTION

THE BROWN SANDS are the dominant soils of the intermediate savannahs of Guyana. These soils are very widespread in their distribution, occupying approximately 9800 km^2 (BRINKMAN, 1965), and are developed from deeply weathered, unconsolidated, brown, sandy deposits of the Berbice formation. They are usually sandy textured with good physical characteristics, but of low inherent fertility. The natural vegetation consists of savannah grass (*Trachypogon plumosus*) with frequent sand-paper trees (*Curatella americana*) (FANSHAWE, 1952).

Although the soils may be suitable for several crops, they are being specially considered for pasture grasses, following observation on similar soils at the Ebini Livestock Station in the same region. There is, however, a scarcity of reliable data on the effect and fate of fertilizers applied to pasture grasses on these soils. WAGENAAR (1965) reported the effect of fertilizers on Pangola grass, but this was confined to yield response. RUTHERFORD and STARK (1959) concluded that the basic fertilizer needs for these soils are nitrogen, phosphorus and potassium, but because of their origin and very leached nature, trace elements may also be important. CHESNEY (1968) has shown that Ebini sandy loam also has a high phosphate fixing capacity.

The study reported here was designed to obtain an indication of the effect of nitrogen, phosphorus, potassium, magnesium and calcium on the yield, tissue composition and nutrient uptake of *Digitaria setivalva*.

MATERIALS AND METHODS

Soil

The experiment was carried out on Ebini sandy loam (Typic Normochrult) at the Ebini Crop Station, Berbice River. This is one of the three important soils of the Brown Sands. *Table 1* gives the particle size distribution and some chemical properties of the top 15 cm of the soil.

Table 1. Particle size analysis and some chemical properties of the top 15 cm of Ebini sandy loam

Sand (%)	60
Silt (%)	24
Clay (%)	16
pH	5·3
Total N (%)	0·04
OM (%)	0·27
CEC (mequiv./100g)	1·22
Exchangeable K (mequiv./100g)	0·02
Exchangeable Mg (mequiv./100g)	0·30
Exchangeable Ca (mequiv/100g)	0·30
Base saturation (%)	61
Truog-P (p.p.m.)	1

Climate

The area has a mean annual rainfall of 2250 mm distributed in two wet seasons—a long wet season from mid-April to mid-August and a short wet season from December to the end of January.

Experimental design and procedures

The experiment was of a 2^5 factorial design with one replicate, giving a total of 32 plots. The three, four and five factor interactions were, however, confounded to give four blocks of eight plots each (COCHRAN and COX, 1957). Plots were 7·2 × 3·6 m with a 0·9 m path separating them.

The five factors were N, P, K, Mg and Ca, the two levels being their absence and presence. The rates per application were N (as ammonium sulphate), 83 kg/ha; P (as triple superphosphate), 50 kg/ha; K (as potassium chloride), 52 kg/ha; Mg (as kieserite), 7 kg/ha; Ca (as calcitic limestone), 1120 kg/ha. The grass, which was about a year old and established from cuttings, was cut before the first application of the fertilizers which were applied broadcast at the start of the experiment in March 1968, and subsequently at 12 week intervals. The four applications of fertilizer are referred to as F_1 to F_4. Lime was applied about three weeks before the grass was planted.

The grass was sampled by cutting three 0·9 m squares, chosen at random from each plot, at six or 12 week intervals depending on the growth of the grass. These were bulked to give one sample per plot. Samples were cut to a height of aproximately 5 cm and the remainder of the grass was cut to the same height. All grass cuttings were removed from the experimental site. Samples were weighed fresh and again after oven-drying at 80°C for 48 hours.

Tissue analysis

Oven-dried grass samples were ground in a stainless-steel mill and analysed for total-N by the micro-Kjeldahl method. P was determined by the vanado-molybdate method and K by flame-photometry after digestion with the tri-acid mixture of conc. HNO_3, conc. H_2SO_4 and 60 per cent $HClO_4$ in the ratio of 10:1:4 by vol. (JACKSON, 1958).

