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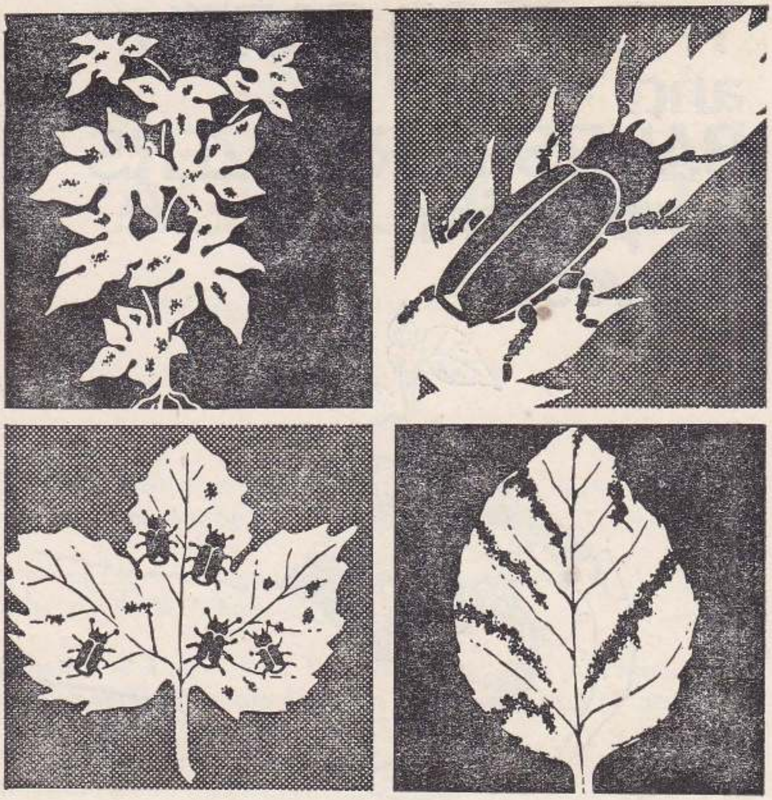

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CEYLON

Some characteristics of the high organic matter content montane soils in the wet zone*

F. S. C. P. KALPAGE

Division of Agricultural Chemistry,
University of Ceylon, Peradeniya

and

M. W. THENABANDU

Division of Chemistry, Central Agricultural
Research Institute, Peradeniya

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INTRODUCTION

IN Ceylon, there are approximately 185,000 acres of land at an elevation of over 5,000 ft. of which 120,000 acres are in the Nuwara Eliya District, 24,400 acres are in the Badulla district, 30,800 acres are in the Kandy district and 10,300 acres are in the Ratnapura and Kegalle districts (3).

Patanas (montane grasslands) inclue the wet *patanas* and the dry patanas. The distinction between ' dry ' and ' wet ' *patana* is based mainly on climate, and in particular on the distribution of rainfall which, in both regions, is typically monsoonal. The rainfall is generally above 60 inches per annum, the average annual rainfall lying between 75 and 125 inches. The wet *patanas* are found in the zone where an average of over 40 inches is caused by the southwest monsoon, July being the month of heaviest rainfall. The rainfall is fairly well distributed throughout the year and, except in February, no real drought is experienced. This rainfall is generally characteristic of tropical wet evergreen forests which at altitudes above 2,000 ft. would merge into sub-tropical or temperate wet evergreen forests. Wet *patanas,* which are therefore subordinate to the main forest type, are found extensively at altitudes above 5,000 ft. In the dry *patana* zone, less than 20 inches of rainfall are contributed by the southwest monsoon, whose influence in weak. The south-west monsoonal winds thus blow as strongly drying winds during the well-marked period of drought in

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* Adapted from a paper presented in Section B (Agriculture & Forestry) of the Ceylon Association for the Advancement of Scien^e at its 24th Annual Session in December 1968.

June and July. Most of the precipitation occurs during the north-east monsoon. An intermediate *patana* zone has been recognised between the wet and dry patanas.

Temperature is controlled mainly by altitude and topography, with averages ranging from 55°C to 74°C. Monthly variations are slight but, due mainly to cloudlessness, there is a great diurnal fluctuation in temperature, this variation being more pronounced in the wet than in the dry patana areas. Relative humidity varies with season, being highest during the rainy season in each area. Frost occurs occasionally and is confined to the wet patana zone only during the dry north-east monsoon period.

According to the Report of the Land Utilization Committee—August, 1967 (3) the more important are aof wet *patanas* grassland occupies 9,500 acres and are found at elevations of over 5,000 ft. About 2,100 acres occur between 4,000-5,000 ft. making a total extent of wet *patana* of 11,600 acres. Dry *patana* grasslands occur at elevations between 3,000 ft. and 5,000 ft. and are approximately 38,000 acres in extent.

Grasslands similar to the *patanas* are found in other parts of the world such as South America, India and in Central, South and East Africa. In some cases the origin of such grassland has been traced to successive firing of primary jungle or forest although de Rosayro (1) regards the 'dry' and 'wet' *patanas* as natural grasland climaxes and preclimaxes respectively, localised by the peculiar topographic formation, geological origin and the prevailing unique climatic conditions.

Patana soils have been described by Jochim and Kandiah (2). They are formed mostly on acid, dark-grey charnockites although in some areas the parent materials are derived from dark greyish-black basic rocks. The typical wet *patana* soil contains an A horizon composed of black, highly acid peaty loam of depth varying from 9 inches to one foot or even more in the higher rainfall areas. A clayey B horizon with much quartz and ironstone concretions may be present over the parent material C horizon which is yellowish and is composed of decomposing rock. The dry *patana* soils have comparatively shallow A horizons less acid than in wet *patana* soils, seldom exceeding 9 inches in depth and usually containing much less organic matter.

The *patanas* constitute an important natural unit whose agricultural potential has not yet been fully exploited. They are often found on the slopes of hillsides the higher aspects of which carry forest vegetation while ill-drained and marshy *deniyas* are found at the foot of slopes and in valley bottoms. Recent research has been directed towards pasture establishment and the growing of crops such as potato in the *patanas*. A better understanding of the fertility characteristics of these soils is therefore necessary. The investigations reported in this paper refer to soils in the wet *patana* region at three elevations: in Bopatalawa (5,000 ft.), Ambawela (6,000 ft.) and in Horton Plains (7,000 ft).

MATERIALS AND METHODS

Soils were sampled from three locations viz: Bopatalawa, Ambawela and Horton Plains. In each case samples were taken from the forested area on the crest of the hill above the *patana*, on the slope in the typical *patana* area and also from the water-logged *deniya* lower down. Samples were collected in polythene bags, transported to the laboratory and allowed to air dry. Air-dried samples of soil which were ground (<2 mm) were used to determine physical and chemical characteristics. Texture was estimated using a rapid texture-testing kit. Munsell Soil Colour Charts were used to determine colour of air dried soils. Walkely and Black's dichromate titration was used for carbon and the Kjeldahl method for nitrogen estimations. pH was determined in a 1 : 1 soil/water suspension using a Beckmann pH meter, available phosphorus by Truog's method, exchangeable sodium and potassium in ammonium acetate extracts using the flame photometer and calcium and magnesium in ammonium acetate extracts using the EDTA method.

RESULTS AND DISCUSSION

Field description of soil profiles are as sollows :—

BOPATALAWA

Profile I

Topographic position ..		.. Slope of hill cose to crest in montane forest area above patana.
Vegetation ..		.. Macaranga (tomentosa) peltata, Rhododenderon zeylanicum, Syzygium operculatum and Pteridium aquilinum.
Relief		.. Normal.
Drainage ..		.. Well drained
Horizon	*Depth* (inches)	*Morphology*
A_1	0—3	.. Dark brown (lOYR 3/3), sandy loam ; weak fine crumb ; leaf litter, many roots ; gradual wavy boundary.
B	3—24	.. Dark yellowish brown (lOYR 4/4), sandy loam ; weak, subangular blocky ; decomposing rocks ; few roots.
C	24 plus	.. Decomposing rocks.

Profile 2

Topographic position ..	..	Upper slope of hill in patana area.
Vegetation ..	..	Predominantly grass (Cymbopogon confertiflorus) with occasional Rhododendron arboreum, Pteridium aquilinum and Centella asiatica.
Relief	..	Subnormal
Drainage ..	..	Imperfect.

Horizon	*Depth* (inches)	*Morphology*
A_1	0—6 ..	Very dark greysih brown (2.5Y 3/2), humicloam ; structureless ; non sticky, non plastic ; many roots and earthworms ; gradual smooth boundary.
A_2	6—15 ..	Dark brown (7.5 YR 4/2), loam ; massive ; non sticky, slightly plastic ; less roots ; clear smooth boundary.
B	15—45 ..	Strong brown (7.5 YR 5/6), clay loam ; weak, subangular blocky.

Profile 3

Topographic position	..	In the valley floor.
Vegetation ..	..	Imperata arundiracea, Drosera pettifolia.
Relief	..	Concave.
Drainage ..	..	Water-logged, water-table at 9–14 inches from surface.

Horizon	*Depth* (inches)	*Morphology*
Ag	0—14 ..	Very dark greyish brown (lOYR 3/2), humic sandy loam ; massive ; sticky, abundant organic matter and partially decomposing plant residues; gradual wavy boundary.
BG	14—24 plus ..	Black (5YR 2/1), humic clay loam ; massive ; sticky ; abundant organic matter.

AMBAWELA

Profile I

Topographic position ..	..	Slope of hill in montane forest above patana.
Vegetation ..	..	Rhododendron zeylanicum, Storbilanthes amabilus and Rannuculus sagittifolius.
Relief	..	Normal.
Drainage ..	..	Well drained.

Horizon	*Depth* (inches)	*Morphology*
A_1	0—6 ..	Dark brown (lOYR 4/3), sandy clay loam ; weak crumb structure, friable ; leaf litter, many roots and earthworms ; gradual wavy boundary.
B_2	6—48 plus ..	Storng brown (7.5YR 5/6), sandy clay loam, gravel and clay content increasing with depth ; week subangular blocky structure.

SOME CHARACTERISTICS OF THE HIGH ORGANIC MATTER CONTENT MONTANE SOILS IN THE WET ZONE

Profile 2

Topographic position	Slope of hill in patana area.
Vegetation	Predominantly Garnotia mutica. Others include Smithia blanda, Fimbristylis pentaptera and Anotis nummularia.
Relief	Subnormal.
Drainage	Imperfect.

Horizon	*Depth* (inches)	*Morphology*
A	0— 7 ..	Very dark greyish brown (lOYR 3/2), humic loam ; structureless ; non sticky, non plastic ; abundant roots and earthworms ; gradual smooth boundary.
B	7—14 ..	Dark brown (7.5YR 4/4), sandy loam with decomposing rock fragments.
D	14 plus ..	Quartzitic bedrock.

Profile 3

Topographic position	On the hill slope in patana area just above valley floor.
Vegetation	Predominantly Garnotia mutica, Pteridium aquillinum and Rhododendron zeylanicus.
Relief	Subnormal.
Drainage	Imperfect.

Horizon	*Depth*	*Morphology*
A_1 ..	0—8 ..	Very dark greyish brown (10YR 3/2) humic sandy loam ; structureless ; non sticky, non plastic ; abundant organic matter and roots.
A_2 ..	8—24 ..	Dark greyish brown (10YR 4/2) ; fine sandy clay loam ; single grained.
B ..	24 plus ..	Yellowish brown (10YR 5/8) ; clay loam with decomposing rock fragments ; few tubular pores.

Profile 4

Topographic position :	In the valley floor.
Vegetation :	Predominantly Garnotia mutica, Crysopogon zeylanicus and Arundinella villosa.
Relief :	Concave.
Drainage :	Poorly drained.

Horizon	*Depth* (inches)	*Morphology*
A_g ..	0—10 ..	Black (10YR 2/1), humic loam with gravel ; abundant organic matter.
D ..	10 plus ..	Quartzitic bedrock.

HORTON PLAINS

Profile 1

Topographic position .. Slope of hill in montane forest area above patana.

Vegetation : Neolitsea fuscata, Actinodaphne speciosa, Saurauja sp., Meliosama sp., Engenia sp., Rhododendron zeylanicum, Sarcowcca zeylanica, Toddalia asiatica and Indocalamus wightianus.

Relief : Normal

Drainage : Well drained.

Horizon	*Depth* (inches)	*Morphology*
A	0—2	Dark brown (7.5YR 4/2), loam ; crumb ; leaf litter and fine roots ; gradual change to,
B_1	2—13	Dark brown (7.5YR 4/3), clay loam ; subangular blocky ; few large roots ; clear wavy boundary.
B_{21}	13—20	Yellowish brown (10YR 5/4), clay loam ; angular blocky ; few roots ; clear irregular boundary.
B_{22}	20—37	Brownish yellow (10YR 6/8), clay with fine sand, sand fraction increasing with depth ; no roots ; decomposing rock below 37 inches.

Profile 2

Topographic position : Upper slope of hill in patana area.

Vegetation : Cheimonobombusa densiflora occupies about 95 per cent. of the area. Other plants include Rhododendron zeylanicum, Eulalia phaeothrix and Chysopogon zeylanicus.

Relief : Subnormal.

Drainage : Imperfectly drained.

Horizon	*Depth* (inches)	*Morphology*
A	0—6	Black (10YR 2/1), humic loam ; friable ; non sticky, non plastic ; abundant roots ; gradual change to,
B_1	6—16	Black (10YR 2/1), silty clay ; blocky to subangular blocky ; few roots.
B_{21}	16—22	Dark grey brown (10YR 4/2), clay loam ; blocky, with gravel.
B_{22}	22—42	Brownish yellow (10 YR 6/8), clay ; compact, massive, little gravel ; occasional black splotches.

Profile 3

Topographic position : Lower slope of hill in patana area.

Vegetation : Cheimonobambusa densiflora covers about 95 per cent. of the area. Other commonly occuring plants are Andropogon lividus, Chysopogon zeylanicus, Tripogon bromoides, Ranunculus sagittifolius and Cyanotis pilosa.

Relief : Subnormal.

Drainage : Imperfect.

SOME CHARACTERISTICS OF THE HIGH ORGANIC MATTER CONTENT MONTANE SOILS IN THE WET ZONE

Horizon	*Depth* (inches)	*Morphology*
A	0—10	Black (10YR 2/1), humic loam ; friable ; non sticky, non plastic ; earthworms and abundant roots ; gradual, change to,
B 1	10—20	Black very dark brown (10YR 2.5/1), humic clay loam ; compact ; few larger roots, clearchange to,
B 21	20—25	Very dark grey brown(10YR 3/2.5), humic clay ; massive fine roots ; water table present.
B 22	25—35	Yellowish brown (10YR 5.5/6), clay with sand ; massive.

Profile 4

Topographic position .. In the valley floor.

Vegetation .. Up to approximately 50 per cent. of the area is occupied by Cheimonobambusa densiflora. Other plants include Garnotia mutica, Rhychospora rugosa, Chrysopogon zeylanicus and Eriocaulon sp.

Relief .. Flat to concave.

Drainage .. Water-logged, water table within 6 inches from surface.

