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Control of Hydrogen Sulphide Formation and Enhancement of the Ethanol Yield in Coconut Toddy — Field Trials

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Abstract: Field trials were carried out to test the finding that the addition of ammonium salts, as a source of nitrogen for the metabolism of toddy yeast, suppresses completely the formation of hydrogen sulphide and enhances the ethanol yields. Four field trials carried out, under normal conditions of tapping, showed that the addition of ammonium salts at a concentration of 0.08% (w/v) of NH_4^+ ions to the collection pot prior to tapping increased the ethanol content of toddy by an average of 12.5% and the total yield of ethanol by an average of 26.5%. At this concentration of NH_4^+ ions the formation of hydrogen sulphide was also completely suppressed. Statistical analysis showed that the results observed are of high statistical significance.

1. Introduction

Coconut palm wine (toddy) is a traditional beverage of Sri Lanka and other coconut growing countries. Toddy is the fermented sap of the young inflorescence of the coconut palm *(Cocos nucifera).* The unfermented sap (sweet toddy) is the exudate obtained from the young inflorescence by subjecting it to a skilled process called tapping. The unfermented sap contains about 15-20% (w/v) sugars (mainly sucrose) which are fermented to ethanol and a number of minor components by a mixture of wild yeast and bacteria. The fermented coconut palm wine which contains about 7% (v/v) ethanol is drunk fresh or bottled (pasteurized) or is distilled to produce a palm brandy (arrack).

The natural fermentation of toddy caused by the various types of wild yeast and bacteria produces not only ethanol but also many by-products. The formation of these by-products is responsible for the low ethanol yields and the off-flavours of coconut toddy.[2,4] It has been reported that the ethanol content of naturally fermented coconut toddy is about 30% less than the theoretical yield.[4]

The main contributory factor for the off flavour of coconut toddy has been traced to the formation of hydrogen sulphide during the natural fermentation. Jansz *et al*[3] who carried out a detailed study on this subject attributed the formation of hydrogen sulphide in toddy to the metabolic activities of some wild yeasts where the sulphur containing amino acid cysteine is utilized with the release of hydrogen sulphide. The mechanism of this process as proposed by Hough *et al*[1] is given in figure 1.

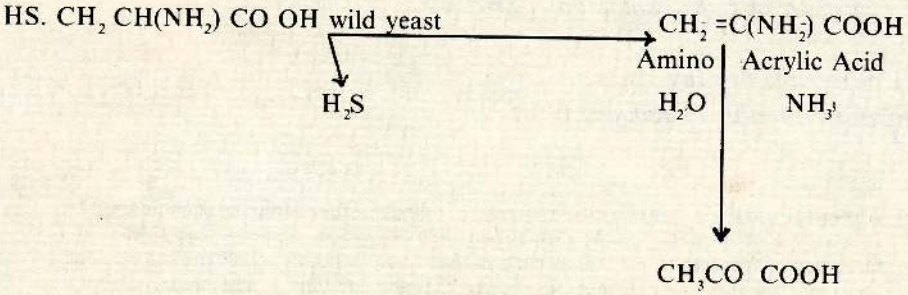

Figure 1. Cysteine metabolism by yeast.

Subsequent work on the control of hydrogen sulphide formation in toddy carried out by Jansz *et al*[2] and Kalyananda *et al*[4] resulted in the discovery of a number of methods for this purpose. Out of these methods the addition of small amounts of ammonium salts to the sweet toddy before the commencement of the fermentation process appeared to be the simplest and the most feasible on a commercial scale. The most attractive feature of this process was the increase in the ethanol yield in the resulting toddy, which was around 25%.[4]

Though coconut toddy has been a popular alcoholic beverage for several centuries and also served as the base for the distillation of coconut arrack, the problems of undesired flavours and low ethanol yields have remained unsolved. The methods reported earlier such as the use of pure culture fermentation for increasing the ethanol yield[5,6] are impracticable on a commercial scale. Therefore, the findings of Jansz *et al*[2] and Kalyananda *et al*[4] after extensive research were considered to be of paramount importance to the coconut toddy industry in solving the above mentioned problems.

These findings were important as they indicated that the low yields of ethanol and off flavour of coconut toddy could be solved by the simple operation of adding ammonium salts to the collecting pot during the normal tapping process used on a commercial scale.

The field trials reported in this paper were carried out to test the applicability of these findings on a commercial scale. A detailed account is presented of four field trials carried out in four different locations and a statistical analysis of the results.