RESULTS AND DISCUSSION

Soil

The soil data in *Table 1* show that N, P, K, Mg, and Ca are all present in amounts that cannot support abundant plant growth, indicating a soil of low fertility. The low cation-exchange capacity (*CEC*) and organic matter (*OM*) content suggest that there are few charged particles to which applied nutrients such as NH_4^+, K^+, Ca^{2+} and Mg^{2+} could be absorbed, and therefore the greater proportion of those nutrients will be in the soil solution. This, and the large proportion of coarse-sized particles which makes the soil very permeable, suggest that excessive leaching of applied nutrients can be expected.

Yields

Because the harvest intervals were unequal, individual harvest data are presented in terms of dry matter (*DM*) production per week (*Figure 1*). Rainfall data (half-monthly totals) are also presented. Generally, yields fluctuated with available moisture; the highest yields were obtained when fertilizers were applied during the heavy rainfall period of May to July, and growth was slowest (visual observation) when fertilizer applications (F_3 and F_4) were followed by comparatively dry spells. Similar relationships between rainfall and *DM* production of tropical pastures have been reported in Hawaii (WHITNEY and GREEN, 1969), Tanzania (WALKER, 1969) and Colombia (CROWDER *et al.*, 1964). Inadequate moisture obviously prevented applied nutrients from showing their full potential in increasing *DM* production. It would seem, therefore, that for highest annual *DM* production of tropical pasture grasses, irrigation must be provided during the drier months. The average night temperature was always above 14·5°C suggested by BRYAN and SHARP (1965) as the critical low temperature for the related Pangola grass (*Digitaria decumbens* Stent.). Temperature, therefore, was not a limiting factor.

After the first and second fertilizer applications (F_1 and F_2), it was possible to harvest at six weeks and again at 12 weeks. Yields of the second harvest were always lower than those of the first, this being especially so with F_2, which was immediately followed by heavy rainfall. This suggests that the applied fertilizers were less available during the last six weeks.

Nitrogen always had a significant effect ($P<0{\cdot}01$) on *DM* production except at the second harvest after F_2, when failure to obtain a response may have been due to the leaching of fertilizer N out of the rooting zone by the heavy rainfall immediately after F_2. The positive effects of nitrogen on *DM* production observed here are in agreement with the findings of CROWDER *et al.* (1964), AHMAD *et al.* (1969) and WHITNEY and GREEN (1969).