Horizon	*Depth* (inches)	*Morphology*
Ag	0—10	Black (10YR 2/1), peaty loam ; abundant roots ; very moist
BG	10—23	Black (10YR 2/1), peaty loam ; massive ; sticky ; very moist.

Data on the chemical characteristics of the soils are given in Tables 1, 2 & 3. The soils are all acid but there is a slight rise in pH from the Ambawela soils (average pH 4.7) to Bopatalawa soils (average pH 4.9) and Horton Plains soils (average pH 5.2).

Organic matter contents were highest for surface soils and decreased with depth for every profile. Average percentages for organic matter for surface soils were 14.4 (Bopatalawa), 8.7 (Ambawela) and 23.2 (Horton Plains). These values are not directly proportional to either elevation or rainfall and are probably determined by vegetation in addition to climate. The influence of vegetation and microbiological activity on the nature and amount of organic matter developed in these soils needs further study.

Average values for total nitrogen in surface soils vary from 0.69 per cent. (Bopatalawa) to 0.46 per cent. (Ambawela) and 1.01 per cent. (Horton Plains). These figures correspond to 13,800, 9,200 and 20,200 lb nitrogen per acre for the surface 6 inches of soil. Assuming that 5 per cent. of the total nitrogen can be mineralized and used by a crop during each season, between 400 and 1,000 lb. of nitrogen should be available for crop growth when these soils are brought under cultivation. Kathirgamathyah and Caesar (5) did not observe any responses by potato to applied nitrogenous fertilizer in virgin forest as well as wet *patana* soils. But in cultivated soils striking responses were observed to applications of up to 50 lb. N per acre on *patana* soils and up to 80 lb. N per acre on forest soils. A 5 ton per acre crop of potato will remove about 50 lb. N. These soils could therefore theoretically supply all the nitrogen requirements of a potato crop for several seasons if the soil nitrogen is efficiently exploited. The rapid decline in nitrogen content with cultivation and methods for maintaining and exploiting the nitrogen in soil organic matter need to be investigated further.

The carbon : nitrogen ratio ranged from 4.5 to 17.6 for all soils with an average of 10.9 *Deniya* soils showed higher C/N values than forest or patana soils. These values are similar to those reported by Joachim and Kandiah (2) and lower than figures given by Moorman and Panabokke (6).

Available phosphorus as determined by Truog's (0.002N H_2SO_4) method varied from 31.1 to 91.1 lb. P_2O_5/acre. Most annual crops remove between 20 -30 lb. P_2O_5 per acre. And yet striking responses were observed on potato (5) to phosphate applications on virgin forest and to a lesser extent on *patana* soils. Phosphorus is likely to be fixed under the acid conditions prevailing. This was confirmed by the gradual build up of phosphorus reserves after a few seasons' cultivation.

Cation exchange capacities vary from 10.0 to 67.7 me/100 g. soil, with an average of 28.8 me/100 g. soil. CEC values decrease with depth for every profile studied. Kalpage *et. al.* (4) reported 85 per cent. kandite and 10 per cent. gibbsite in the clay fraction of a red-yellow podzolic soil from Pelmadulla. If this is typical of the red-yellow podzolic soils studied here the high cation exchange capacities indicate a major contribution from the organic matter fraction. The cation exchange capacity is directy proportional to organic matter content (Figure I).

The correlation between organic matter content of soils and their cation exchange capacities is highly significant. The dependence of cation exchange capacity on organic matter shows the importance of maintaining a satisfactory level of organic matter in these soils. It explains also the response that has invariably been observed by crops like potato and vegetables to additions of cattle manure and composts. When organic matter reserves are low, retention of added nutrients will be poor and fertility will decline.

Base saturation varies from about 5 per cent. to a little over 30 per cent. So long as CEC remains high fertilizer retention in these soils should be good and there will be much potential chemical fertility. Forest surface soils contain most exchangeable calcium, the values for Bopatalawa, Ambawela and Horton Plains being 5.19, 10.59 and 8.72 me/100 g. respectively. For an average exchangeable calcium content of 8 me/100 g. the quantity of exchangeable calcium in plough depth will be 3,200 lb. Ca per acre. In the *patana* surface soils an average exchangeable calcium content of 1.37/100 g. would correspond to only 548 lb. Ca per acre in the plow depth. There is slightly more exchangeable calcium in the *deniya* soils with an average of 1.8 me/100 g. or 720 lb. Ca/acre in the plow depth.

The highest exchangeable magnesium content is also to be found in the forest surface soils in each locality. The Ca/Mg ratios are 6.2, 3.7 and 3.6 respectively for the Bapatalawa, Ambawela and Horton Plains forest surface soils. The Ca/K and Ca/Na ratios are, on the other hand, lower for the Bopatalawa than for the Ambawela and Horton Plains. This probably reflects differences in vegetation and indicates a different type of vegetation at Bopatalawa when compared to Ambawela and Horton Plains.

CONCLUSIONS

In all profiles studies at three different locations, organic matter contents were high and decreased with depth for each profile. The amount of organic matter developed depends not only on climate but also on vegetation and micro-organic activity.

The nitrogen contents are high and these soils could theoretically supply nitrogen to crops for several seasons if the soil nitrogen is efficiently exploited. Deniya soils showed higher C/N ratios than forest or patana soils at all locations.

There is a satisfactory level of Truog available P_2O_5 but phosphorus fixation is likely to be a problem on these acid soils.

Cation exchange capacity is high and is directly proportional to organic matter, indicating the importance of maintaining a satisfactory level of organic matter in these soils. The differences in base ratios probably reflect differences in vegetation at the three altitudes.

ACKNOWLEDGMENT

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Figure 1. Variation of cation exchange capacity with organic matter content

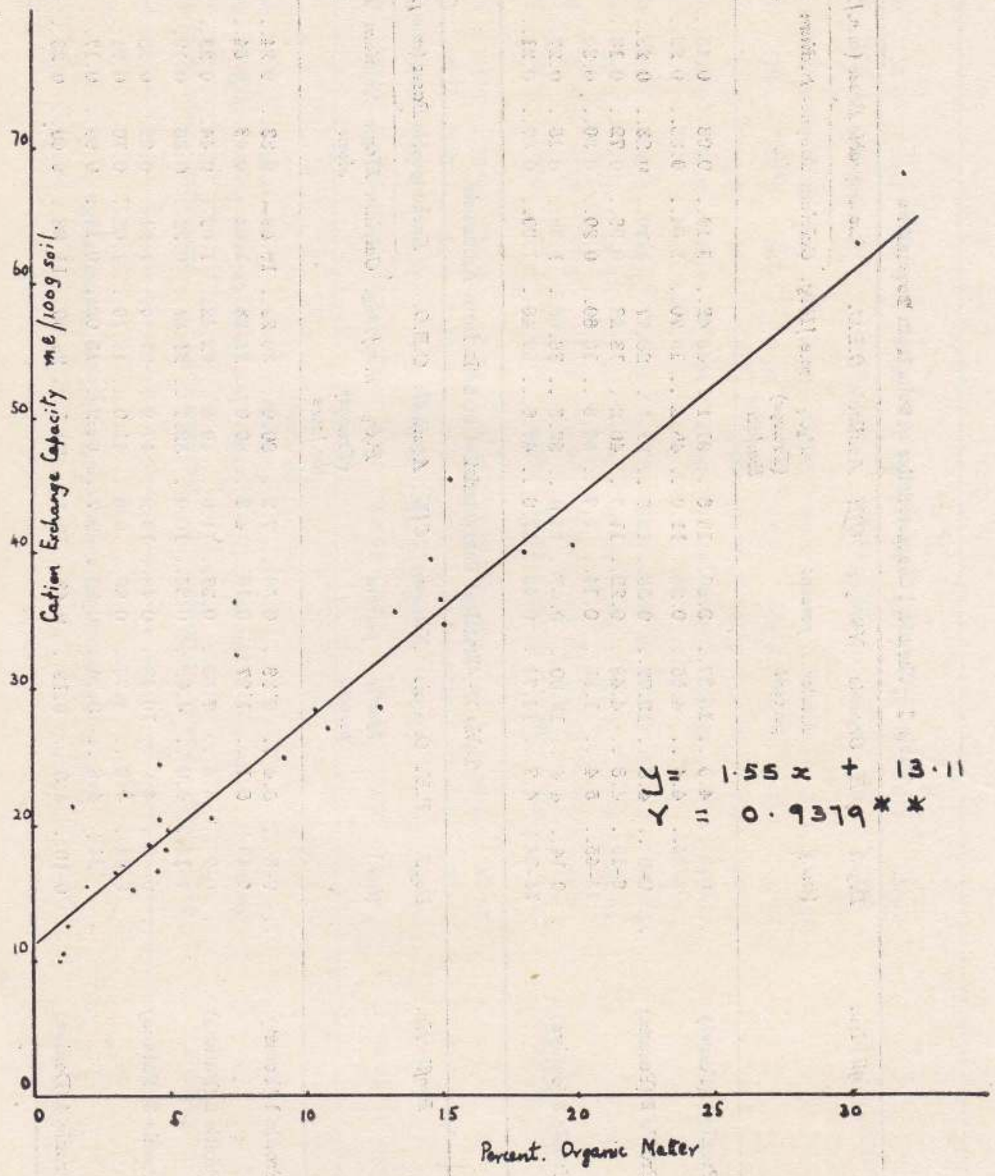

Table 1—Chemical Characteristics of Soils form Bopatalawa

Profile No.	Depth (ins.)	p.H.	Organic Matter percent	Nitrogen percent	C/N	Available P_2O_5 (Truogs) lbs./acre	C.E.C. m.e./100g.	Exchangeable Bases (m.e./100g) Calcium	Magnesium	Sodium	Potassium	T.E.B. m.e./100g	%Base Saturaction
Profile 1 (Forest)	0–3	4.5	15.37	0.86	10.6	91.1	45.42	5.19	0.08	0.45	0.78	7.26	26.0
	3–24	4.4	4.55	0.24	11.0	45.4	16.70	1.04	0.33	0.25	0.19	1.81	10.8
Profile 2 (Patana)	0–6	4.5	12.79	0.55	13.5	31.1	28.77	1.30	0.23	0.23	0.26	2.02	7.0
	6–15	4.8	4.43	0.22	11.7	46.2	18.28	0.96	0.72	0.18	0.09	1.95	10.7
	15–45	5.4	1.86	0.14	7.7	53.6	15.60	0.90	0.30	0.30	0.14	1.79	11.5
Profile 3 (deniya)	0–14	4.4	15.00	0.67	12.9	32.5	36.65	1.38	0.15	0.27	0.31	2.11	5.8
	14–24+	4.7	14.74	0.49	17.6	47.6	39.46	1.00	0.57	0.21	0.24	2.02	5.1

Table 2—Chemical Characteristics of Soils form Ambawele

Profile No.	Depth (ins.)	P.H.	Organic Matter percent	Nitrogen percent	C/N	Available P_2O_5 (Truogs) lbs./acre	C.E.C. m.e./100g.	Exchangeable Bases (m.e./100g) Calcium	Magnesium	Sodium	Potassium	T.E.B. m.e./100g	%Base Saturaction
Profile 1 (Forest)	0–6	5.4	7.36	0.58	7.3	60.0	36.29	10.59	2.83	0.24	0.44	4.10	11.3
	6–48+	5.1	1.27	0.16	4.3	86.6	21.36	1.62	0.43	0.54	0.13	2.72	12.7
Profile 2 (Patana)	0–7	4.8	7.53	0.37	11.9	49.5	32.42	1.09	0.44	0.23	0.26	2.02	6.2
	7–14	4.8	4.62	0.25	10.9	52.7	24.64	0.73	0.36	0.19	0.12	1.40	5.7
Profile 3 (Patana)	0–8	4.9	10.48	0.48	13.2	47.2	27.10	1.24	0.62	0.23	0.25	2.34	8.6
	8–24	4.8	4.75	0.29	9.6	44.0	18.10	1.02	0.16	0.21	0.13	1.52	8.4
	24+	4.8	3.74	0.22	9.7	68.2	15.02	0.17	0.99	0.17	0.15	1.48	9.9
Profile 4 (Deniya)	0–10	4.8	9.19	0.43	12.4	70.1	25.00	11.28	0.60	0.23	0.24	0.24	9.4

Table 3—Chemical Characteristics of Soils form Horton Plains

Profile No.	*Depth*	*p.H.*	*Organic*	*Nitrogen*	*C/N*	*Available*	*C.E.C.*	*Exchangeable Bases (m.e./100g)*				*T.E.B.*	*%Base*
	(ins.)		*percent*	*percent*		*PiOi (Truogs) lbs./acre*	*m.e./100g*	*Calcium*	*Magnesium*	*Sodium*	*Potassium*	*m.e./100g*	*Saturaction*
Profile 1 (Forest)	0–2	6.0	15.08	6.22	10.64	74.4	35.9	8.72	2.39	0.26	0.84	12.21	34.0
	2–13	5.3	6.50	0.387	9.75	49.9	20.3	1.67	1.19	0.16	0.22	3.24	16.0
	13–20	5.2	2.97	0.248	6.94	42.4	16.6	0.73	1.10	0.15	0.12	2.10	12.6
	20–37	4.9	1.27	0.134	5.51	50.6	12.6	0.84	0.54	0.12	0.09	1.59	12.6
Profile 2 (Patana)	0–6	5.6	19.71	0.787	14.52	49.0	40.2	1.67	0.42	0.38	0.84	3.31	8.2
	6–16	5.6	13.37	0.542	14.31	46.0	35.9	1.14	0.78	0.22	0.22	2.36	6.6
	16–22	4.9	3.26	0.141	13.40	50.4	22.3	1.15	0.06	0.22	0.16	1.59	7.1
	22–24	5.2	0.97	0.092	6.11	52.4	10.4	0.96	0.84	0.18	0.11	2.09	20.1
Profile 2 (Patana)	0–10	5.1	26.07	1.149	13.16	60.0	40.7	1.55	0.84	0.26	0.61	3.26	8.0
	10–20	5.1	18.07	0.795	13.18	43.3	39.9	0.96	0.48	0.10	0.35	1.89	4.7
	20–25	5.2	4.65	0.220	12.25	36.0	20.3	0.96	0.12	0.31	0.20	1.59	7.0
	25–35	5.2	0.92	0.106	5.04	43.2	10.0	1.07	0.83	0.18	0.12	2.20	22.0
Profile 4 (Deniya)	0–10	5.1	32.12	1.294	14.40	59.8	67.7	2.75	0.24	0.22	0.72	3.93	5.8
	10–23	4.8	30.31	1.160	15.16	58.8	62.9	1.03	1.63	0.27	0.30	3.23	5.1

Response of rice to different forms of nitrogen fertilizer

D. M. Rodrigo, B. M. Nizar

and

P. S. G. Perera

Division of Agricultural Chemistry, Central Agricultural Research Institute, Peradeniya,

(Received, July, 1969)

INTRODUCTION

The anaerobic environment of flooded rice soils has important consequences on the nutrition of the rice plant. The absence of oxygen in water-logged soils prevents nitrogen mineralization from proceeding beyond the ammonium stage (Ponnamperuma, 1955; Rodrigo, 1961, 1962, 1967; Thenabadu, 1966; International Rice Commission, 1966). The production of ammonium in water-logged soils, in contrast to nitrate in uupland soils, is favourable for rice since the plant readily utilises ammonium nitrogen.