2. Experimental

2.1 Tapping and Fermentation of Coconut Toddy

Tapping of coconut palms for toddy was carried out by the regular tappers using the normal tapping procedure and schedule. The total number of coconut palms in each field trial were grouped into batches for convenience, and one sample (200 ml) from each batch was drawn for analysis. Control (without added NH_4^+) and experimental (with added NH_4^+)trials were carried out on alternate days. The same collection pot was used for both the control and the experimental trials for each inflorescence. In the experimental trials a calculated amount of ammonium chloride was added (as a solution or in the form of tablets) to the collecting pot at the time of tapping. Each ammonium chloride tablet weighed about 0.6 g and contained 0.20 g of NH_4^+. The amount of ammonium chloride to be added was calculated based on the volume of toddy collected on the previous day. The number of tablets added was one for every 250 ml of toddy. The volume of toddy collected per pot ranged from 250 ml to 2000 ml. In order to complete the fermentation, toddy samples collected 24 hours after tapping were allowed to stand for another 8-10 hours before analysis. However the evolution of hydrogen sulphide was monitored right from the time the samples were collected ie. from 8.00 a.m. to 3.00 p.m. on the same day of collection.

2.2 Analytical Methods

2.2.1 *Estimation of Ethyl Alcohol* — The ethyl alcohol content of samples of toddy was estimated by the use of an Ebulliometer and was expressed as a percentage by volume.

2.2.2 *Estimation of Residual Sugar* — The total residual sugar after inversion was estimated by the Lane and Eynon method and was expressed as a percentage by weight.

2.3 Detection of Hydrogen Sulphide — Hydrogen sulphide was detected qualitatively by the use of lead-acetate paper.

2.4 Ammonium chloride powder (technical grade) was obtained from British Drug House Limited, Overseas Division, U.K.

3. Results

3.1 Field trials Ia and 1b – Conducted at the Bandirippuwa Estate Coconut Research Institute Lunuwila (From 15th March to 20th March 1978)

For these field trials a total number of seventy seven (77) trees were used, which were grouped into 9 batches. The effect of adding NH_4^+ on the yield of ethanol and the formation of hydrogen sulphide was studied using two concentrations of ammonium chloride. The ammonium chloride was added in the form of a solution and the two concentrations used were 0.05% (w/v) and 0.08% (w/v) of NH_4^+ based on the volume of toddy.

The results of this field trial are given in Table 1.

Incorporation of NH_4^+ at a concentration of 0.05% (w/v) only partly suppressed the formation of hydrogen sulphide. In some batches there was no suppression at all. However, the ethanol yield was found to increase appreciably and the results showed an average increase of 28% in total yield of ethanol per batch and an average increase of 13.0% in the ethanol content of the toddy. With the increase of the NH_4^+ concentration to 0.08% (w/v) a complete suppression of the hydrogen sulphide formation was observed in all batches. At the same time the total yield of ethanol per batch increased by an average of 46% while the ethanol content in toddy increased by an average of 32%. The residual sugar contents of fermented toddy was found to be very much less in samples treated with NH_4^+ (at both concentrations) as compared with untreated (control) samples.

3.2 Field Trial 2 — Conducted at the Galawatte Estate, Land Reform Commission, Bandirippuwa (From 13th February to 20th February 1979)

In this field trial, ammonium chloride was incorporated into toddy in the form of tablets to give the required concentration of NH_4^+ ions. The concentration of NH_4^+ ions used was 0.08% (w/v) based on the volume of toddy expected. The results are given in table 1.

Table 1. – The effect of NH_4^+ (as an alternative source of nitrogen for yeast metabolism) on the ethanol yield and the formation of hydrogen sulphide in coconut toddy.

Field trial	No. of trees	NH_4^+ conc. (%)	Volume of toddy (ml)		Avg. Ethanol content of toddy % (v/v)		Avg. Residual sugar (% w/v)		H_2S* formation		Total yield of ethanol (ml)		Avg. % increase in the yield of ethanol	Increase in the ethanol content %
			*C	E	C	E	C	E	C	E	C	E		
1 a	77	0.05	65350	74750	7.6	8.6	1.4	0.4	+++	–+	5032	6450	28.3	12.5
1 b	77	0.08	152770	165500	7.0	9.2	3.0	0.2	+++	---	10604	15276	46.3	32.0
2	360	0.08	—	—	7.1	7.5	0.34	0.08	+++	–+	—	—	—	7.0
3	21	0.08	64925	70847	7.8	8.4	0.76	0.33	+++	---	5122	5976	17.1	6.6
4	100	0.08	752200	820650	7.7	8.1	1.65	0.66	+++	---	51163	58554	14.1	4.4
Total	635	—	1,035,245	1,131,747	7.4	8.4	1.43	0.33	—	—	71921	86256	26.5	12.5

* Key — C — control, without added NH_4^+
E — Experimental, with added NH_4^+
H_2S formation : +++ high
–+ traces
--- absent

Three hundred and twenty four (324) trees were used in this trial which were grouped into nine batches. In this trial the effect of adding NH_4^+ ions on the ethanol content of the toddy and the formation of hydrogen sulphide was studied. The effect of NH_4^+ on the total yield of ethanol per batch was not studied.