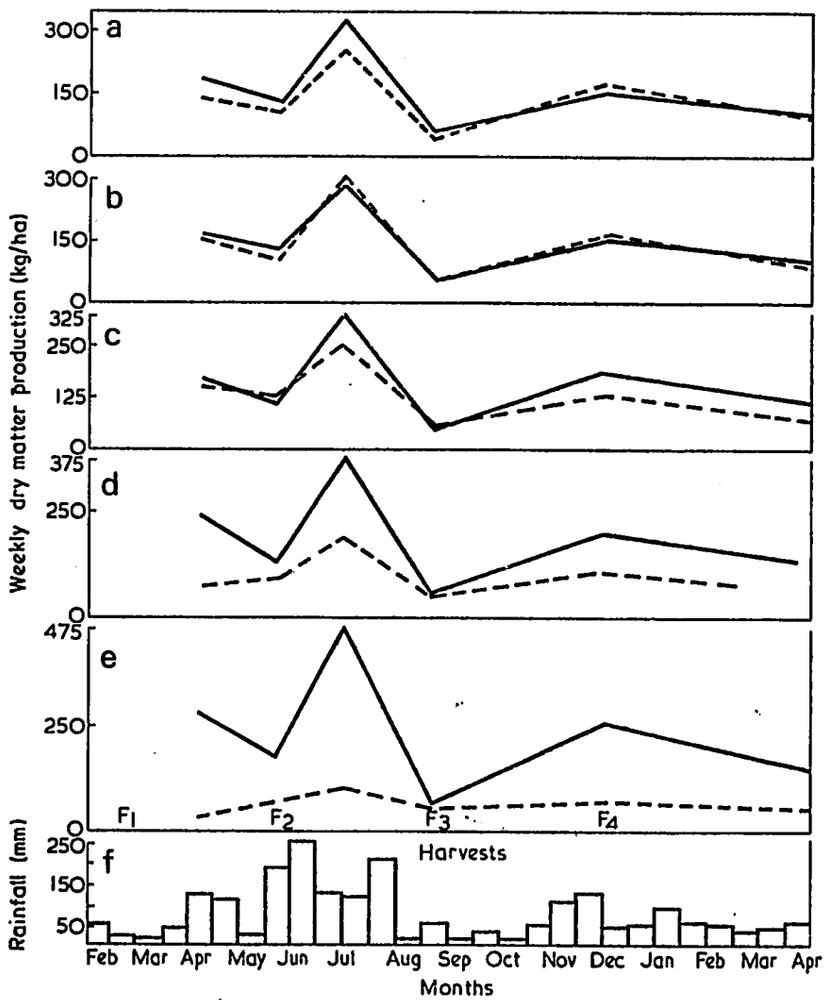

Figure 1. Effect of (a) *calcium*, (b) *magnesium*, (c) *potasium*, (d) *phosphorus*, (e) *nitrogen* and (f) *rainfall on weekly dry matter production of* Digitaria setivalva. ——, With; - - - -, without fertilizer application

Phosphorus always had a significant effect ($P<0{\cdot}05$) on *DM* production except at the second harvest after F_2 and that after F_3. In the second instance, moisture was a limiting factor for about nine weeks, and the growth of grass was very slow. During this period, applied-P was probably fixed and therefore unavailable to the grass when there was adequate moisture for growth. In support of this argument, CHESNEY (1968) showed in incubation studies that these soils fixed as much as 90 per cent of 75 p.p.m. applied-P within two weeks. The generally positive response to P observed here disagrees with the findings of AHMAD *et al.* (1969) with Pangola grass on River Estate loam in Trinidad. They attributed lack of response first

to the grass obtaining its P requirements from the soil reserves, and second that most of the applied-P was fixed within one month of application. It is possible that on Ebini sandy loam the soil reserves were not available to the grass, and even though some of the applied-P was very probably fixed, the grass had to depend on the remainder of this applied-P for its growth.

Potassium and Mg had no significant effect on *DM* production at any harvest. This agrees with the results of AHMAD *et al.* (1969) but disagrees with those of WAGENAAR (1965). However, plots dressed with K appeared healthier than those receiving no K.

Lime had a significant effect only at the second harvest of F_1. This general failure of the grass to respond to liming is in agreement with the findings of BONNETT and RIERA (1950) with Guinea grass but differs from those of ABRUNA *et al.* (1964) with Napier and Pangola grasses. This conflict in findings may be related to the exchangeable aluminium in the respective soils, the effect of lime on this and the tolerance of the individual grass to this element.

At the first harvest of both F_1 and F_2 the NP interaction was significant ($P<0{\cdot}05$). Examination showed that N had a greater effect on *DM* in the presence of phosphorus and *vice versa*.

Table 2. Effect of applying N, P, K, Mg and Ca on annual dry matter production of Digitaria setivalva

Nutrient	*Annual dry matter yield (kg/ha)*	
	With	*Without*
N	10 674	2 514
P	8 661	4 527
K	7 374	5 814
Mg	6 663	6 525
Ca	6 953	6 235

LSD (0·05) = 2229
(0·01) = 3107

The annual *DM* production values are given in *Table 2*. The application of N and P caused an increase in *DM* of 8000 and 4000 kg/ha respectively. LITTLE *et al.* (1959), CROWDER *et al.* (1964) and WHITNEY and GREEN (1969) have obtained similar increases in *DM* production using approximately 332 kg N/ha per year. AHMAD *et al.* (1969) have reported much larger increases, but these have been extrapolated from results over a four month period and it was assumed that irrigation would be provided during the drier months, a period when increases would have been much lower.

Of the nutrients tested, it seems that under existing environmental conditions at Ebini, N and P (especially the former) are the most important nutrients for increasing the *DM* production of *D. setivalva*. This agrees with the findings of RODRIGUES (1949).