Surface applied nitrogen fertilizers are easily converted to nitrate in the superficial oxidizing layer of the soil and subsequently denitrified on reaching the reduced zone (Rodrigo, 1961, 1962, 1967; Matsuo, 1966; Thenabadu, 1966; Kalpage, 1967; Panabokke, 1967; Simsiman *et al.*, 1967). Denitrification appears to be universal in flooded rice soils and losses of nitrogen ranging from 20 percent to 50 percent have been recorded (Parsall, 1950; Abichandani and Patnaik, 1955; Mitsui, 1956; Patnalk, 1965). In order to reduce the loss of nitrogen by leaching and to prolong the period of availability of nitrogen for the purpose of ensuring its steady supply according to the needs of the plant, a new type of nitrogen fertilizer, Guanylurea, developed in Japan, with the property of slow and controlled release, appears to be promising (International Rice Commission, 1966).

There are reports that ammonium forms of nitrogen are superior in the early stages of growth of the rice plant but during the later stages nitrate forms appear equally effective (International Rice Commission, 1966). This could be explained by the fact that it is only during the late stages of the vegetative period that horizontal superficial roots or the mat of surface roots are developed. These roots which are functioning in the oxidizing surface layer of the soil and even protruding to the layer of water above the soil should be able to absorb oxidised radicals, one of which is nitrate. From the above it is apparent the form of nitrogen fertilizer applied to rice is important.

In the United States urea forms of nitrogen are most commonly used for rice while anhydrous ammonia, ammonium sulphate and other forms are used in lesser amounts (International Rice Commission, 1966). In the Philippines ammonium sulphate and ammonium chloride at 40 kg/ha. were equally good for rice in Barrio Lamao, Limay and Bataan, while the plots which received urea did not produce yields higher than the control (International Rice Commission, 1964). In the U. A. R. yields obtained in greenhouse and field experiments using equivalent amounts of different forms of nitrogen fertilizer showed considerable differences in their effectiveness. Ammonium sulphate, aqua ammonia, calcium ammonium nitrate and urea, were about equal in value as sources of nitrogen, while calcium nitrate and calcium cyanamide were less effctive (International Rice Commission, 1964). In the degraded rice soils of Japan which are low in active iron where hydrogen sulphide toxicity is known to occur, ammonium chloride is used instead of ammonium sulphate. In Ceylon, urea performed better than ammonium sulphate in the sandy acid soils low in iron (Jayasekera and Ariyanayagam, 1962).

MATERIALS AND METHODS

Fertilizer trials were conducted in a number of Rice Experiment Stations, Government Farms, and in Cultivators' fields in Polonnaruwa Administrative District, for a number of seasons to test the relative efficiency of six forms of nitrogen, namely, urea, ammonium sulphate, ammonium chloride, ammonium sulphate nitrate, calcium ammonium nitrate, and ammonium nitrate. The design of the experiment in the Rice Experiment Station and in Government Farms was a randomised block containing seven plots in a block and replicated four times. In Cultivators' Fields too the design was a randomised block with seven plots in a block and each location was considered a replicate. In the Yala (dry) season of 1967 there were six locations and in the Maha (wet) season of 1967/68 there were eight locations.

Total nitrogen, ammonium nitrogen and nitrate nitrogen contents of the six forms of fertilizer tested are given below.

	Total N%	NH_4-$N\%$	No_3-$N\%$
Urea	46	—	—
Ammonium sulphate	20·6	20·6	—
Ammonium chloride	25	25	—
Ammonium sulphate nitrate	26	19·5	6·5
Calcium ammonium nitrate	20·5	10·25	10·25
Ammonium nitrate	34	17	17

At different sites different quantities of nitrogen applied at different times were tested. However, at each site the response to equal quantities of nitrogen of the six different sources applied at identical times was evaluated.

The treatments at each site indicating the time of application and levels of nitrogen in kg/ha. are shown below.

Rice Experiment Station, Bombuwela

	At planting	*At 3 weeks from planting*	*At 3 weeks before heading*	*At heading*
T1 Control (C)	0	0	0	0
T2 Urea (U)	17	17	34	17
T3 Ammonium sulphate (AS)	17	17	34	17
T4 Ammonium chloride (AC)	17	17	34	17
T5 Ammonium sulphate nitrate (ASN)	17	17	34	17
T6 Calcium ammonium nitrate (CAN)	17	17	34	17
T7 Ammonium nitrate (AN)	17	17	34	17

1 kg/ha = 0.892 lb/acre.

Dressings of phosphorous and potassium were given to all plots including the control.

Phosphorous—At the rate of 189 kg/ha. of saphosphosphate applied at planting.

Potassium—At the rate of 126 kg/ha. of muriate of potash. Half this quantity was applied as a basal dressing; quarter of it at three weeks from planting and the other quarter at three weeks before heading.

The variety of rice used was H-4.

Government Farms at Karapincha and Wagolla

	At 2 weeks from planting	*At one month before heading*	*At heading*
T1 Control	0	0	0
T2 Urea	17	34	17
T3 Ammonium sulphate	17	34	17
T4 Ammonium chloride	17	34	17
T5 Ammonium sulphate nitrate	17	34	17
T6 Calcium ammonium nitrate	17	34	17
T7 Ammonium nitrate	17	34	17

1 kg/ha. = 0.892 lb/acre

Dressings phosphorous and potassium were given to all plots including the control.

Phosphorous—At the rate of 189 kg/ha. of saphosphosphate applied at planting.

Potassium—At the rate of 95 kg/ha. of muriate of potash. 63 kg/ha. were applied as a basal dressing, and the remaining 32 kg/ha. were applied one month before heading.

At Karapincha the variety used was H-4 in all seasons. At Wagolla the variety H-4 was used in the Yala (dry) season of 1966, Podiwi a-8 in the Maha (wet) season of 1966/67, and H-7 in the Yala (dry) season of 1967.

Seed Paddy Stations at Hingurakgoda and Polonnaruwa, Government Farm at Paranthan, and Cultivators Fields in Polonnaruwa Administrative, District

	At 2 weeks from planting	*At 2 weeks before heading*
T1 Control	0	0
T2 Urea	25	50
T3 Ammonium sulphate	25	50
T4 Ammonium chloride	25	50
T5 Ammonium sulphate nitrate	25	50
T6 Calcium ammonium nitrate	25	50
T7 Ammonium nitrate	25	50

Dressings of phosphorous and potassium were given to all plots including the control.

Phosphorous—At the rate 126 kg/ha. of concentrated superphosphate applied at planting.

Potassium—At the rate of 95 kg/ha. of muriate of potash. 63 kg/ha. were applied as a basal dressing, and the remaining 32 kg/ha. were applied two weeks before heading.

At Hingurakgoda and Polonnaruwa Paddy Stations the variety used was H-4. At Paranthan the variety Pachchaiperumal was used in the Yala (dry) season of 1967 and H-4 was used in the Maha (wet) season of 1967/68. In cultivators' fields in Polonnaruwa, Pachchaiperumal was planted in the Yala (dry) season of 1967 and H-4 was planted in the Maha (wet) season of 1967/68.

RESULTS AND DISCUSSION

Grain yields of paddy (rough rice) in kg/ha. obtained by using the different forms of nitrogen at the respective locations, coefficients of variation and the significant differences at 5 per cent level of significance are given in tables 1 to 7.

Table 1.—Yields of Paddy (Rough Rice) in Kilograms per hectare. At Rice Experiment Station, Bombuwela

Season	T1 C	T2 U	T3 AS	T4 AC	T5 ASN	T6 CAN	T7 AN	Cof. V	L.S.D.
Yala 1966	2406	3072	3859	4318	4000	3945	3027	9.1	474
Maha 1966/67	1584	2442	3062	3380	3087	2790	2603	9.0	363
Yala 1967	1539	2093	2507	2850	2805	2638	2285	9.8	348
Maha 1967/68	964	1599	1801	2391	1680	1902	1564	15.0	378
Mean	1623	2302	2807	3235	2893	2819	2370		

1 kg/ha=0.0198 Bu/acre or 50 kg/ha approx : equal to 1 Bu/acre.

The above table clearly indicates the necessity for the application of fertilizer nitrogen as all nitrogen treatments were significantly better than the control treament in all seasons. Ammonium chloride performed best in all seasons. In the Yala (dry) season of 1966 there were no significant differences between ammonium chloride, ammonium sulphate nitrate, calcium ammonium nitrate and ammonium sulphate. Further these four forms of nitrogen were significantly better than urea and ammonium nitrate. There was no significant difference between urea and ammonium nitrate. In the Maha (wet) season of 1966/67 there were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride, ammonium sulphate nitrate and ammonium sulphate, (*b*) ammonium sulphate nitrate, ammonium sulphate and calcium ammonium nitrate, (c) calcium ammonium nitrate, ammonium nitrate and urea. In the Yala (dry) season of 1967 there were no significant differences within the following groups, (*a*) ammonium chloride, ammonium sulphate nitrate, calcium ammonium nitrate and ammonium sulphate, (*b*) ammonium sulphate and ammonium nitrate, (*c*) ammonium nitrate and urea. In the Maha (wet) season of 1967/68 ammonium chloride was significantly better than all other forms of nitrogen fertilizers. There were no significant differences between the other forms of nitrogen. However the order of merit is as follows:—calcium ammonium nitrate, ammonium sulphate, ammonium sulphate nitrate, urea and ammonium nitrate.

Table 2.—Yields of Paddy (Rough Rice) in Kilograms per hectare At Government Farm Karapincha

Season	T1 C	T2 U	T3 AS	T7 AC	T5 ASN	T6 CAN	T7 AN	Cof. V	L.S.D.
Yala 1966	2860	3360	3415	3617	3455	3597	3294	4·9	247
Maha 1966/97	2880	3496	3587	3849	3577	3652	3425	4·4	227
Yala 1967	3400	3703	3758	3915	3814	3909	3602	3·7	207
Maha 1967/68	2608	3012	3012	3425	3097	3138	2931	5·5	247
Mean	2937	3393	3443	3702	3486	3574	3313		

1 kg/ha = 0·0198 Bu/acre or 50kg/ha approx : equal to 1 Bu/acre.

The need for nitrogen is clearly seen from the above table as all nitrogen treatments are significantly better than the control treatment in all seasons. Ammonium chloride performed best in all seasons. In the Yala (dry) season of 1966 there were no significant differences among the different forms of nitrogen fertilizer as the F value for within nitrogen treatments was not significant. In the Maha (wet) season of 1966/67 there were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride and calcium ammonium nitrate, (*b*) calcium ammonium nitrate, ammonium sulphate, and ammonium sulphate nitrate, (*c*) ammonium sulphate, ammonium sulphate nitrate, urea and ammonium nitrate. In the Yala (dry) seson of 1967 there were no significant differences within the following groups, (*a*) ammonium chloride, calcium ammonium nitrate, ammonium sulphate nitrate, and ammonium sulphate, (*b*) calcium ammonium nitrate, ammonium sulphate nitrate, ammonium sulphate and urea, (*c*) ammonium sulphate, urea and ammonium nitrate. In the Maha (wet) season of 1967/68 ammonium chloride was significantly better than all other forms of nitrogen fertilizer. There were no significant differences between the other forms of nitrogen fertilizer. However, the order of merit is as follows :—calcium ammonium nitrate, ammonium sulphate nitrate, urea, ammonium sulphate and ammonium nitrate.

Table 3.—Yields of Paddy (Rough Rice) in Kilograms per hectare At Government Farm, Wagolla

Season	*T1* *C*	*T2* *U*	*T3* *AS*	*T4* *AC*	*T5* *ASN*	*T6* *CAN*	*T7* *AN*	*Cof. V*	*L.S.D.*
Yala 1966	2820	4121	4308	4434	4247	4212	4278	6·1	368
Maha 1966/67	3334	3799	3698	4046	3894	3889	3622	3·6	197
Yala 1967	3682	4182	4152	4363	4303	4268	4212	3·0	227
Mean	3279	4034	4053	4281	4148	4123	4037		

It is seen from the above table that nitrogen is necessary as all nitrogen treatments were significantly better than the control treatment in all seasons. Ammonium chloride performed best in all seasons. In the Yala (dry) season of 1966 there were no significant differences between the different forms of nitrogen fertilizer. In the Maha (wet) season of 1966/67 there were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride, ammonium sulphate nitrate, and calcium ammonium nitrate (*b*) ammonium sulphate nitrate, calcium ammonium nitrate, urea, and ammonium sulphate, (*c*) urea, ammonium sulphate, and ammonium nitrate. In the Yala (dry) season of 1967 there were no significant differences between the different forms of nitrogen fertilizer.

Table 4.—Yields of Paddy (Rough Rice) in Kilograms per hectare. At Seed Paddy Station, Hingurakgoda.

Season	*T1* *C*	*T2* *U*	*T3* *AS*	*T4* *AC*	*T5* *ASN*	*T6* *CAN*	*T7* *AN*	*Cof. V*	*L.S.D.*
Yala 1967	4308	5519	4873	5317	4934	5236	5135	9·7	726

The table indicates the necessity for fertilizer nitrogen as the F value for the control treatment versus the nitrogen treatments was significant. Further there were no significant differences between the different forms of nitrogen fertilizer.

Table 5.—Yields of Paddy (Rough Rice) in Kilograms per hectare At Seed Paddy Station, Polonnaruwa

Season	T1 C	T2 U	T3 AS	T7 AC	T5 ASN	T6 CAN	T7 AN	Cof. V	L.S.D.
Yala 1967	3360	3940	4348	3879	4076	3768	3859	10.2	590
Maha 1967/68	4222	5342	5221	5761	5145	5019	5085	6.2	469
Mean	3791	4641	4785	4820	4611	4394	4472		

The above table reveals the need for nitrogen as the F value for the control treatment versus the nitrogen fertilizer treatments was significant in both seasons. In the Yala (dry) season of 1967 there were no significant differences between the different forms of nitrogen fertilizer. During this season the trial was affected by a severe drought. In the Maha (wet) season of 1967/68 ammonium chloride performed best and the others performed in the following order of merit ; urea, ammonium sulphate, ammonium sulphate nitrate, ammonium nitrate, and calcium ammonium nitrate. There were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride and urea, (*b*) urea, ammonium sulphate, ammonium sulphate nitrate, ammonium nitrate, and calcium ammonium nitrate.