The results showed that the suppression of the formation of hydrogen sulphide in the NH_4^+ treated samples was not complete and also the increase in the ethanol content of toddy was around 7%.

The results of this field trial was affected by the changing weather conditions mainly by the intermittent fall of rain.

3.3 Field Trial 3 — Conducted at the Kiripallagahawatte Estate, Molligoda, Wadduwa (From 30th November to 5th December 1979)

In this field trial, NH_4^+ (0.08% w/v) were added to the pot in the form of NH_4Cl tablets as in the case of the 2nd field trial. The results are given in Table 1.

At this concentration of NH_4^+ in the toddy an average increase of 17.1% in the total yield of ethanol per batch and an average increase of 6.6% in the ethanol content of the toddy was observed. In addition the hydrogen sulphide formation in toddy was also completely suppressed.

3.4 Field Trial 4 — Conducted at the Molligoda Estate, Molligoda, Wadduwa (From 29th October to 7th November 1980)

In this field trial too NH_4Cl was added to the pot in the form of tablets to give a concentration of 0.08% (w/v) of NH_4^+ based on the expected yield of toddy. As a result, an average increase of 14.1% in the total yield of ethanol per batch and an average increase of 4.4% in the ethanol content of the toddy were observed. The hydrogen sulphide formation in toddy was also completely suppressed (Table 1).

3.5 Statistical Analysis of the Results

A statistical analysis of the results obtained with respect to the total yield of ethanol and the ethanol content of toddy is given in Table 2. The average increase in the total yield of ethanol and the ethanol content of the toddy were statistically analysed to determine the significance of the observed increases. In this analysis the 'Paired-sample Test' was applied. This analysis showed that the observed mean increases in both the ethanol content of toddy and the total yield of ethanol were very highly significant.

Table 2.— Statistical Analysis of Results of the five field Trials on the Effect of Adding NH_4^+ Salts on the Ethanol content and the Total yield of Ethanol in Toddy

	No of samples	Average increase in ethanol content	Average increase in total yield of ethanol	t	Degrees of freedom	Probability	Significance of the Avg. increase*
Field Trial 1a	9	12.5%	—	7.5757	8	p 0.001	VHS
	—	—	28.0%	1.8182	8	p 0.1	NS
Field Trial 1b	9	31.7	—	10.5000	8	p 0.001	VHS
	—	—	46.3%	6.4076	8	p 0.001	VHS
Field Trial 2	10	7.0%	—	2.5080	9	p 0.02 p 0.05	S
	—	—	—	—	—	—	—
Field Trial 3	7	6.6%	—	2.8947	6	p 0.02 p 0.05	S
		—	17.1%	3.5330	6	p 0.01 p 0.02	S
Field Trial 4	10	4.4%	—	3.3613	9	p 0.002 p 0.01	HS
		—	14%	9.6932	9	p 0.001	VHS
All Trials	45	12.5%	—	6.9800	44	p 0.001	VHS
	35	—	26.5%	5.5439	34	p 0.001	VHS

* Key : VHS — Very Highly Significant
HS — Highly Significant
S — Significant
NS — Not Significant.

4. Discussion

In the natural fermentation of coconut toddy it appears that organic nitrogen in the form of amino acids acts as the main source of nitrogen for the yeast metabolism.[3] During the utilization of cysteine hydrogen sulphide is formed as a by-product which contaminates both toddy and the distilled product 'Arrack' giving rise to off-flavours. Furthermore, the ethanol yields obtained by the natural fermentation are usually far below the theoretical yields. The low efficiency of sugar utilization under normal conditions appears to be the main reason for this which is apparent by the high residual sugar contents observed. The supply of an alternative and an easily digestible source of nitrogen in the form of NH_4^+, as recommended by Jansz *et al*[2] appears to suppress the utilization of amino nitrogen by the wild yeast. As a result the formation of hydrogen sulphide is avoided, and the utilization of sugar is increased resulting in higher yields of ethanol.

In the field trials carried out to test this finding on a commercial scale as reported in this paper a mean increase of 26.5% in the total yield of ethanol and a mean increase of 12.5% in the ethanol content were observed. The significance of these increases on statistical evaluation showed to be very high. It was necessary in this study to express the increases in the ethanol yields in terms of both the total yield per field trial and the percentage ethanol content of the toddy. This was because the percentage ethanol content itself was inadequate to give a true picture due to dilution of the toddy by rain water on many occasions.