Tissue composition

Nitrogen.—The nitrogen contents of the grass at the various harvests are presented in *Table 3*. These data show that the N content of the grass at all harvests, except that after F_3, was increased by the application of N; similarly it was decreased by the application of K. Magnesium and

phosphorus had negative effects on tissue-N content at some harvests. Lime had no effect on forage-N content. The NP interaction was negative and significant at all harvests except the first; examination of this interaction

Table 3. Effect of applying N, P, K and Mg on the N content of the forage of Digitaria setivalva *at separate harvests*

Treatment	% N in forage (oven-dry basis)				
	F_1*		F_2*	F_3*	F_4*
	Harvest 1	Harvest 2	Harvest 2	Harvest	Harvest
−N	0·92	0·86	0·78	0·72	0·56
+N	1·53	1·00	0·96	0·88	0·83
−P	1·24	1·01	0·95	0·78	0·71
+P	1·20	0·85	0·79	0·82	0·68
−K	1·30	0·99	0·92	0·74	0·81
+K	1·14	0·87	0·82	0·86	0·58
−Mg	1·30	1·00	0·90	0·87	0·75
+Mg	1·10	0·86	0·84	0·73	0·64
LSD (0·05)	0·13	0·08	0·08	0·17	0·19

* F_1, F_2, F_3 and F_4 refer to the first, second, third and fourth fertilizer applications respectively.

showed that P reduced the positive effect of applied-N on the tissue-N content. The positive effects of N within the range tested on tissue-N content have also been reported by CROWDER *et al.* (1964) and AHMAD *et al.* (1969). The negative effects of K and Mg may be attributed to cation competition or antagonism. The negative effect of P is of interest. It may be attributed to the increased yields caused by the application of P, which resulted in the dilution of the N fraction in the forage.

Where analyses are available for two harvests after the application of fertilizer, i.e., after F_1, the N content decreased in the second harvest; this agrees with the findings of AHMAD *et al.* (1969).

Phosphorus.—The P content values are presented in *Table 4.* Application of P always increased the P content. The levels of P in the tissue to which

Table 4. Effect of applying N, P, K and Mg on the P content of the forage of Digitaria setivalva *at separate harvests*

Treatment	% P in forage (oven-dry basis)				
	F_1*		F_2*	F_3*	F_4*
	Harvest 1	Harvest 2	Harvest 2	Harvest	Harvest
−N	0·28	0·23	0·25	0·22	0·30
+N	0·18	0·14	0·14	0·16	0·17
−P	0·08	0·06	0·06	0·05	0·08
+P	0·38	0·31	0·32	0·33	0·39
−K	0·24	0·19	0·24	0·21	0·27
+K	0·22	0·18	0·15	0·17	0·20
−Mg	0·24	0·19	0·20	0·20	0·23
+Mg	0·22	0·18	0·19	0·18	0·24
LSD (0·05)	0·15	0·07	0·03	0·02	0·02

* F_1, F_2, F_3 and F_4 refer to the first, second, third and fourth fertilizer applications respectively

P was not applied were always lower than the minimum value of 0·17 per cent suggested by MORRISON (1959) for fodder for beef cattle. This explains why cattle fed on native or established pasture receiving little or no fertilizer have been reported to suffer from stiffness of the joints—a symptom of possible P deficiency (LEGG, S. P., personal communication, 1965). If only for this reason, pastures for cattle on the Brown Sands must be adequately dressed with P.

Application of N and K significantly decreased forage-P content at most harvests. The negative effect of N was probably attributable to the large increases in yield it caused and hence dilution of the P content. The reason for the decrease caused by K is not obvious. The effects of N and K are substantiated by the significant NP and PK interactions, examination of which showed that both K and N reduced the positive effect of applied P on the P content of the tissue. Lime and Mg had no effect on P content of the forage.

Potassium.—The K content of the forage is shown in *Table 5.* Fertilizer K increased the K content of the forage at all harvests, except the first after F_1. Usually the K content was doubled by the application of K. Since K did not increase yields, *D. setivalva* obviously shows 'luxury consumption' of this element. The observation of VICENTE-CHANDLER *et al.* (1964) that less than 1·50 per cent in 60 day old Pangola grass indicates a deficiency of K suggests that the untreated soil does not satisfy the requirements of *D. setivalva.*

Table 5. Effect of applying fertilizer N, P, K and Mg on the K content of the forage of Digitaria setivalva *at separate harvests*

	% *K in forage (oven-dry basis)*				
	F_1*		F_2*	F_3*	F_4*
Treatment	*Harvest 1*	*Harvest 2*	*Harvest 2*	*Harvest*	*Harvest*
−N	0·77	0·85	1·56	0·65	0·50
+N	1·32	1·26	2·22	1·14	0·78
−P	1·26	1·14	2·18	0·85	0·68
+P	0·83	0·97	1·60	0·94	0·60
−K	1·12	0·76	1·24	0·54	0·32
+K	0·97	1·35	2·54	1·25	0·96
−Mg	1·11	1·12	2·06	1·05	0·72
+Mg	0·98	0·99	1·72	0·74	0·56
LSD (0·05)	0·58	0·12	0·23	0·19	0·10