Table 6.—YieldsofPaddy (Rough Rice) in Kilograms per hectare At Government Farm, Paranthan

Season	T1 C	T2 U	T3 AS	T7 AC	T5 ASN	T6 CAN	T7 AN	Cof. V	L.S.D.
Yala 1967	1624	2875	2658	2966	2679	2457	2522	6.8	257
Maha 1967/68	1448	2653	2517	2830	2714	2391	2164	5.3	192
Mean	1536	2764	2588	2898	2697	2424	2343		

The need for nitrogen is clearly seen from the above table as all nitrogen treatments were significantly better than the control treatment during both seasons. In the Yala (dry) season of 1967 ammonium chloride performed best and then came the following in order of merit, urea, ammonium sulphate nitrate, ammonium sulphate, ammonium nitrate, and calcium ammonium nitrate. There were no significant differences within the following groups of fertilizers, (*a*) ammonium chloride and urea, (*b*) urea, ammonium sulphate nitrate, and ammonium sulphate, (*c*) ammonium sulphate nitrate, ammonium sulphate, and ammonium nitrate (*d*) ammonium sulphate, ammonium nitrate, and calcium ammonium nitrate. In the Maha (wet) season of 1967/68 ammonium chloride performed best. The following is the order of merit of the other fertilizers, ammonium sulphate nitrate, urea.

ammonium sulphate, calcium ammonium nitrate, and ammonium nitrate. There were no significant differences within the following groups, (*a*) ammonium chloride, ammonium sulphate nitrate, and urea, (b) urea and ammonium sulphate, (*c*) ammonium sulphate and calcium ammonium nitrate.

Table 7.—Yields of Paddy (Rough Rice, in Kilograms per hectare In Cultivators Fields in Polonnaruwa Administrative District

Season	*T1* *C*	*T2* *U*	*T3* *AS*	*T4* *AC*	*T5* *ASN*	*T6* *CAN*	*T7* *AN*	*C of V*	*L.S.D.*
Yala 1967 Mean of 6 Locations	3723..	4626..	4812..	4868..	4767..	4712..	4273..	7·7..	409
Maha 1967/68 mean of 8 Locations	3698..	4333..	4394..	4611..	4298..	4348..	4142..	7·4..	318
Mean ..	3711..	4480..	4603..	4740..	4533..	4530..	4208		

The above table indicates the need for nitrogen as all nitrogen treatments were sngnificantly better than the control treatment in both seasons. There were no significant differences between the different forms of nitrogen fertilizer as the F value for within the different forms of nitrogen treatments was not significant in both seasons. However, during both seasons ammonium chloride performed best and ammonium nitrate was the worst.

From the above-mentioned data and inferences drawn from them two definite conclusions could be made. They are :—

1. The application of fertilizer nitrogen in whatever form gave significant and remunerative yield responses.
2. Ammonium chloride performed best in all locations in all seasons except at Hingurakgoda Farm. At Hingurakgoda Farm urea performed best and then came ammonium chloride. However, the trial was conducted only in one season at this farm and furthermore there were no statistical significant differences between the different forms of nitrogen fertilizer.

From these field trials no reasons could be adduced for the better performance of ammonium chloride. Nevertheless, its superiority over the other forms of nitrogen fertilizer has been attributed to the following characteristics.

1. Ammonium chloride inhibits the growth of nitrifying soil bacteria, nitrosomonas and nitrobacter. Nitrification is therefore retarded, consequent to which denitrification and loss of nitrogen is lessened (Okuda and Takahashi, 1966).

2. Cholorine is an effective trace element in strengthening the stems and roots of plants (Goto, 1968 ; Okuda, 1959, 1960).
3. Chlorine improves the ripening of rice (Honya, 1966. ; Okuda *et al.*, 1965).
4. Chlorine imparts extra resistance to disease (Honya, 1966).
5. Ammonium chloride shortens the internodal lengths at the lower parts of the plant (Omura, 1968 ; Kishida, 1968 ; Sato, 1968).
6. There is no danger of incipient hydrogen sulphide toxicity as ammonium chloride contains no sulphur (Mitsui *et al.*, 1951).

SUMMARY

Fertilizer trials were conducted in a number of Rice Experiment Stations, Government Farms and in Cultivators' Fields in one Administrative District for a number of seasons to test the relative efficiency of six forms of nitrogen fertilizer, namely, urea, ammonium sulphate, ammonium chloride, ammonium sulphate nitrate, calcium ammonium nitrate, and ammonium nitrate. At each location the response to equal quantities of nitrogen of the six different forms of fertilizer applied at identical times was evaluated. Dressings of phospharus and potassium fertilizers were given to all plots including the control.

From these trials two definite conclusions could be inferred. They are :—

1. The application of fertilizer nitrogen in whatever form gave significant and remunerative yield responses.
2. Ammonium chloride performed best in all locations in all seasons except at Hingurakgoda Farm where the trial was conducted only one season when there were no significant differences between the different form of nitrogen fertilizer.

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The combination of a short term pueraria fallow, zero cultivation and fertilizer, application

Its effect on a following maize crop

A. Kannegieter

University of Science & Technology, Kumasi, Ghana

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SUMMARY

A trial was carried out in the forest zone of Ghana to test the effect of a short-term fallow under *Pueraria phaseoloides* (kudzu) on a following maize crop.

Based on the favourable experience with this method, using a 3-4 year old Pueraria cover in 1961 and 1962, the maize was planted into the undisturbed and spraykilled Pueraria covered soil (zero cultivation).

In view of the clear response by the maize crop to fertilizer application in a trial in 1963, fertilizer was in this year's trial applied to the Puerraria (i.e. indirectly to the maize crop) and to the maize crop.

The amount of Pueraria mass involved and the mineral content of tthe Pueraria and the soil were determined. Also determined were maize plant numbers and plantheights at two stages of growth, as well as the maize yields.

An attempt was made to separately evaluate the effects of the factors " keeping the soil undisturbed " and " maintaining the soil covered " by introducing the treatment No. 1 below.

The main treatments were, after a complete 3-year food cropping sequence of maize, groundnuts and casava :

0 = one green gram crop during the small 1964/65 rains ; maize after normal tillage, during the 1965 main season ;

1 = 9 months of unfertilized Pueraria fallowing ; maize planted after removing the Pueraria, soil tillage and returning the Pueraria trash as a mulch ;

2 = 9 months of unfertilized Pueraria fallowing ; maize planted into the undisturbed and spraykilled Pueraria covered soil.

3 = 9 months of fertilized Pueraria fallowing ; maize planted into the undisturbed and spraykilled-Pueraria covered soil.

In all four treatments the subtreatment of " feritilizer application to the maize crop " was superimposed in splitplots.

The results show the beneficial influence of the Pueraria fallowing in combination with " zero cultivation " and fertilizer application, on the performance of the maize crop during the particularly unfavorable 1965 season.

INTRODUCTION

This trial carried out in 1964-65 is a logical follow-up on the work done on " zero cultivation and other methods of reclaiming Pueraria fallowing land for foodcrop cultivation " during the previous 3 years. This previous work has been reported on in this journal (Kannegieter, 1968).

The earlier trial showed that at least as good yeilds of maize could be obtained by " zero cultivation " of a Pueraria fallowing as with conventional methods involving soil-tillage, incorporating the Pueraria ash after burning or the Pueraria trash after slashing.

The " zero cultivation " i.e. spraykilling the Pueraria cover and planting the maize straight into the undisturbed and trash-covered soil, saved the need for expensive tillage equipment, gave better seedling emergence (saving the need for extensive filling of vacancies) and provided weedcontrol and complete erosion control. The trashcover in combination with the factor of " leaving the soil undisturbed " was found to have a strong moisture conserving value. It was further found that a major limiting factor to satisfactory maize production on these soils was the lack of mineral soil-fertility.

The question arose then how a shortterm Pueraria fallow would affect the mineral content of the topsoil when fertilized or not fertilized, what amount of plantfood mineral would be accumulated in the Pueraria mass and to show these in combination with the factor of maintaining the Pueraria mass in the maizecrop as a soilcover would benefit the maizecrop.

To separately evaluate the influence of the factor " leaving the soil undisturbed ", on the maizecrop, the treatment (1) of removing the Pueraria cover, soil-tillage, returning the Pueraria trash as a mulch was included in the trial. However, it was found that the Pueraria trash thus returned could no more be compared with the soil-cover maintained by the Pueraria which was spraykilled and left undisturbed ; the latter was compact whereas the former was loose and incomplete.

This thus leaves us with the evaluation of the effect on the following maize crop or an unfertilized and of a fertilized short-term Pueraria fallow in combination with " zero cultivation " in which the maize did or did not receive a fertilizer application.

Treatment 0, " one green gram crop ", actually consisted of weed-growth during the remainder of the 1964 main season followed by a very poor crop of green gram during the 1964-65 minor season.

The effects found are the more striking since this maize season was a very unfavorable one in that the first weeks after planting were excedingly dry.

ENVIRONMENT

Environmental conditions for the trial area were as far as the soil is concerned the same as described for the earlier trials (Kannegieter, 1968).

Climatical condition were quite different this season : the early part of the 1965 season was exceptionally dry as is illustrated in fig. 1 which also gives the dates of the main operations in relation to this rainfall distribution.

EXPERIMENTAL

A. *Calender of Operations*

8/22-5-64 *Soilpreparation and layout* : after the 1963/64 Casava crop of a 3-year foodcropping sequence, the land was intensively discharrowed.

The experiment was thereupon layed out as a randomized blocks trial, accomodating the 4 main treatments in 12 blocks within the 6 contour-strips of the sloping field.

23-5 64 *Pueraria sowing* on treatment 1, 2, and 3 plots with the MF combined seed-fertilizer drill, at the rate of 48 lbs. of seed per acre at roughly ½″ depth in contour rows 2′ apart and at 8 rows per plot.

23-5-64 *First fertilizer application to the Pueraria* in treatment 3 plots, simultaneously with the drilling of the seed, at the rate of 165 lbs./acre of a 1 : 4 : 1 mixture of Sulphate of Ammonia + Di Calcium Phosphate + Sulphate of Potash. The fertilizer was placed in rows 6″ away from and a little below the seed.

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10-6-64 *Erosion control* in the establishing Pueraria crop by cutting slits on the contour between the seedling-rows with the tine cultivator 17 days after sowing, to count-eract soil-wash.

8-7-64 *First soil sampling* in treatment 0 plots.

31-8-64 *Sowing green gram* (*Phaseolus mungo*) in treatment 0 plots.

1-11-64 *First Pueraria sampling* in treatments 2 and 3 plots.

5-11-64 *Setting out nettplots* which due to the narrowness of the contourstrips had to be fitted between the bunds as 40′ × 16′ = acre parrallelograms in such a way that sufficient headland was left around the treatment 0 and 1 plots for effective soil tillage without disturbing teretment 2 and 3 plots.

11-11-64 *Second fertilizer application to the Pueraria* in treatment 3 plots, broadcasting the same mixture at the same rate per acre as in May, by hand at the beginning of the minor rains.

1-3-65 *Second soil sampling* in treatment 2 and 3 plots.

1-3-65 *Second Pueraria sampling* in treatment 2 and 3 plots.

2-3-65 *Spraykilling the Pueraria* cover in treatments 2 and 3 plots with Brushkiller 32 (2.4-D + 2.4.5-T) at the rate of 7 pints in 75 gallons of water to the acre with the knapsack sprayer, at the start of the major rains.

16-3-65 *Cutting and temporarily removing the Pueraria* cover in treatment 1 plots by cutlassing at groundlevel and rolling aside the mat before soil tillage.

17-3-65 *Soiltillage for the maize* crop in treatment 0 and 1 plots with the mouldboard plough followed by discharrowing. The headlands around these nett plots allowed the plough to reach its proper working depth before entering the nett plot.

1-4-65 *Respraying the Pueraria* cover in treatments 2 and 3 to suppress regrowth.

8/12-4-65 *Maize planting* in successive blocks, by hand using seed of the white-grain variety Mexican 17, at 3 seed/hole, holes 2′ × 2′. The seed was Ceresan treated and dibbled into holes punched into the soil which were subsequently covered by foot. In treatments 2 and 3 the holes were punched through the compact layer of dead Pueraria.

14-5-65 *Weeding* in the 0 treatment plots became necessary on account of heavy sprouting of Centrosema seed remaining from a 1960 (i) grass-legume fallow ; it was done by hand-hoeing all treatment 0 plots.

In treatments 2 and 3 plots a light cutlassing of surviving Pueraria vines was done to prevent these from climbing into the maize plants.

21-5-65 *Fertilizer application to the maize* in slitplots of the 6 weeks old crop at the rate of 100 lbs. Sulphate of Ammonia + 100 lbs. Single Super Phosphate + 50 lbs. Sulphate of Potash per acre.

This was done by hand, supplying 10.5 g of the mixture by calibrated cups into holes punched around the plants and closing these holes afterwards.

24-5-65 *First maize plant height measurement* in the 6 weeks old crop.

24-5-65 *First maize plant count* in the 6 weeks old crop.

24-6-65 2*nd maize plant height measurement* in the 10 weeks old crop.

24-6-65 2*nd maize plant count* in the 10 weeks old crop.

Maize harvest and *final plant count* in all splitplots.

B. *Determinations*

Soil sampling.—three random samples per plot were taken to the depth of 5″ and then compounded into one sample per plot. The first sampling was done at the beginning of the experiment in the unfertilized and uncovered treatment 0 plots.

The second sampling was done in the unfertilized-Pueraria covered soil of treatment 2. plots and in the fertilized-Pueraria covered soil of the treatment 3. plots, 8 months after the first sampling. The aim was to determine any changes in mineral and organic matter content of the topsoil resulting from the unfertilized and the fertilized Puera-ria fallowing.

Pueraria sampling.—three random samples of 1′ × 1′ of the cover down to the mineral soil, were taken per plot and then bulked up into one sample per plot for the treatment 2. and 3. plots. The first sampling was done just before the second fertilizer application to the Pueraria.

The second sampling was done 3 months after the first sampling and just before the spraykilling of the Pueraria.

The aim was to determine how much organic matter and minerals had been accumulated in the Pueraria mass.

N.B.—All analysis of soil and crop samples were done by the Laboratory for Soil and Crop Analysis at Oosterbeek, Holland.

Plantheights of the Maize.—plantheights of the tallest plant per each planthole were recorded over 80′ of row-length in the two central rows of the unfertilized-maize splitplots ; measurements were up to the highest leaf-axil.

The first recording was made in the 6 weeks old crop, the second one 4 weeks later.

Maize plant counts.—simultaneously with the plantheight recording the numbers of occupied (one or more plants) plantholes were recorded over the same 80′ of rowlength in the unfertilized-maize splitplats (first count) and in both the unfertilized-maize and the fertilized maize splitplots (second count) to determine any influence of treatments and subtreatments on the emergence and survival of the maize plants.

Maize yields.—the yields expressed in grams of dry (9 per cent. moisture) grain per 80′ of rowlength, were recorded for the central rows of both the unfertilized-maize and the fertilized-maize splitplots. The yields per acre have been calculated from these figures to give a rough idea of the order of magnitude of these yields.

C. *Field Observations*

Pueraria development.—about 3 months from sowing the Pueraria had formed a complete soilcover ; the fertilized Pueraria seemed in the beginning to outgrow the unfertilized Pueraria and cover up earlier whereas it appeared slightly healthier in colour during these first months but any differences gradually disappeared. At the time of spraying there was some interveinal yellowing in the leaves in all plots.

The soil cover.—formed by the undisturbed spray-killed Pueraria was far more compact and complete than that produced by removing and later on returning the cut Pueraria as a mulch over the tilled soil in treatment 1.