The high statistical significance of the observed trends in these experiments are important when the highly variable experimental conditions under which the field trials were conducted are considered. The higher increases in the alcohol yields observed in trials 1a and particularly in 1b may be attributed to the use of ammonium chloride in the form of a solution in these trials. However, comparative studies on the solubility and mixing of ammonium chloride in the toddy, when it is used as a solution or as a tablet, revealed that even in the form of a tablet ammonium chloride dissolved and mixed adequately in the toddy. Some of the main problems encountered in this study were:

(a) Inaccuracies caused by uneducated tappers in the estimation of the number of tablets or the volume of solution of NH_4Cl to be added to the collection pot on the basis of the expected volume of toddy.

(b) Adverse weather conditions mainly rainfall, which cause variation of sugar content of the sap, dilution of the toddy, etc.

The most attractive feature of the findings of this study is the financial benefits that could be achieved by the commercial implementation of the process. From preliminary calculations it has been shown that the successful commercial implementation of this process would bring about the following:

(a) An increase of 0.36 million proof gallons of ethanol per annum from the coconut toddy based distillation industries in Sri Lanka.

(b) A saving of Rs. 6.2 millions per annum in foreign exchange spent for the import of potable spirit.

(c) An increase of Rs. 6,350/- per annum per acre in the income from coconut toddy production.

The above figures were calculated on the following data and assumptions:

(i) Total production of coconut spirits/annum
= 1.47 million proof gallons

(ii) Increase in the ethanol yield by the use of the reported process = 25%

(iii) Total imports of rectified spirits = 1.5 million proof gallons/year (at the cost of Rs. 22/- per proof gallon)

(iv) Approximate volume of toddy/acre/day = 96 litres
price of NH_4Cl (Technical)/kg = Rs. 12.00
Cost of NH_4Cl tablets/acre/day = Rs. 6.60
Price of a gallon of coconut toddy (7% v/v alcohol) = Rs. 6.00

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Studies on the Toxicology of the Palmyrah Palm (*Borassus flabellifer* L.) Part III. Development of Malignant Lymphomas in Rats after Prolonged Feeding of Palmyrah Flour.

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Abstract: Palmyrah flour which is consumed by humans in some Asian and African countries, has previously been reported to produce acute and chronic toxic effects in rats. This report describes the characteristics of neoplasms which developed in rats which were either fed directly on a 20% flour diet or were the offspring of palmyrah fed females. Single or multiple malignant lymphomas of varying degrees of differentiation were the commonest tumour; their predominant location was the small intestinal mesentery. Thymic and pulmonary lymphomas and lymphomatous nodules attached to the spleen and kidney were also present in some of these cases. A cervical fibrosarcoma and an intra-abdominal tumour of possibly pancreatic origin were also included in this series. Hind limb paralysis was observed in three tumour bearing rats, one of which had an atrophic spinal cord. The toxic effects of this flour, notably aberrations of immune competence, are discussed in relation to the pathogenesis of these tumours with special reference to a possible aetiological role of C-type viruses.

1. Introduction

Feeding of flour from the young shoot of the palmyrah palm, which is consumed by humans in some Asian and African countries, was reported to produce hepatotoxic and neurotoxic effects in short term feeding experiments[1], hepatic veno-occlusion with hepatic fibrosis[15] and depression of humoral and cell-mediated immune competence[2] after prolonged feeding in rats. The partial purification of a neurotoxin from this flour was reported by Greig *et al.*[8]

During prolonged feeding trials for the investigation of a possible hepatocarcinogenic effect of this flour, it was found that malignant tumours, notably malignant lymphomas developed after 2 to 7 months of feeding of a 20% flour diet[1,6] terminally some of these tumours became infected.

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This report describes the characteristics of these tumours and discusses their possible pathogenesis together with their relevance to malignant lymphomas in rodents and in humans in Sri Lanka with special reference to aberrations in immune competence as a pathogenetic factor.

2. Experimental

2.1 Flour

Flour was obtained by grinding boiled and sundried, recently harvested shoots of the palm; the flour was stored at 4°C to prevent microbial spoilage. This flour showed no contamination with the commonly used agrochemicals (chlorinated hydrocarbons, organophosphorus compounds or paraquat) or with aflatoxin; nitrosamines and pyrrolizidine alkaloids were not detected in this flour.

2.2 Rats

Four batches of male, random bred, Wistar rats (150-200 g) were used, each batch having consisted of 10 test rats, free fed on a 20% flour-pellet powder mixture with water *ad lib.* and 5 control rats in each of the 4 batches, free fed on standard rat pellet powder with water *ad lib.* A total of 40 test rats and 20 control rats were thus used. Each cage housed 5 rats, test or control.