* F_1, F_2, F_3 and F_4 refer to the first, second, third and fourth fertilizer applications respectively

The increase in K content of the tissue on application of N probably arose from NH_4^+ ions replacing fixed K^+ ions on the soil exchange complex; the K then became available to the grass. The amount of K so released must have been rather large, to neutralize and overcome the dilution of the K fraction within the plant as would follow the increased yields that resulted from the application of N.

At all harvests, Mg and P reduced the K content in the tissue probably by cation antagonism and dilution effect respectively.

Lime had no effect on K content. There were no significant two-factor interactions.

Nutrient recovery

The percentage recovery of a given nutrient is calculated as $(a-b)/c \times 100$, where a is the amount of nutrient recovered when the particular nutrient was added, b is the amount of nutrient recovered when none of the particular nutrient was added, and c is the amount of nutrient applied as fertilizer. The amount of nutrient recovered is obtained by multiplying the tissue content of the element by total dry matter yield.

The percentage recoveries of fertilizer N, P and K are presented in *Table 6.*

Table 6. Percentage of fertilizer nitrogen, phosphorus and potassium recovered in the forage at the different harvests

Nutrient	Percentage recovered after				
	F_1*		F_2*	F_3*	F_4*
	Harvest 1	Harvest 2	Harvest 2	Harvest	Harvest
N	24	7	1	35	15
P	6	4	2	4	8
K	7	7	6	14	23

*F_1, F_2, F_3 and F_4, refer to the first, second, third and fourth fertilizer applications respectively.

Nitrogen.—The recovery of applied N after all fertilizer applications was relatively much lower than that reported by other workers (AHMAD *et al.*, 1969; CROWDER *et al.* 1964). This low recovery may have been attributable to one or more of the following factors: leaching, ammonium fixation or volatilization. Immediately after F_4 there were scattered showers of medium intensity presenting numerous wet and dry cycles; such conditions have been shown by VOLK (1959), CHESNEY (1967) and WATSON *et al.* (1962) to cause increased losses of nitrogen by volatilization and were possibly the cause for the even lower recovery of N during this period. The lower recovery of N at the second harvest after F_2 as compared to that after F_1 may have been because of the heavier rainfall in the first period causing greater leaching of applied N. At F_1 where the results of two harvests are available, it is seen that about 77 per cent of the fertilizer N was recovered at the first harvest; this compares favourably with the 70 per cent obtained by AHMAD *et al.* (1969).

Phosphorus.—The total recovery of applied P was 10, 4 and 8 per cent after F_1, F_3 and F_4 respectively. The values for F_1 and F_3 compare favourably with the 12·5 per cent obtained by AHMAD *et al.* (1969). These generally low recovery values may be the result of fixation of applied P rendering it unavailable to the grass. The very low value obtained at F_3 can be explained by the reason given above for the failure of P to increase yields at this harvest. At F_1 approximately half of the P recovered was at the first harvest.

Potassium.—As with N and P, the percentage of fertilizer K recovered was low, that for F_4 being about 64 per cent higher than those of F_1 and F_3. The remainder of the applied K may have been fixed by the soil and/or leached out of the rooting zone of the crop. The higher recovery obtained at the F_4 harvest, where the rainfall was adequate but of low intensity, suggests that less of the fertilizer K was leached than after F_1 and F_3 when there was heavy rainfall. This is supported by the fact that the largest response in yield to K (even though not significant) was also at this harvest. This indicates that perhaps KCl is too soluble a source of K to be used under the prevailing soil and rainfall conditions at Ebini. AHMAD and DAVIS (1970) have shown that the ratio of water-soluble K to exchangeable K in the soil was higher when K was applied as KCl as compared to KH_2PO_4 and KNO_3. Further work on the sources of K in this soil is required.