The ploughing for the maize crop revealed a noticeable difference in soil friability and colour between the treatment 0 plots and the treatment 1. plots. The latter showed much easier penetration and formed a much better tilth when ploughed immediately upon removal of the Pueraria cover ; the soil in the treatment 1. plots also looked much darker than in the treatment 0 plots.

Maise crop development.—right after sowing the maize there followed a period of sharp drought (see fig. 1) which very adversely affected seedling emergence in particular in treatment 0 plots where only few plants had emerged even after 10 days from sowing. These treatment 0 crops in fact never recovered from this setback which is amply illustrated in plant-numbers, height-recording figures, yleld-figures and the photographs No 1 and 2. The good rainfall of May 23 and 24 improved the situation to some extent but could not save the treatment 0 crops in particular. This poor development of the treatment 0 crops gave ample opportunity to weedgrowth.

The treatment 2 and 3 crops showed very little difference in emergence and development throughout, emergence being nearly complete and plants reaching to about 8″ after the first 3 weeks.

Treatment 1 crops ranked in general development between those of treatments 0 and those of treatments 2 and 3 ; emergence was nearly complete however.

During the months of April-May there were further spells of very hot and dry weather during which the maize plants showed symptoms of drought stress.

RESULTS AND DISCUSSION

Soil fertility.—figures for mineral contents are given in table 1. Only the increase P_2O_5 content, resulting from application of 88 lbs. of P_2O_5 in the fertilizer, was found to be statistically significant. The application of the rather large amount of CaO in the DiCalcium Phosphate may also have influenced the CaO content of the soil significantly but this content was not determined.

As was commented for the 1962 trials, these soils must be qualified as poor for the Ghana Forest soils.

It is remarkable that the 9 months of Pueraria fallowing have apparently not significantly increased the Organic Matter content of the topsoil as measured in the analysis.

At the time of ploughing it was found that the soil in treatment 1. plots was much darker and of much better structure than that of the unfallowed treatment 0 plots ; this may however largely have been due to higher moisture content.

The Pueraria cover.—average amounts of dry matter, calculated from the 12 sets of 3 square feet random samples from both the unfertilized and the fertilized Pueraria plots were :

Sample dates	*Tons of D. M. per acre* *unfert.*	*fert.*
1.11.64	3 ..	3.1
1. 3.65	5.1 ..	4.9

Variation between individual sample weights was too great for the differences between unfertilized and fertilized Pueraria to reach signifiance.

It is remarkable that the application in the fertilizer of the 11 lbs. of N, 88 lbs. of P_2O_5, 28 lbs. of K_2O and 70 lbs. of CaO per acre did not result in significantly more production of mass by the Pueraria. However, compared to the 6.2 tons of Dry Matter per acre represented by the 4 year old Pueraria cover on the same soil in 1962, this amount of 5 tons of D.M. formed in 9 months is quite considerable.

The analysis figures for the Pueraria cover (leaf + vines ÷ decaying material, down to the mineral soil) are given in table 2. They show a statistically signifiant increase resulting from fertilizer application, only for the P_2O_5, second sampling.

The drastic fall in percentage for several of the minerals with ageing of the cover is logical when we consider that the total mass of the Pueraria cover has been analysed and that the proportion of woody and dead material therein under the relatively thin layer of green foliage has increased appreciably with time.

The total amounts of minerals temporarily immobilised in the Pueraria mass however have remained practically constant for K_2O and substancially increased for the other elements with time.

Even though the P_2O_2 and K_2O contents should be considered below the levels required for vigorous growth (Dirven and Ehrencron, 1963), the total amounts of plant nutrients contained in the Pueraria mass which should to a greater or smaller extent become available to the following maize-crop, are considerable. The soil-analysis figures do not suggest that this build up in the Pueraria has gone at the cost of the topsoil-fertility.

It may be expected that the K, Ca and Mg would readily become available to the maize crop (Laudelot, 1962) whereas the release of the P will have been slow and uncertain and a good deal of the N may have got lost during decomposition of the trashcover in the maize crop under treatments 1, 2 and 3.

For general interest the trace elements have also been determined ; the Co and particularly the Mn figures are remarkably high when compared with those given by Dirven and Ehrencron (1963) : 0.17 and some 220 ppm respectively.

Maize plant numbers.—the means for numbers of occupied plantholes per 80′ of the two central rows are given in tables 3 an 4. Those for the 6 weeks old crop in table 3 reflect the degree of emergence of the maize under the very adverse (drought) conditions of those first weeks. For the unfertilized maize they show that :

(*a*) all three treatments involving Pueraria fallowing followed by maintaining a soilcover in the maize crop resulted in a statistically significant better emergence than the " one green gram cropp " treatment 0.

(*b*) the " zero cultivation " treatments did not result in a better plant-emergence than the " removing—soiltillage—returning the Pueraria mass as a mulch " treatment 1,

(*c*) within the " zero cultivation " treatments the fertilizer application to the Pueraria fallow made *no* significant difference to seedling emergence of the maize.

The figures for the 10 weeks old maize crop were practically identical with those for plantnumbers for the 6 weeks old crop and have therefore been omitted.

Table 4 gives the means of plantnumbers *at harvesting* for both the unfertilized and for the fertilized maize.

These figures show that :—

(*a*) all three treatments involving Pueraria fallowing followed by maintaining a soil cover in the maize crop resulted in statistically significant better final stands of the maize crop than the " one green gram crop " treatment 0.

(*b*) the " zero cultivation " treatments now resulted in statistically significant better ultimate stands of the maize crop than the treatment of " removing—soiltillage—returning the Pueraria trash as a mulch " treatment 1,

(c) within the " Zero cultivation " treatments, fertilizer application to the Pueraria fallow did not have a significant effect on ultimate maize plant numbers,

(d) fertilizer application to the maize did *not* have a significant effect on ultimate maize plant numbers.

The degeneration in maize stand (plant numbers) in the " remove soiltillage—return the Pueraria trash as a mulch " treatment is most likely due to poorer moisture conservation under the loose mulch cover in this treatment.

From the above it is clearer that the combination of Pueraria fallowing and " zero cultivation " resulted in the best maize crop stands whereas the application of fertilizer to either the Pueraria fallow or to the maize crop did not influence these stands at any time.

N.B. Analysis of variance caluculations done separately for the unfertilized maize subplots gave exactly the same results under a band c.

Maize plant heights.—Treatment means and their differences are given in tables 5 and 6 for the 6 and 10 weeks old unfertilized maize crops respectively.

The figures for the 6 weeks old maize crop show that.

(*a*) all three treatments involving Pueraria fallowing followed by maintaining a soil cover in the maize crop, resulted in significant better first growth of the maize plants than in the " one green gram crop " treatment 0.

(*b*) the " zero cultvation " treatments gave a statistically significant better growth of the maize plants than the treatment of " removing—soiltillage—returning the Pueraria trash as a mulch " treatment.

(c) within the " zero cultivation " treatment, fertilizer application to the Pueraria fallow resulted in a statistically significant better growth of the maize plants.

Since under *b*. the amounts of plant nutrients involved in treatments 2 and 1 are the same, it is most likely that the factor of soil-moisture conservation has decided the result.

From the above results it is clear that combination of fertilized Pueraria fallow and " zero cultivation " gave the best initial growth of the maize plants.

The figures for the 10 weeks old maize crop show that :

(*a*) all three treatments involving Pueraria fallowing followed by maintaining a soil cover in the maize crop resulted in a further statistically significant better growth of the maize plants than the " one green gram crop ", treatment 0,

(*b*) only the " zero cultivation " treatment *with* fertilizer application to the Pueraria fallow resulted in further statistically significant better growth of the maize plants than the " removing—soiltillage—returning the Pueraria trash as a mulch " treatment 1,

(*c*) within the " zero cultivation treatment " however, fertilizer application to the Pueraria fallow did *not* result in a statistically significant better growth of the maize plants over the 10 weeks.

From the above it is clear that the combination of Pueraria fallowing and " zero cultivation " resulted in the best plantgrowth over the 10 week period. Whereas the fertilizzer application to the Pueraria fallow initially resulted in taller plants, this effect disappeared later on.

Maize yields.—the means for yield figures for the unfertilized and the fertilized maize under the various main treatments are given in tables 7 and 8. To give a rough idea of the order of magnitude of the yields, the calculated yields/acre have also been given in table 7. The large coefficients of variation illustrate how necessary it was to even where the trials were executed with the utmost precision, have a large number of replicates since the disturbing influence of local soil variation is very great.

The figures of table 7 that show for the main treatments :

(*a*) all three treatments involving Pueraria fallowing followed by maintaining a soil cover in the maize crop statistically significantly outyielded the " one green gram crop " treatment 0,

(*b*) both treatments involving " zero cultivation " significantly outyielded the treatment of " removing—soiltillage——returning the Pueraria trash ash a mulch ",

The figures in table 8 show that for the subtreatments :

(*c*) fertilizer application to the maize crop resulted in a significant yield increase in the " unfertilized Pueraria fallow zero cultivation " treatment 2, and in the " unfertilized Pueraria removed—soiltillage—Pueraria trash returned as a mulch " treatment 1.

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Neither in the " fertilized Pueraria fallow + zero cultivation " nor in the " one green gram crop " treatments was there significant effect from fertilizer application to the maize.

From the above it would appear that the combination of Pueraria fallowing with " zero cultivation and fertilizer application to either the Pueraria fallow or to the maize, results in the best yields of the following maize crop.

CONCLUSION

Where large scale tractor ploughing has been introduced in the forest zone and its fringes, putting an abrupt end to the traditional system of natural soilregeneration under a shifting cultivatioon system, there is a dire need for quick regeneration of soilfertility and providing a soilcover against insolation, erosion and for soil moisture conservation.

A short term Pueraria fallow, combined with fertilizer application and " zero cultivation " appeared to fill this need. The Pueraria phaseoloides which within 3 months from sowing formed a complete soilcover, had in 9 months time built up 5 tons or dry matter per acre above ground, containing appreciable amounts of plantfood minerals even when not fertilized. When spraykilled, the Pueraria mass compacted into an unbroken mat close to the soil, providing effective soilprotection, weedcontrol and mositure-conservation in the following maize crop which was established in the undisturbed soil by punching holes through the " dead " Pueraria mat.

This in combination with fertilizer application to either the Pueraria fallow or later to the maize crop, resulted during the very unfavourable 1965 season in maize yields of around 2,000 lbs. of dry grain per acre, about twice the average for the area in normal years.

The next step will now have to be to dovetail the establishing of the Pueraria fallow crop (or any other suitable fallowcrop) into the cropping sequence in such a manner that a more continuous soilcover is maintained throughout with a minimum loss of productive cropping time.

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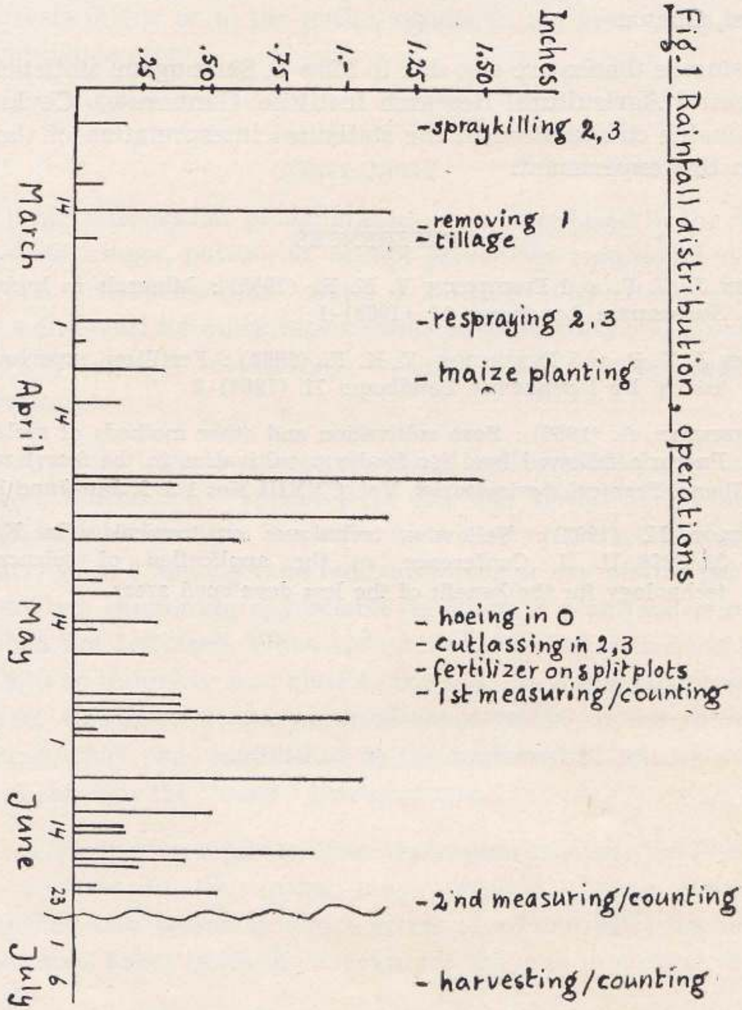

Fig. 1 Rainfall distribution, operations

Table 1.—Soil analysis figures

Treatment/date	*pH* (H_2O)	*O.M.* %	*N Total* %	K_2O *content mg/100 g*	P_2O_5*(P-A- mg/100 g*
0= No Pueraria No. fertil. 8.7.64	4.96	1.91	.105	5.93	4.00
2= 9 months unfertil, Pueraria 1.3.65	5.20	2.06	.111	6.50	3.25
3= 9 months fertilized Pueraria 1.3.65	5.12	2.11	.112	6.50	4.00

The only satistically significant (at 5% level) increase in mineral content due to fertilize application was found to be in the P_2O_5.

Table 2.—Mineral content of the Pueraria cover

Date	*Mineral*	*Content in Unfertil.*	*% of D.M. Fertilized*	*Amounts in Unfertil.*	*lbs./acre Fertilized*
1.11.64	N	2.71	2.51	179	176
1. 3.65	N	2.29	2.34	252	257
1.11.64	P_2O_5	.40	.40	26.5	26.5
1. 3.65	P_2O_5	.30	.49*	33	54
1.11.64	K_2O	1.77	1.63	117	108
1. 3.65	K_2O	.97	1.04	107	114
1.11.64	CaO	1.31	1.26	87	83
1. 3.65	CaO	1.50	1.65	165	182
1.11.64	MgO	.38	.37	25	25
1. 3.65	MgO	.39	.41	43	45
1. 3.65	B	35.1 ppm			
	Co	.44 ppm			
	Cu	12.30 ppm			
	Mn	587.00 ppm			
	Zn	31.00 ppm			

The only statistically significant (at 5% level) increase resulting from fertilizer application was found to be in the P_2O_5 content at the final sampling.

Table 3.—Maize plant numbers for the 6 weeks old crop

Occupied plant holes per 80 central rowlength

Treatment means		*Differences with*				
		0 = 20.00		1 = 32.33		3 = 34.66
2 = 35.00	..	15.00+	..	2.67	..	.34
3 = 34.66	..	14.66+	..	2.33	..	—
1 = 32.33	..	12.33+	..	—	..	—
0 = 20.00	..	—	..	—	..	—

L.S.D. 5% = 3.67+ C.V. = 14.46 %

Thus : means for treatments 3.2 and 1 were significantly higher than for 0.