Included in this series, are 3 tumour bearing rats (No. 10, 17 and 18) which were not directly fed the flour diet but were the offspring of females which were fed the test diet during pregnancy in separate experiments. The offspring were fed normal rat pellets after weaning while the mothers were fed the normal diet after parturition.

2.3 Histology

Representative portions of the tumours and other organs were fixed in 10% formol-saline. Sections 5 μ in thickness, of paraffin blocks were stained with haematoxylin and eosin (H & E), reticulin stain and Gram's stain. With infected tumours, the walls of the abscesses especially at the sites of attachment, were examined microscopically for neoplastic tissue.

On account of the obscurity of the disease when first encountered, no specimens such as blood or bone marrow smears, lymph nodes, which were considered relevant in retrospect, were examined.

2.4 Ultrastructural studies

Multiple pieces of tumour from the abdominal and thymic lymphomas in rat N. 12 were processed in glutaraldehyde, osmium tetroxide and Epon for electron microscopy. These specimens were examined by Dr. Robert J. Huebner (National Cancer Institute, Bethesda, Maryland, USA).

2.5 Bacteriology

At necropsy done as soon as possible after death or under ether anaesthesia of moribund rats, the tumour was exposed aseptically; the pus from the 5 infected tumours was examined by Gram's and Ziehl-Neelsen stains and cultured on sheep blood agar which was incubated aerobically and anaerobically at 37^0 C for 2 to 3 days. Standard bacteriological tests[4] were used to characterise and identify the isolates.

3. Results

This series comprised 18 rats with tumours or abnormal histology which was suggestive of neoplasia. Of these, 15 rats from the 4 batches (40 rats) which were directly fed the test diet, developed tumours. The remainder of the test diet fed rats, died spontaneously without evidence of neoplasia. Three rats (No. 10, 17 and 18) were not directly fed the test diet but were the offspring of females which had been on the test diet during pregnancy in separate experiments, None of the control rats (nor stock rats in the animal facility) fed the same standard pellet diet developed neoplasia.

3.1 Time of appearance of tumours

The tumours were first detected between 2 and 7 months of the commencement of feeding of the test diet.

3.2 Location of tumours

The location and number of tumours in each of the 18 rats is shown in Table 1.

Except in 3 rats, the site of origin of the single and multiple intra-abdominal lymphomas was not obvious, although the mesenteric lymph nodes could have been the site of origin. These tumours were associated with the small intestinal mesentery and adherent to the adjacent viscera and intestines. In 3 rats, one lymphoma was retroperitoneal on the infrarenal posterior abdominal wall. In 2 other rats, single large lymphomas were diffusely adherent to the posterior abdominal wall in the paravertebral region.

3.3 Macroscopic appearances

The uninfected intra-abdominal lymphomas were thin walled, multinodular, cystic and haemorrhagic in some areas and solid in others, with marked vascularity in restricted zones. The large infected tumours had thick walled fibrous capsules and contained viscid or caseous yellowish pus; the haemorrhagic cysts contained brownish material.

The pulmonary lymphoma in rat No. 4 was a small well defined nodule within the lung tissue. In rat No. 18 the apical pulmonary lymphoma was confluent with the

thymic mass. An ill defined indurated area in the lung of rat No. 12 consisted of diffuse lymphoid cell infiltration.

Table 1. — The distribution according to site and number of tumours or lymphoid tissue abnormalities, in palmyrah treated rats.

Number, site and nature of tumour	Experimental number of rat
directly fed rats	
1 intra-abdominal lymphoma	1, 2, 3, 6, 7, 16
1 intra-abdominal lymphoma with 1 pulmonary lymphoma	4
1 intra-abdominal lymphoma with 1 lymphoma on ventral surface of base of heart	14
3 intra-abdominal lymphomas; 1 thymic lymphoma	9
4 intra-abdominal lymphomas; 1 on upper pole of right kidney, adherent to liver; 1 thymic lymphoma; a lymphoma on posterior thoracic wall	12
1 cervical lymphoma of obscure origin	5
1 axillary lymphoma of obscure origin	15
1 cervical fibrosarcoma (Figure 2) of ill defined origin	11
1 intra-abdominal tumour of possibly pancreatic origin	13
progeny of palmyrah fed mothers	
2 intra-abdominal lymphomas; 1 in gastro-splenic omentum	10
1 thymic lymphoma confluent with apical pulmonary lymphoma	18
abnormal thymic tissue	17

Table 2.— The Provincial incidence of malignant lymphomas in Sri Lanka (1973-1977). Total number of malignant tumours examined, 11844. Total number of malignant lymphomas 739.