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REFERENCES

ABRUNA, F., VICENTE-CHANDLER, J. and PEARSON, R. W. (1964). 'Effects of liming on yields and composition of heavily fertilized grasses and on soil properties under humid tropical conditions.' *Proc. Soil Sci. Soc. Am.* **28**, 657–661

AHMAD, N., TULLOCH-REID, L. I. and DAVIS, C. E. (1969). 'Fertilizer studies on Pangola grass (*Digitaria decumbens* Stent.) in Trinidad. I—Description of the experiments and effect of nitrogen. II—Effect of phosphorus, potassium and magnesium.' *Trop. Agric. (Trinidad)* **46**, 173–186

AHMAD, N. and DAVIS, C. E. (1970). 'Forms of K fertilizers and soil moisture content on potassium status of a Trinidad Soil.' *Soil Sci.* **109**, 121–126

BONNET, J. A. and RIERA, A. R. (1950). 'Tracing the mineral from the soil to the plant to the animal blood.' *J. Agric. Univ. P. Rico* **33**, 257–273

BRINKMAN, R. (1965). *Report of the soil survey project of British Guiana.* Vol. 6. 'Semi-detailed soil survey of the Ebini–Ituni–Kwakwani area.' FAO, Rome

BRYAN, W. W. and SHARP, J. P. (1965). 'The effect of urea and cutting treatments on the production of Pangola grass in South-eastern Queensland.' *Aust. J. Exp. Agric. Anim. Husb.* **5**, 433–441

CHESNEY, H. A. (1967). 'Denitrification in some Trinidad Soils.' M.Sc. Thesis. University of the West Indies Library (unpubl.)

CHESNEY, H. A. (1968). 'Phosphate fixation and availability on some soils in Guyana.' *Res. Rep. Minist. Agric. Natl. Res. Guyana, Vol. 2*

CROWDER, L. V., MICHELIN, A. and BASTIDAS, A. (1964). 'The response of Pangola grass (*Digitaria decumbens* Stent.) to rate and time of nitrogen application in Colombia.' *Trop. Agric. (Trinidad)* **41**, 21–29

COCHRAN, W. G. and COX, C. M. (1957). *Experimental Design.* John Wiley & Sons, New York

FANSHAWE, D. B. (1952). 'The vegetation of British Guiana. A preliminary review.' Institute Paper No. 29. Imperial Forestry Institute, Univ. of Oxford

JACKSON, M. L. (1958). *Soil Chemical Analysis.* Prentice Hall, Englewood Cliffs, New Jersey.

LITTLE, S., VICENTE, J. and ABRUNA, F. (1959). 'Yield and protein content of irrigated Napier grass, Guinea grass and Pangola grass as affected by nitrogen fertilization.' *Agron. J.* **51**, 111–113

MORRISON, F. B. (1959). *Feeds and Feeding*, 21st edn, 786 pp. Morrison, Ithaca (N.Y.)

RODRIGUES, J. P. (1949). 'Effect of nitrogen applications on the yields and composition of forage crops.' *J. Agric. Univ. P. Rico* **46**, 297–306

RUTHERFORD, G. K. and STARK, J. (1959). *Soil and Land Use Surveys. No. 6.* Regional Research Centre, University of the West Indies, Trinidad

VICENTE-CHANDLER, J., CARO-COSTAS, R., PEARSON, R. W., ABRUNA, F., FIGARELLA, J. and SILVA, S. (1964). 'The intensive management of tropical forages in Puerto Rico.' *Univ. P. Rico Agric. Exp. Stn. Bull. No. 187*

VOLK, G. M. (1959). 'Volatile losses of ammonia from urea applied to turf or bare soil.' *Agron. J.* **51**, 746–749

WAGENAAR, G. (1965). *Report on the soil survey project of British Guiana.* Vol. 2. 'Soil Chemistry and Soil Management.' FAO, Rome

WALKER, B. (1969). 'Effects of nitrogen fertilizer on natural pastures in western Tanzania'. *Exp. Agric.* 5, 215–222

WATSON, G. A., CHIN, T. T. and WONG, P. W. (1962). 'Losses of ammonia by volatilization from surface dressings of urea in *Hevea* cultivation'. *J. Rubb. Res. Inst., Malaya* 17, 77–90

WHITNEY, A. S. and GREEN, R. E. (1969). 'Pangola grass performance under different levels of nitrogen fertilization in Hawaii'. *Agron. J.* 61, 577–581