Table 4.—Maize plant numbers at harvest time for fertilizer and unfertilized maize

Occupied plantholes per 80 central rowlength

Main treatment means		*Sub treatment means Fertilized maize*		*Unfertilized*		*Differences between Fertilized and Unfertilized*
3 = 31.25+	..	31.83	..	31.54	..	0.29
2 = 32.04+	..	32.33	..	31.77	..	0.58
1 = 27.58+	..	28.58	..	26.58	..	2.00
0 = 18.00	..	18.92	..	17.08	..	1.84

For differences between main treatments : L.S.D. (5%) = 3.44+ C.V. = 21.50 %

Thus : the main treatment means for treatments 3, 2 and 1 are significantly higher than for treatment 0 and the main treatment means for treatments 3 and 2 are significantly higher than that for treatment 1.

Differences between subtreatment means within main treatments did not reach significance. C.V. for subplots was = 13.25 %

Table 5.—Maize plant heights in the 6 weeks old crop

Treatment means in"	*Differences with*		
	0 = 8·22	1 = 16·21	2 = 24·53
3 = 30·07 ..	.. 21·85+ ..	13·86+ ..	5·54*
2 = 24·53 ..	.. 16·32+ ..	8·32+ ..	—
1 = 16·21 ..	.. 7·99+ ..	— ..	—
0 = 8·22 ..	.. — ..	— ..	—

L. S. D. 5* = 5·26+. C. V. = 24·00%.

Thus : the means for treatments 3, 2 and 1 were significantly greater than the mean for treatment 0,

the means for treatments 3 and 2 are significantly greater than the means for treatment 1, and

the mean for treatment 3 is significantly greater than the mean for treatment 2.

Table 6.—Maize plant heights in the 10 weeks old crop

Treatment means in "	0 = 43·33	1 = 57·17	2 = 69.17
3 = 79·08 ..	.. 35·75+ ..	21·91+ ..	9·91
2 = 69·17 ..	.. 25·84+ ..	12·00 ..	—
1 = 57·17 ..	.. 13·84+ ..	— ..	—
0 = 43·33 ..	.. — ..	— ..	—

L. S. D. 5% = 13·90. C. V. = 20·20%.

Thus : the means for treatments 3, 2 and 1 are significantly greater than the mean for treatment 0,

the mean for treatment 3 is significantly greater than the mean for treatment 1.

Table 7.—Maize yields (main treatment means) in g of dry (9% moisture) grain per 80′ of rowlength in fertilized and unfertilized crops

Main treatment means	*Differences with treatment means*			*per acre (Calc. yields)*
	0 = 925·92	1 = 1,536·42	2 = 3,244·54	
3 = 3,607·71	2,681·79+	2,071·29+	363·17	2,160 lbs.
2 = 3,244·54	2,318·62+	1,708·12+	—	1,943 lbs.
1 = 1,536·42	610·50+	—	—	920 lbs.
0 = 925·92	—	—	—	555 lbs.

L. S. D. 5% for the main treatment means = 519·85+. C.V. = 38·02%.

Thus : treatment 3, 2 and 1 means are statistically significantly higher than the treatment mean for treatment 0,

treatment 3 and 2 means are statistically significantly higher than treatment 1 mean.

Table 8.—Maize yields (subtreatments means) in g of dry (9% moisture) grain per 80′ of rowlength in fertilized and unfertilized crops

Main treatments	*Fertilized*	*Unferitlized*	*Differences*
3	3,805·00	3,410·42	394·58
2	3,832·42	2,656·67	1,175·75+
1	1,800·67	1,271·33	529·34+
0	1,099·42	752·42	347·00

L. S. D. 5% for the differences between subtreatment means

for a given main treatment = 527·77 C.V. = 27·56+.

Interactions did not reach statistical significance.

Thus : the differences between the subtreatment means for fertilized and unfertilized maize reached statistical significance only in treatments 2 and 1.

Preliminary studies with ammonium-sulphate-nitrate as a source of nitrogen for rice on ill-drained soils*

M. W. Thenabadu & K. Wickremasinghe,

Division of Agricultural Chemistry, Central Agricultural Research Institute, Peradeniya

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INTRODUCTION

Adverse soil conditions, as a consequence of poor drainage, limit rice yields in many parts of the wet-zone of Ceylon. Factors responsible for ill-drained conditions in these soils are primarily excessive rainfall and low topographical locations of fields which do not permit ready out flow of excess rain water. Such water-logged, ill-drained soils are characterised by a relatively high content of organic matter. These soils are extremely reduced and accumulate reduced products such as ferrous iron, hydrogen sulphide and products of the anaerobic decomposition of organic matter, such as aliphatic acids and phenols which are detrimental to plant growth. The adverse effects of poor aeration, caused by water-logging, would be more pronounced at high temperatures than at relatively low temperatures. The rhizosphere of the rice plant is kept oxidized by excretion of oxygen which would serve as a protective function against the build up of high concentrations of reduced products. But under extreme conditions of soils reduction the oxidative capacity of the roots is likely to be ineffective against the accumulation of excessive amounts of toxic substances. Under these conditions poor plant growth is inevitable.

An effective remedy for such ill-drained situations, where draining the fields in order to oxidize obnoxious products through the introduction of atmospheric oxygen into the soils is impossible, is the incorporation of chemical compounds that arrest or retard soil reduc-

* Adapted from a paper presented at the Eleventh Session of the Working Party on Rice, Soils, Water and Fertilizer Practices of the International Rice Commission, 2nd–5th September, 1968, at Peradeniya, Ceylon.

tion. The beneficial effects of manganese dioxide and nitrate fertilizers for rice on such ill-drained soils have been observed and reported (1, 2, 4).

MATERIALS AND METHODS

The results of a preliminary investigation in the Ratnapura district of the wet-zone of Ceylon where the mean annual rainfall of a large part of the district ranges between 150-200 inches is reported herein. The fertilizer ammonium-sulphate-nitrate (which contains 26 per cent nitrogen, a quarter of which is in the nitrate form) was used in fertilizer trials with rice in cultivator's fields to evaluate, (1) the efficiency of four forms of nitrogenous fertilizers, and (ii) the effect of sulphur fertilization on these soils. The other fertilizers tested were urea, ammonium sulphate and ammonium nitrate. Nitrogen at the rate of 40 lbs. per acre, was added as top dressings to all treatments except the control at the following rates and times :

(i) 20 lbs. nitrogen per acre one week after planting.

(ii) 13 lbs. nitrogen per acre two weeks before heading.

(iii) 7 lbs. nitrogen per acre at heading.

Phosphorus was applied at the rate of 47 lbs. P_2O_5 per acre as saphos phosphate and potassium was applied at the rate of 42 lbs. K_2O per acre as muriate of potash (50% grade), except in treatment 3 which received potassium sulphate (Table 1). These fertilizers were applied before planting to all treatments including the (zero nitrogen) control.

The experiment was conducted in cultivator's fields during Maha 1966-67 in the Ratnapura district. Blocks of six treatments were replicated at none locations. Of these, four were ill-drained and five were relatively better drained. The better drained locations were on the higher aspects of the land scape in the relatively drier parts of the district.

RESULTS AND DISCUSSION

The data on yield of rice as affected by treatments is presented in Table 1. The effect of treatments on grain yield was highly significant.

In the well-drained locations ammonium sulphate performed best. Ammonium-sulphate-nitrate was inferior to urea (alone) and ammonium sulphate, but the differences in yield between these sources of nitrogen were not significant. The results further indicate no effect of soluble sulphate on rice yields in these locations.

In the ill-drained locations, however, ammonium-sulphate-nitrate yielded the highest over all other forms of nitrogen fertilizers, and was significantly better than ammonium sulphate and ammonium nitrate. The yield increase from ammonium-sulphate-nitrate was approximately 13 and 15 bushels per acre over ammonium sulphate and ammonium nitrate respectively. Therefore ammonium-sulphate-nitrate would probably have had a favourable effect on plants growing in these situations in addition to supplying the nutrients nitrogen and sulphur.

It is possible that this nitrate containing fertilizer exerted a retarding influence on the reduction processes in these ill-drained soils as has been observed by other investigators (4). This however, does not explain the relatively inferior yield from the use of ammonium nitrate which supplied 20 lbs. nitrogen as the nitrate in comparison to only 10 lbs. nitrate nitrogen from ammonium-sulphate nitrate.

It is generally claimed that plants absorb nitrate nitrogen more readily than they absorb ammonium nitrogen. But the former form of nitrogen is more easily lost from the soil due to leaching and denitrification than the latter form of the element. Nitrate nitrogen has also been reported to increase the uptake of manganese by rice (3,4). This would be extremely beneficial on ill-drained soils that contain an excess of ferrous iron, for the effect of manganese in depressing the uptake of iron by rice plants has been noted (4).

The use of nitrate fertilizers is not a practicable method for retarding soil reduction as their effects are not likely to last more than a single season. However, if the cost of ammonium-sulphate-nitrate is comparable with those of other nitrogenous fertilizers generally used for rice, it may not be inadvisable to use this fertilizer for ill-drained soils if it retards oil reduction in addition to supplying the nutrient elements nitrogen and sulphur.

An advantage of ammonium-sulphate-nitrate over ammonium sulphate is that it contains 26 percent introgen in contrast to 21 percent in the latter. Thus there would be savings in the cost of packing, handling and transport as a result of using ammonium-sulphate-nitrate, because only 7.7 tons of ammonium-sulphate-nitrate are required to supply the same quantity of nitrogen as 10 tons of ammonium sulphate. On the other hand ammonium nitrate contains up to 35 percent nitrogen but this compound has the disadvantages of being explosive and hygroscopic.

SUMMARY

Ammonium-sulphate-nitrate gave significantly higher grain yields of rice in comparison with ammonium sulphate or ammonium nitrate on some ill-drained soils of the Ratnapura district. The superiority of this fertilizer may possibly be due to its effect in retarding soil reduction.

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Table 1.—Effect of Treatments on Yield of Rice as affected by Drainage Conditions

Treatments	*Well-drained locations*		*Ill-drained locations*	
	Bush./acre	*Kg./ha.*	*Bush./ac.*	*Kg./ha.*
1. No Nitrogen	53.6	2,524	57.4	2,703
2. Urea	72.6	3,418	70.8	3,334
3. Urea Plus Sulphate (as potassium sulphate)	63.5	2,990	74.0	3,484
4. Ammonium Sulphate	76.3	3,593	68.4	3,221
5. Ammonium Sulphate Nitrate	68.3	3,216	81.6	3,842
6. Ammonium Nitrate	65.8	3,098	66.9	3,150
L. S. D. at 1%	11.5	541	15.9	748
L. S. D. at 5%	8.4	395	11.5	541
Coefficient of Variation	9.6%		10.9%	

Radiations and chemicals in the control of Diplodia stem-end rot of mango fruits

V. N. Pathak and G. L. Khandelwal

University of Udaipur, College of Agriculture, Jobner (Raj) India

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Diplodia stem-end rot is one of the most serious diseases of ripe mango fruits in India (Pathak & Srivastava, 1967). Since epidemiological investigations on the disease revealed infection of the fruits while in the orchard (Pathak & Srivastava, 1967), attempts were made to evaluate various fungicides *in vitro,* which could later be tested as orchard sprays. Besides this, the possibility of curing infected fruits by radiations was also investigated.

Fungicides were tested *in vitro* at four concentrations, viz. 10,20,100 and 200 ppm. Measured quantities of the test fungicides were incorporated into melted sterilized potato dextrose agar media under aseptic conditions and the media poured into 10 cm. Petri dishes (20 ml per dish) which were inoculated with a 48-hour-old monoconidial culture of the pathogen. Controls were maintained on potato dextrose agar. Treatments were replicated five times. Colony diametres were measured after incubation for 3 and 15 days and the inhibition of growth calculated according to Vincent's formula (1947) from the average for each treatment, Table 1.

Table 1.—Percent inhibition of growth of D. natalensis by various fungicides at different concentrations

Fungicide	*Inhibition (%) at*							
	10 ppm after		*20 ppm after*		*100 ppm after*		*200 ppm after*	
	3 days	*15 days*	*3 days*	*15 days*	*3 days*	*15 days*	*3 days*	*15 days*
Dithane Z–78 ..	19..	12..	36..	18..	99..	56..	100..	89
Antracol ..	95..	86..	99..	89..	100..	100..	100..	100
Ferbam ..	9..	1..	23..	11..	26..	13..	67..	61
Dithane M–45 ..	0..	0..	19..	12..	99..	63..	100..	83
Blue Copper ..	0..	0..	0..	0..	0..	0..	27..	13
Ceresan ..	77..	53..	87..	83..	100..	100..	100..	100
Thiourea ..	0..	0..	0..	0..	0..	0..	0..	0
Miltox ..	12..	2..	13..	6..	27..	8..	31..	23
Cuman ..	0..	0..	58..	41..	69..	58..	89..	83
Control— ..	0..	0..	0..	0..	0..	0..	0..	0

Antracol and Ceresan were the most effective of the fungicides tested and inhibited growth of the fungus at concentrations of 100 ppm. Dithane Z-78, Cuman and Dithane M-45 were effective only at higher concentrations. Thiourea did not inhibit growth even at higher concentrations. Antracol and Ceresan should be investigated further to determine their suitability as orchard sprays.

Among the radiations, gamma rays (Cobalt-60, Gamma Cell, Division of Botany, Indian Agricultural Research Institute, Delhi-12) and ultra-voilet rays (Philips Germicidal Lamp, TUV-15W, transmitting 2537 A) were investigated. Their efficacy in curing the disease was studied by exposing the inoculated fruits (healthy fruits were surface sterilized and inoculated with a 48-hour old culture at stem-end) to radiations after 10 hours of incubation at 30 $\pm$ 1°C. Fruits in batches of five, were exposed to each of the three doses of gamma rays and ultra-violet rays, which were 2 x 10^5 2 x 7.5 x 10^5 and 4.5 x 10^5 rads for 5, 10 and 15 minutes respectively. Following iradiation treatments, fruits were held at 30 $\pm$ 1° C in sterilized desiccators along with control fruits, which were inoculated but not irradicated.

The influence of irradiations on growth of the pathogen was also studied. Petri dishes poured with potato dextrose agar were inoculated with a 48-hour-old culture of the incitant. These were irradiated with gamma and uv rays at the above mentioned doses after 10 hours of incubation at 30 $\pm$ 1° C and were held at this temperatue following irradiation. Inoculated Petri dishes without irradiation served as control. Inoculated fruits and Petri dishes following irradiation were observed daily after third day of treatment. The rate of decay of irradiated and unirradiated fruits was comparable and the same results were obtained regarding the rate of growth in irradiated and unirradiated Petri dishes. In this work with gamma rays, only the total doses and their effects were investigated. Further investigations on gamma flux as well as the total dose in curing this disease should be carried out. These studies have shown that the cure of infected fruits by radiation is not feasible. However, the fungicides Antracol and Ceresan strongly inhibited growth of the pathogen *in vitro* and their suitability as orchard sprays should be investigated.