Province	malignant lymphomas per 100,000 population
Northern	13.8
Southern	2.0
Western	22.8
Eastern	2.6
North Central	0
North Western	3.2
Central	3.3
Uva	5.1
Sabaragamuwa	3.4

The thymic lymphomas were solid, thin walled, well defined masses.

The intra-abdominal tumour of apparently pancreatic origin in rat No. 13 was a large (5 cm diameter) hard, fibrous, coarsely multinodular, non-infected tumour which in comparison with the intra-abdominal lymphomas was relatively vascular.

Serous pleural effusions were present in rat No. 12 with multiple (mesenteric, thymic and pulmonary) lymphomas and in rats No. 3 and 13; pleural and peritoneal effusions were present in rat No. 16.

Hind limb paralysis was present in 3 rats - No. 7 which had a single mesenteric lymphoma, No. 12 which had multiple intra-abdominal lymphomas together with a thymic lymphoma, and in No. 14. The spinal cord of the lumbar region was macroscopically atrophic in rat No. 12; the cords in rats No. 7 and 14 were not available for study.

3.4 Microscopic appearances

Intra-abdominal mesenteric lymphomas. A noteworthy feature of these tumours was the variation, between rats and within the tumour of an individual rat, of the degree of differentiation of the lymphoid cells, from poorly differentiated, large pleomorphic cells (Figure 3) with a large, indented, single nucleus and numerous mitotic figures, to smaller cells with scanty cytoplasm which were more typical of mature lymphocytes. Giant cells were occasionally present, especially in the less differentiated tumours. Five lymphomas had a predominantly lymphoblastic morphology while 6 had appearances of mixed (lymphoblastic and lymphocytic) patterns; one was predominantly lymphocytic. In 3 tumours with infection, a clear identification of the pattern from the residual lymphoid tissue, was difficult although neoplastic lymphoid cells were present in the wall. In two infected intra-abdominal tumours (rat No. 7 and 8) which were closely adherent to the posterior abdominal wall lymphoid cell infiltration into the muscle of the wall was noted.

Thymic lymphomas. These were multinodular with a thin fibrous encapsulation. The cortical-medullary pattern was replaced by a mass of lymphomatous cells; in some areas, the cells were pleomorphic, poorly differentiated and resembled lymphoblasts while in other areas, the cells were more differentiated, resembling lymphocytes. The overall appearances were those of a mixed cell lymphoma. There were areas of necrosis without haemorrhage or infection. Scattered giant cells were present.

In rat No. 17 the enlarged thymus had lost its normal architecture, which was replaced by well differentiated lymphomatous cells without evidence of infiltration. In rat No. 18 the thymus showed a normal histological pattern in some areas; in other areas which were confluent with the pulmonary lymphoma, bizarre cells with a pleomorphic morphology suggestive of lymphoblasts, were present.

Dr. Robert J. Huebner (personal communication) reported on the ultrastructure of the thymic lymphoma in rat No. 12 as ".....packed thymus tumour cells having no evidence of type-C virus".

Pulmonary lymphomas. In 3 rates (Nos. 4,9,16) the alveolar septa were diffusely infiltrated with lymphoid cells which were well differentiated and distinct from the peribronchial masses of lymphocytes seen in normal rats. One of the tumour bearing rats (No. 4) had a localised, 4 mm lymphomatous nodule in addition. The pulmonary lymphoma in rat No. 18 was poorly differentiated and had infiltrated the pulmonary veins. In rat No. 9 microscopic collections of lymphoid cells were present in the alveolar septa. Vascular congestion and alveolar oedema were noted in rat No. 8 and 13.

The lymphoma in the posterior thoracic wall of rat No. 12 was of the more differentiated lymphocytic type but more haemorrhagic than its abdominal counterpart, and had infiltrated the muscles of the thoracic wall (Figure 4).

Renal lymphomas. The lymphoma in the anterior pole of the right kidney in rat No. 12 had a mixed lymphoblastic-lymphocytic pattern with a predominance of more differentiated cells.

Fibrosarcoma. The single large fibrosarcoma in rat No. 11 (Figure 2) was a mesenchymal, malignant tumour with wide variations in histological appearances (Figure 5). In solid areas the tumour was vascular and cellular with large, elongated pleomorphic cells containing bizarre nucleii and many mitotic figures. Other areas were cystic with haemorrhages and necrosis without infection, and were more fibrotic. Infected areas showed a neutrophilic cell reaction.

The reticulin pattern was that of connective tissue with no evidence of an adenomatous structure. Cellular differentiation into fibroblasts with myxomatous change in the stroma was present in some areas. The peripheral blood smear showed a normoblastaemia with polychromasia of the red cells.

The liver. In rats Nos. 6, 12, 13, 14 and 15, the liver showed vascular abnormalities which were similar to those described in earlier reports[15] viz., central and portal venous subendothelial oedema or occlusion with fibrous tissue. In rat No. 12 which had 4 intra-abdominal lymphomas and a thymic lymphoma, well marked veno-occlusive reactions were present with extensive tracts of fibrous tissue which bridged portal tracts, with scattered areas of hepatocellular necrosis (Figure 6) and hyperplasia of the hepatocytes with multinucleated cells. Infiltration of the liver by lymphoblastoid cells was seen in rat No. 16.

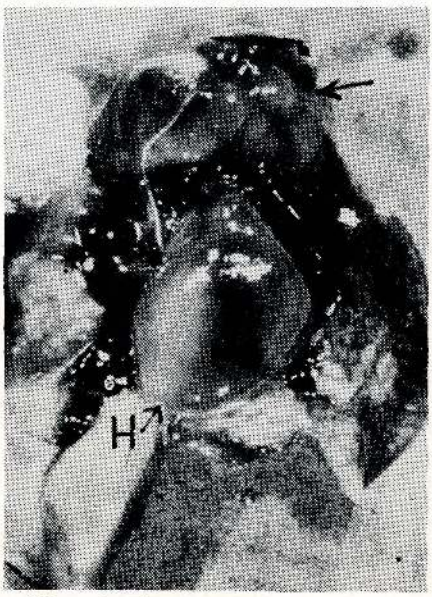

Figure 1. Thymic lymphoma (arrow) at base of heart (H) in rat No. 12.x 1.8

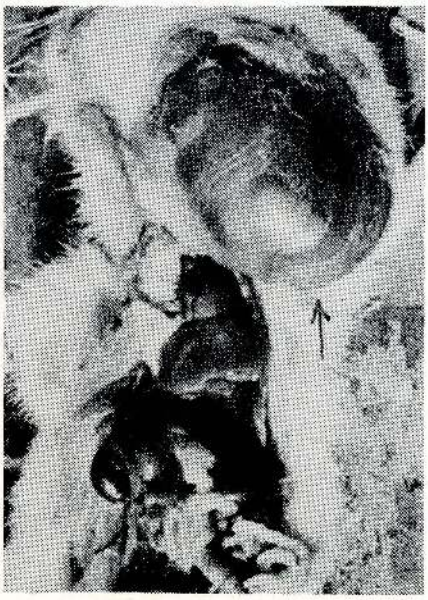

Figure 2. Cervical Fibrosarcoma (arrow) in rat No. 11. x 3/4.

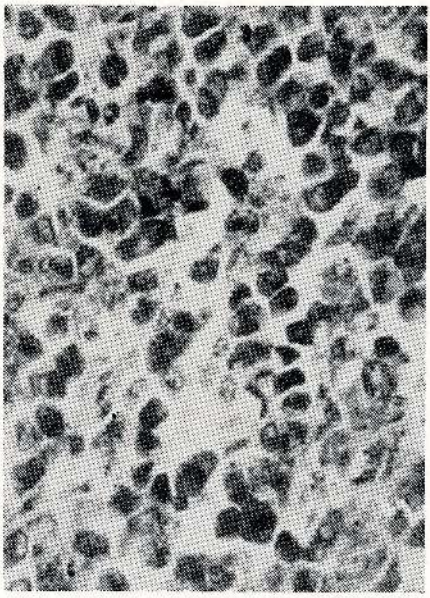

Figure 3. Poorly differentiated lymphomatous cells in single mesenteric lymphoma in rat No. 5. H&E, x 18000.

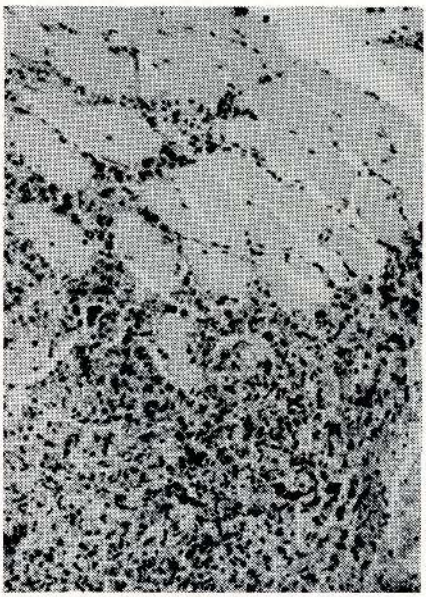

Figure 4. Site of attachment of pulmonary lymphoma to posterior thoracic wall, showing lymphomatous cell infiltration into muscle. H&E, x 210