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A study of potato cultivation in the Jaffna peninsula (maha 1967-68)

S. THAVARAJAVEL

Agricultural Instructor, District Agricultural Extension Office, Jaffna

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INTRODUCTION

POTATOES have been grown in small observation plots from 1957 in the Jaffna District. From 1964 onwards these plots became bigger and ceased to be observation plots. The extent under potato cultivation rapidly increased till in Maha 1967-68 the extent was 489 acres. The conditions prevailing in this Peninsula are quite distinct with hot dry climate from March to September when temperature differences between day and night are small and warm wet climate from October to February when temperatures differences between day and night are greater. Different cultivators in previous seasons have reported different results. In order to understand the problems associated with potato cultivation (and to determine suitable solutions to the different problems) a study was carried out at the end of the Maha 1967-68 season. This study became still more important as the bookings for seed potatoes for the Maha 1968-69 were for 1,300 acres.

METHOD OF STUDY

The method adopted was by questionaire of randomly selected cultivators. It is generally accepted that cultivators do not keep records of expenses and incomes. The recording of the data was done immediately after the harvest so as to allow the minimum time to lapse and thus ensure maximum correctness of data obtained as all data are memory recorded in the minds of the cultivators. Altogether 124 farmers out of a total of about 1,200 farmers were sampled.

(*a*) *Size of holding* : The holdings under potatoes varied in extent from 1/16th acre to a maximum of 1 acre. The model holding was 1/4th acre. The average holding was 0.23 acres. Details of the distribution of holdings are given in table 1.

Table I.—Distribution of Holdings

Size of holding		*No. of farmers*		*Percentage*
1/16th acre holdings	..	06	..	4.8
1/8th acre holdings	..	39	..	31.4
1/5th acre holdings	..	10	..	8.1
1/4th acre holdings	..	43	..	34.7
1/2 acre holdings	..	18	..	14.6
3/4th acre holdings	..	04	..	3.2
1 acre holding	..	04	..	3.2
Total	..	124		100

Another mode occurs at 1/8th acre level. There were found to be beginners who did not want to risk too much capital on seed and fertiliser on a new crop and had ristricted the extent to 1/8th acre for the season to gain experience.

(b) *Variety and yield.*—During the season under study, varieties Arka, Condea, Multa, and Cosima all listed as 3 to 3½ months varieties were cultivated. However under the conditions prevailing in the District, they all matured in less than 95 days from the date of planting immaterial of the date of planting. Plantings were done from 1.11.67 to 13.1.68. Early maturity is attributable to the increasingly warm temperature that prevails in January-February and which hastened the maturity of the crop. Field observations also confirm these findings.

Though seed potatoes of the various varieties were planted over a period of 2½ months, it was difficult to sort out for each variety the various dates of planting to determine whether for each variety different planting dates would give different yield responses. The data for each variety were therefore bulked together to evaluate the yield ability of each variety. This is given in table II from which it is seen that the variety Arka has outyielded all other varieties. The poor yield of Cosima may be attributed to the fact that all fields which carried Cosima were planted in January and hence the low yields might have been due to late planting.

Table II.—Yield ability of varieties

Variety	*Total acreage under each variety*	*No. of samples*	*Total yield in cwts.*	*Average yield p/a in cwts.*	*Deviation from average plus or minus cwt.*
Arka	145	41	6,131	149.5	+25.9
Condea	285	59	6,519	110.53	—23.1
Multa	64	19	2,329	122.6	— 1.0
Cosima	30	5	346	69.3	—54.4
	524	124	15,325	123.6	

(c) *Relationship between time of planting and yield.*—In this District, as with the rest of Ceylon, the cultivator is not in a position to ascertain his best date of planting. Most of the seed potatoes have to be imported by ship from European countries at the end of their summer harvest's. This procedure is fraught with delays. It is feared that late arrival of seed potatoes will result in a poor harvest or no harvest at all due to the high temperature in March-April as could be seen from table III.

Table III.—Monthly Temperature in Jaffna

Month	*Mean temperature*	*Maximum temperature*	*Minimum temperature*
January	77.8°F.	83.4°F	72.3°F
February	78.7°F	85.6°F	71.8°F
March	82.2°F	88.6°F	75.6°F
April	85.8°F	91.2°F	80.5°F
May	85.4°F	88.8°F	82.0°F
June	85.4°F	86.7°F	80.8°F
July	83.2°F	86.2°F	80.2°F
August	82.6°F	86.1°F	79.1°F
September	82.8°F	86.3°F	79.4°F
October	81.0°F	85.4°F	76.5°F
November	78.6F°	83.2°F	74.0°F
December	78.3°F	83.0°F	73.6°F

It is often stated that the potato requires an optimum temperature of around 70°F for proper tuberisation and development of tubers. In the Jaffna Peninsula, if this be so planting has to be so adjusted that before the commencement of higher temperature in February, the plants grow and cover up the soil, thus helping to ensure that tuberisation takes place before the on-set of the hot spell. The cool night temperature of around 70°F prevailing during the months of December, January and February contributes towards tuberisation and proper development of tubers. In trying to make adjustment for this factor, care should be exercised to avoid the continuous rainy period in November. Experience has shown that planting could commence during the latter part of November after the cessation of the heavy rains and could continue up to about the 25th of December. Planting after this date generally gives lower yields. During the Maha 1967-68 season, there were unusually heavy rains during the first week of December 1967 and this affected the November plantings adversely. From past experience, we do not recommend any planting in January due to the low yields obtained by such late planting. Since a portion of the seed potatoes were received late and as the cultivators were keen, January planting could not be avoided. Out of the 124 farmers sampled 19 planted in November, 89 in December and 16 in January. As the majority had planted during December, the month of December has been sub-divided into 3 groups to compare the yields in relation to the date of planting. The results are given in the table IV.

Table IV.—Yields in relation to time of planting

Time of planting	*No. of planting*	*Yield per acre in cwt.*
November	19	76 5/7
December 1st to 10th	Nil*	—
December 11th to 20th	54	145 6/7
December 21st to 31st	35	119 6/7
January 1st to 13th	16	98 2/7

*No planting was done during this period due to heavy rains culminating in heavy floods on 6.12.67.

From the findings it could be duduced that January planting gives lower yields than December planting and the current recommendation of planting immediately after the heavy rain is confirmed as a justifiable recommendation.

(*d*) *Cultivation and Cultural Retails.*—To every cultivator in the District an instruction leaflet on how to cultivate potatoes indicating what operations should be done and when, almost in the patern " do it yourself " was given. It was generally observed that every cultivator without exception kept to the schedule though there were limited variations in the amount of insecticides used and the amount of fertiliser used. These could not be evaluated.

COST OF CULTIVATION AND ECONOMICS

The cultivation costs were broken up into cost of labour inputs comprising tillage, planting, after care and irrigation, harvest and sale and cost of material inputs comprising organic manure, fertilizer, seed-potatoes, agro chemicals, pump hire and land rent.

The traditional method of tillage is by the use of the mammoty. This costs much more than the tractor-drawn ploughs and implements. But the custom of mammotying the fields is considered superior by the cultivators. It was not possible to evaluate the difference between the two systems of tillage as there was not a single case where a tractor has been solely used. The average cost of tillage worked to Rs. 212 per acre (variation Rs. 480—75).

The fields were laid into ridges and furrows 2′ apart and planting was done in the furrows having incoporated fertilizers in the furrows. All these operations were included under planting which worked out at an average of Rs. 100 per acre (variation Rs. 192 to 32).

After-care included mainly weeding, earthing-up, application of insecticides and fungicides and irrigation. In this item of expenses wide variations were noted. While some did two weedings, there were others who did none. Some sprayed more often than others. Some did earthing up twice and some irrigated more often than necessary. The average cost of this item turned out to be Rs. 380 per acre (variation Rs. 768 to 120).

Harvesting is done by hand by loosening the soil with a mammoty and pulling out the plants. The tubers were cleaned in the field and bagged and weighed by the cultivator and sometimes by the purchasing agent. In some instances cultivators incurred costs in marketing by transporting the produce to selling points. The volume of the harvested tubers by itself affects the cost of harvesting and sale. The average cost for harvesting and sale worked out at Rs. 131 (variation Rs. 275 to 32).

MATERIAL INPUTS

The highest cost of material input besides seed is the cost of organic manure, without the use of which no successful highland cultivation is possible in this region. Of the 124 cultivators surveyed only 3 cultivators did not adopt any organic manuring for this crop as they had manured their previous crop. Organic manure is used in the form of cattle manure, composted household sweepings, green leaves and dried leaves. The cost is therefore very variable, depending on the material used, cattle manure being the most costly. The average cost of organic manure turned out to be Rs. 776.94 cents (variation Rs. 1,600 to 160).

Next to organic manuring it has been found that the use of fertilisers gives very good response to yields to all crops in these soils. Fertiliser use is still in it's infancy and the average cost of fertiliser worked out at Rs. 97.44 (Variation Rs. 432 to 48). It is worthy of mention that 7 cultivators did not use fertilisers but their yields were not below the average of the others. This is attributed to the fact that they used very high doses of organic manure.

At the recommended rate of planting one would require 16 cwts of 2 oz. tubers and this would cost Rs. 1,075.20 at the Departmental sale price of Rs. 67.20 per cwt. The average cost of seed potatoes turned out to be Rs. 1,129.94 (variation Rs. 1,162 to 688). This variation is due to the variation in tuber size.

Insecticides and fungicides had to be used to protect the crop from pests and diseases. Here it was found that all cultivators had used some form of agrochemicals. The average cost of these chemicals worked out at Rs. 117.33 (variation Rs. 340.20 to 35).

The crop has to be irrigated every 4th to 5th day unless water has been provided by rainfall. For irrigation a water pump is necessary and the prevailing pump hire rates have been included in the data sheets even when the cultivator owned his pump. The pump hire rates however vary from village to village depending on the availability of pumps. The depth of the well and the frequency of irrigation. The average cost of hire of water pump turned out to be Rs. 253.87 (variation Rs. 480 to 120).

Land rent varies from village to village and is also affected by location and accessibility and type of soil and the average worked out to be Rs. 155.04 (variation Rs. 400 to 60).

It could be seen from table VI that the model sale price was Rs. 51 to 55 at which price range the largest number of cultivators had sold their produce and this is also the lowest price that had been obtained. This is due to the fact that majority of the cultivators (75 out of 124 cultivators sampled) had sold between 1.3.68 and 20.3.68. After this period there was a steady rise in the price to Rs. 70 by 20.4.68. If the cultivators had stored their produce for a period of 3 to 4 weeks, it would have been possible for them to obtain at least Rs. 10 more for each cwt. they sold, even after making allowances for loss of weight due to storage which would have been in the region of about 10 per cent for that period.

SUMMARY

The average cost of cultivation of potatoes during Maha 1967-68 in Jaffna was Rs. 3,353.56. The average yield was 123.6 cwts. The lowest selling price recorded in the survey was Rs. 51 per cwt. Hence the profit on the average yield at the lowest selling price with average cost of cultivation was :—

	Rs. c.
123.6 × Rs. 51	6,303 60
Minus cost of cultivation	3,353 56
Net profit	2,950 04

Potato being a three months crop the profit of Rs. 2,950 in four months (allowing one month for preparatory tillage) is very high and it is not possible to obtain such high profits with any other three months crop. In the case of cultivators who obtained yields higher than the average and those who sold at prices higher than the lowest selling price of Rs. 51 the proft could be in the region of 3,500 per acre or more. However it has to be mentioned that successful potato cropping requires high inputs, especially of materials and hence the risk by incompetent cropping is high.

Potato being a new crop, the majority of the farmers adopted the recommended techniques in a systematic manner and this resulted in successful crops and high returns.

ACKNOWLEDGMENTS

The author is thankful to Mr. K. N. Jayaseelan, former District Agricultural Extension Officer, Jaffna, for initiating this study and to Dr. K. Caesar, Potato Consultant to the Government of Ceylon for valuable suggestions in the preparation of this paper.

The average cost of cultivation works out to be Rs. 3,353.56 cts. (variation Rs. 6,579.20 to Rs. 1,370.00). Details are given in table V.

Table V.—Cost of production and profit account

Labour inputs	*Average* Rs c.	*Maximum* Rs. c.	*Minimum* Rs. c.
Tillage	212 0 ..	480 0 ..	75 0
Planting	100 0 ..	192 0 ..	32 0
After care and irrigation	380 0 ..	768 0 ..	120 0
Harvest and sale	131 0 ..	275 0 ..	32 0
Material inputs			
Organic manure	776 94 ..	1,600 0 ..	160 0
Fertilisers	97 44 ..	432 0 ..	48 0
Seed Potatoes	1,129 94 ..	1,612 0 ..	688 0
Agro-chemicals	117 33 ..	340 20 ..	35 0
Pump hire	253 87 ..	480 0 ..	120 0
Land rent	155 04 ..	400 0 ..	60 0
	3,353 56 ..	6,579 20 ..	1,370 0

Average Yield	123·6 cwt. ..	
Sale value at the modal price of Rs. 55 per cwt..		6,789 0
Gain per acre	.. ..	3,444 44 (at average cost).

(*Continued on page* 109)

Table VI—Sale Pattern of Harvested Potatoes

Time of Sale	*Sale Price Obtained by Cultivators*										*Total No. of Cultivators*
	Rs. 51–55	*Rs.* 56–60	*Rs.* 61–65	*Rs.* 66–70	*Rs.* 71–75	*Rs.* 76–80	*Rs.* 81–85	*Rs.* 86–90	*Rs.* 91–96	*Rs.* 96–100	
25. 1.68 to 31. 1.68	—	—	—	—	—	—	—	—	1	2	3
1. 2.68 to 10. 2.68	—	—	—	6	1	—	1	1	—	—	9
11. 2.68 to 20. 2.68	—	1	—	3	—	2	—	—	—	—	6
21. 2.69 to 29. 2.68	—	—	2	2	—	—	—	—	—	—	4
1. 3.68 to 10. 3.68	23	1	1	—	—	—	—	—	—	—	25
11. 3.68 to 20. 3.68	32	12	2	4	—	—	—	—	—	—	50
21. 3.68 to 31. 3.68	5	13	2	—	—	—	—	—	—	—	20
1. 4.68 to 10. 4.68	—	3	3	—	—	—	—	—	—	—	6
11. 4.68 to 20. 4.68	—	—	—	1	—	—	—	—	—	—	1
	60	30	10	16	1	2	1	1	1	2	124

The effect of slaked lime on rice yield at Panagoda, Pussellawa and Bombuwela

MERVYN W. THENABADU

Division of Agricultural Chemistry, Central Agricultural Research Institute, Peradeniya, Ceylon

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INTRODUCTION

LIMING is one of the oldest practices for maintaining soil fertility especially in humid regions where leaching removes bases from the soil which encourages the build up of soil acidity. Many crops grow best only if the soil reaction is optimum for them and the adjustment of soil acidity to a suitable level is important in good soil management. Although the importance of liming acid soils was known to the Japanese since the beginning of this century, Japanese farmers attached more importance to limiting of paddy soils than upland soils (1).

The effect of slacked lime on the yields of rice in the low-country wet-zone of Ceylon has been studied by Ponnamperuma (2, 3). Slaked lime at the rate of 6 tons per acre gave yield responses of 20.6 and 14.2 bushels per acre on imperfectly drained strongly acid clay loams at Mirigama and Panagoda respectively. At Mirigama the response to lime was in the absence of nitrogen. It was also observed that slaked coral lime performed better than ground coral limestone or ground dolomite. On the ill-drained humic soils of Bombuwela, Labuduwa and Karapincha however, there were no significant effects of lime on the yield of rice.

In the investigation reported here a study of the response to liming of soils on growth and yield of rice was made at three stations in the wet-zone of Ceylon. The levels of slaked lime used ranged between 0.25 and 3.00 tons per acre at each location.

MATERIALS AND METHODS

Four field trials were laid down at three Research Stations, in the wet-zone, viz. Panagoda, Pussellawa, and Bombuwela during Yala 1960. At Bombuwela the effect of slaked lime was studied on two soil types—(*a*) the very poorly drained humic clay loam and (*b*) the sandy soils. The characteristics of soils at the experimental sites are presented in Table 1. The levels of lime used were 0 ; 0.25 ; 0.50 ; 1.00 ; 2.00 ; and 3.00 ; tons per acre. The design of the experiment at each location (and on each soil type) was a randomized block replicated four times. At each of these levels of lime the same quantity of N, P and K. fertilizers was added. For comparison, lime at 3 tons per acre was applied without NPK fertilizer. There was a NPK fertilizer treatment without any lime, and a control plot without lime and without fertilizer was also included. Two additional treatments with 3 and 6 tons straw compost per acre were included in the experiment on the sandy soils at Bombuwela. In all treatments lime was applied to the plots two weeks before transplanting.

In the NPK fertilizer, nitrogen was supplied at the rate of 40 lbs. N per acre, as ammonium sulphate at Panagoda and Pussellawa and as urea at Bombuwela. These were applied in three split doses at transplanting, two weeks after transplanting and at primordial initiation. Phosphorus, in the form of concentrated superphosphate, was supplied as a basal dressing at the rate of 84 lbs. P_2O_5 per acre. Potassium was supplied as muriate potash (50 per cent. grade) at the rate of 100 lbs. K_2O per acre, half of it being given at planting and the remainder at the stage of primordial initiation.

The variety of rice used in all trials was H-4. Soil samples were collected at regular intervals from each plot throughout the experiment for PH determinations. The trials at Bombuwela were continued during Maha 1960-61 to evaluate the residual effects of slaked lime.

RESULTS AND DISCUSSION

The effect of treatments on the yield of rice at the four locations are presented in Table 2 and 3.

Panagoda

The data on the effect of treatments on yield of rice at Panagoda is presented in Table 2. This information has been presented earlier (4). At Panagoda the plots that received lime at the rates of 2 and 3 tons per acre showed luxurient vegetative growth, particularly that of leaves. In the early stages of growth there was better root development in plants from plots at the lower levels of lime, but at the later stages plants in plots treated with 2 and 3 tons of lime per acre generally had more extensive root development. These observations may be explained on the basis of the toxic effects of excess lime on root growth although lime was applied two weeks before transplanting.

The plot receiving no fertilizer and no lime gave 60.8 bushels per acre. The addition of NPK fertilizers alone significantly increased yields by 19 bushels per acre. The addition of lime at levels ranging from 0.25 to 2 tons per acre together with NPK fertilizer made no further contribution to yield. Where 3 tons of lime were applied in addition to NPK fertilizer a yield of 86.6 bushels per acre was obtained, representing an increase in yield of 26 bushels over the unfertilized and unlimed control. Lime alone at 3 tons per acre gave a 11 bushels per acre increase in yield in the season of application. Increase in yield with lime was 11 bushels per acre with NPK fertilizer 19 bushels per acre.

From the above it is seen that the effect of lime and fertilizer were nearly additive. The conclusion is therefore drawn that a level of at least 3 tons per acre lime is necessary to effect an increase in yield in the season of application and this increase in yield can be more than doubled (26 bushels per acre) by the further addition of NPK fertilizer. In contrast to these findings, Ponnamperuma (3) obtained a very highly significant and linear response to lime in the range 0-6 tons per acre at Panagoda. This difference may most probably be due to the fact that the soil on which Ponnamperuma worked was relatively more acidic, low in cation exchange capacity and deficient in nutrients than the soil on which this investigation was made.

Canges in pH of the soil were expected due to application of lime, and therefore determinations of pH were made at various stages of growth in each treatment. Contrary to expectation there were no marked differences in pH with application of lime. It appears that 3 tons of lime per acre was insufficient to appreciably alter the pH of the soil. It is probable that the effect of lime was neutralized to some extent by the organic acids and carbon dioxide liberated during the mineralization of soil organic matter.

Pussellawa

The response to liming at Pussellawa is seen from the results in Table 2. The effect of treatments was significant at Pussellawa. Lime at the rate of 0.5 to 1.0 ton per acre increased the yield of rice by approximately 5 to 6 bushels per acre as compared with the no lime treatment. Levels of lime higher than 1.0 ton per acre depressed yields on this soil. As expected the need for fertilizers on this soil is seen from comparison of the yields of treatments 1, 2, 7 and 8. There was a yield increase of approximately 15 bushels per acre, 200 per cent, due to NPK alone when the yields of the first two treatments are compared. One ton of lime with NPK gave the highest increase in yield, viz. 21 bushels per acre. This benefit of lime is not apparent with applications of 2 and 3 tons lime per acre. This may most probably be due to accelerated mineralization of soil organic matter with release of nitrogen and phosphorus, especially phosphorus. The data in table 1, indicates that the available phosphorus is low while nitrogen and exchangeable potassium are relatively well supplied on this soil.

Bombuwela

The effect of treatments on rice yields on the two soil types at Bombuwela during Yala 1969 and the residual effects of liming studied during Maha 1960-61 are presented in Table 3.

There was no significant responses to lime applications in the presence of fertilizer on the humic clay loan during Yala 1960, nor were there any significant residual effects seen during the following season (Maha 1960-61). These results confirm the findings of Ponnamperuma (2, 3).

The effect of treatments on the sandy soil were however significant during the season of application, i.e., Yala 1960. There were significant yield responses to NPK fertilizers on this sandy soil which is relatively poor in organic matter (Table 1). The effect of lime showed a maximum response at 0.50 tons per acre and the difference between this treatment and the control was significant. Straw compost only at 3.0 tons per acre was almost as good as the no lime with NPK treatment indicating a beneficial effect of the compost on this sandy soil. At 6.0 tons per acre the straw compost treatment was not better than that at the lower level, (there being a slight depression of yield).

The residual effects of liming or fertilizer treatments were not significant on the sandy soil during Maha 1960-61. However, the residual effects of lime treatments could be observed in some treatments. (viz., treatments 2 to 7). Straw compost at the rate of 6.0 tons per acre appeared to contribute to a yield increase of approximately 14 bushels per acre over the unfertilized plots. Straw compost at this rate appeared to be equivalent to NPK fertilizers plus lime at 1 ton per acre.

CONCLUSIONS

Slaked lime at the rate of 3 tons per acre increased yields of rice at Panagoda and the application of fertilizers in addition to the lime more than doubled this yield increase. At Pussellawa the best response was to 1 ton slaked lime per acre with fertilizers. There was no response to lime applications on the humic clay loan soil at Bombuwela, but there was a response to lime on the sandy soil.

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Table 1.—Some characteristics of soils from experimental fields

Location	*Texture*	*pH 1:1 soil: water*	*Organic matter %*	*Total Nitrogen %*	*Available p_2o_5 (Olsen) ppm*	*Available Sio_2 (Imaizumi and Yoshoida) ppm*	*Cation Exchange capacity me/100 g*	*Total exchangeable cation me/100g*	*Exchangeable cations me/100g*		
									Potassium	*Calcium*	*Magnesium*
Panagoda	Clay Loam	5.3	5.95	0.37	2.5	192.6	18.0	2.00	0.11	0.88	0.28
Pussellawa	Sandy clay loam	5.13	8.4	0.38	14.5	509.6	15.6	2.42	0.24	0.98	0.58
Bombuwela	Humic clay loam	5.4	7.02	0.38	41.3	128.4	16.4	3.38	0.16	1.57	0.80
Bombuwela	Sand	5.2	2.54	0.19	7.8	24.1	2.8	1.68	0.04	0.29	0.10

Table 2.—Effect of Treatments on yield of rice at Panagoda and Pussellawa (bu/ac)

No	*Treatment*	*Location*	
		Panagoda	*Pussellawa*
1	No lime, no NPK	60.8	7.4
2	No lime with NPK	79.5	22.2
3	0.25 tons lime/ac with NPK	79.5	21.6
4	0.50 tons lime/ac with NPK	79.5	27.0
5	1.00 tons lime/ac with NPK	79.8	28.3
6	2.00 tons lime/ac with NPK	79.2	20.0
7	3.00 tons lime/ac with NPK	86.6	23.4
8	3.00 tons without NPK	72.0	19.9
	L.S.D. 0.05	15.0	3.68

Table 3.—Effect of Treatments on yield of rice at Bombuwela (bu/ac)

	Soil type	*Humic Clay Loam Soil*		*Sandy Soil*	
	Season	*Yala 1960*	*Maha 1960/61*	*Yala 1960*	*Maha 1960/61*
No.	*Treatment*				
1	No Lime no NPK	62.2	62.3	42.1	27.6
2	No Lime with NPK	65.7	72.2	53.9	39.5
3	0.25 tons lime/acre with NPK	73.8	70.3	52.2	36.2
4	0.50 do.	63.4	74.5	61.8	41.8
5	1.00 do.	62.3	70.7	59.1	42.8
6	2.00 do.	67.9	69.5	48.5	41.7
7	3.00 do.	67.9	71.9	59.6	40.9
8	3.00 do.	62.4	66.4	41.2	29.0
9	3.00 tons Straw compost/acre only	—	—	53.1	23.8
10	6.00 do.	—	—	52.4	42.1
	L.S.D.=0.05	8.6	8.4	11.3	6.7
		(N.S.)	(N.S.)	(Significant)	(N.S.)

RESEARCH NOTE

Root and rhizome necrosis or black-head disease of banana

(Received July, 1969)

The burrowing nematode parasitizes banana and many other species of plants, with considerable attendant losses, in different parts of the world. In Ceylon, infestation of banana in Mirigama, Gampaha, and Peradeniya areas is common.

Symptoms and Effects : On the primary roots, lesions vary from minute reddish brown specks to long sunken dead areas, 4-6 cm. in length. Larger lesions may completely girdle the root. The affected tissue is brown to black with longitudinal fissures. The advancing edges of the lesions are of a characteristic red colour. Internally the discolouration extends inward to the stele. Nematode lesions extend from the larger roots into the rhizome and suckers where they cause a reddish brown discolouration. When lesions are tested out in water, nematodes in all stages can be seen under the microscope. In heavily infested soils, the primary roots may be almost uniformly light purple in colour without evidence of blackening. The cortex of such roots is heavily infested with nematodes. In soils with a high nematode population, the fine feeding rootlets may be invaded and destroyed as quickly as they are formed. Nutrient uptake of the plant is thus affected. Damage to the roots reduces the effective anchorage of the plant which can then be easily tipped over by wind.

Casual Agent : Radopholus similis (Cobb. 1893(Thorne, 1949, is the burrowing nematode.

These nematodes breed very rapidly. A single female may lay 6 to 7 eggs per day. The males are apparently unable to enter the roots but larvae and females of all stages of development move about freely in the soil and also into and out of roots.

Control Measures : Use clean propagation material—select rhizomes with care and ensure freedom from nematode infestation by cutting off any affected parts and then subjecting the material to hot water treatment at 55°C for 15 minutes or 60°C for 10 minutes. An organomercurial seed dip should be used in conjunction with this treatment and the treated rhizome sealed in a polythene envelope till the roots develop.

Soil population of the pathogen is known to be reduced considerably with a bare fallow, or by long rotation with non susceptible crops.

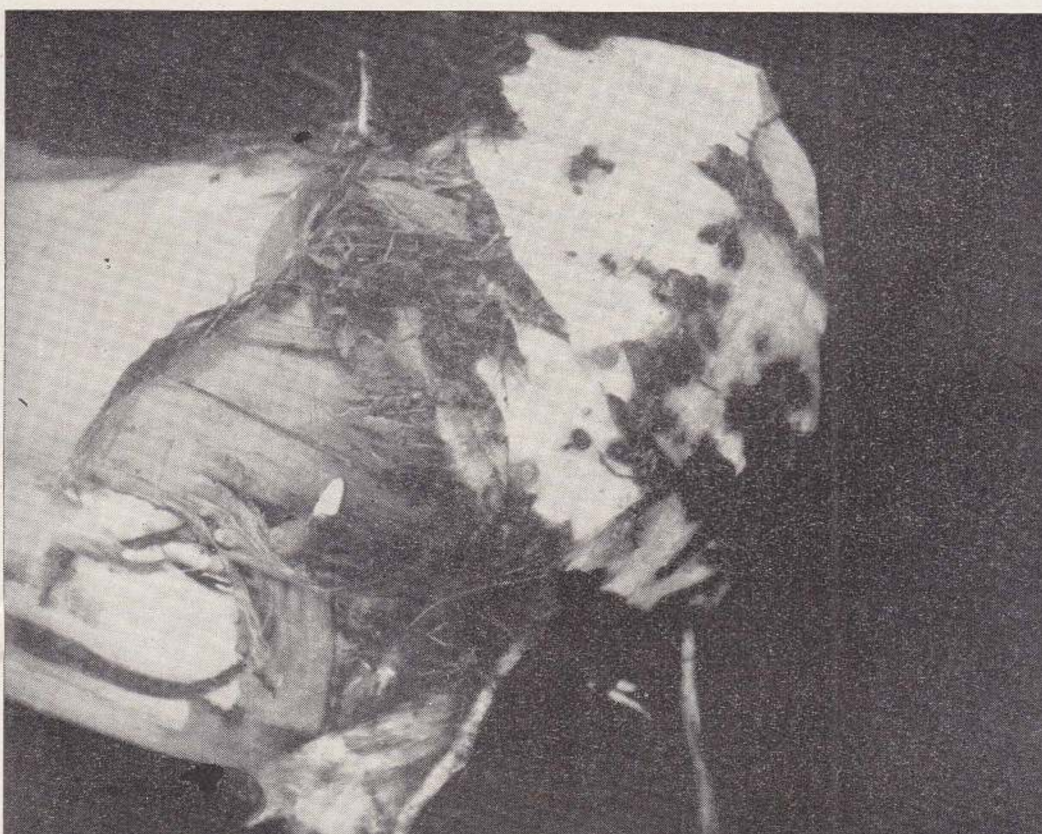
Use of soil fumigants and nematocides in the control of this disease is been practised in countries like Hawaii, but in Ceylon this method may not be economical.

A. W. SENANAYAKE.

Division of Plant Pathology,
Central Agricultural Research Institute,
Gannoruwa, Peradeniya.

Fig. 1 b. A root invaded by nematodes, showing typical lesions.

Fig. 1 a. Typical symptoms of nematode infestation on a banana rhizome.



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