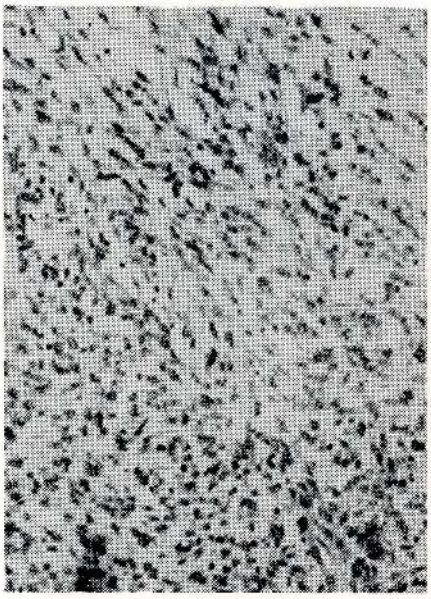

Figure 5. Uninfected cellular region of cervical fibrosarcoma of rat No. 11. H&E, x 210.

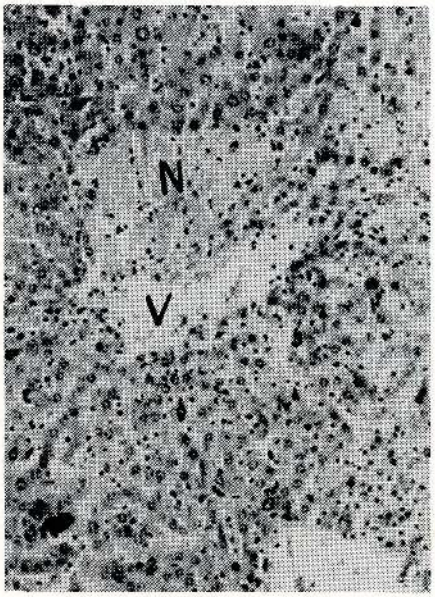

Figure 6. Commencing central venous occlusion (V) and hepatocellular necrosis (N) in rat No. 11. H&E, x 120.

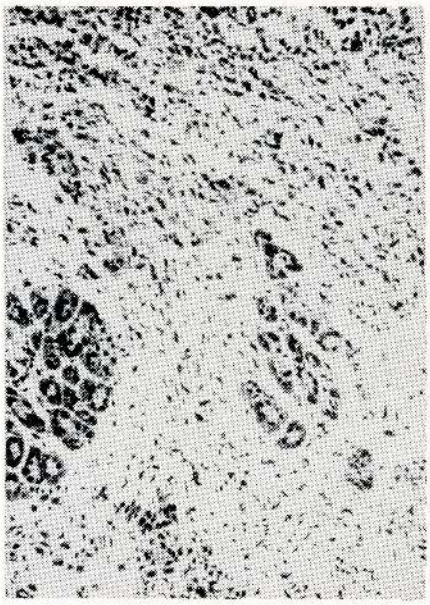

Figure 8. Loss of follicular pattern in spleen in rat No. 10 with 2 intra-abdominal lymphomas. H&E, x 100

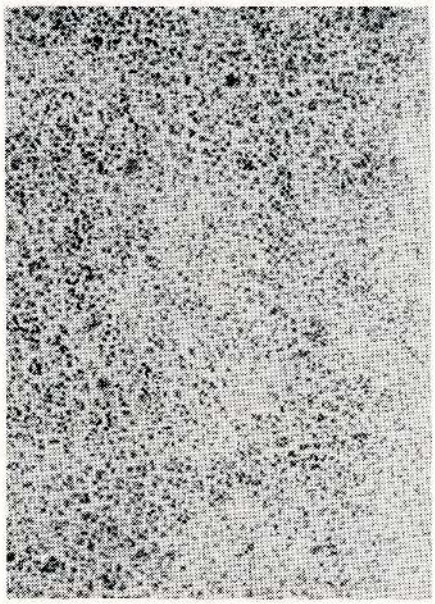

Figure 7. Lymphomatous cell infiltration into pancreas in rat No. 16. H&E, x 650.

The pancreatic tissue was infiltrated by lymphomatous cells in rat No. 6 (Figure 7).

The intra-abdominal tumour in rat No. 13 had a fibroadenomatous structure; proliferating acini, both tubular and solid were scattered in a densely fibrotic mass. The tumour was of uncertain origin although it bore some resemblance to the well differentiated pancreatic adenocarcinoma described and illustrated as 'Figure 5' by Roe and Roberts[21]; no evidence of cell infiltration was noted in our tumour.

Spleen. In rat No. 10, the large 8 cm infected lymphoma was accompanied by a small 1 cm lymphoma in the gastro-splenic omentum, closely attached to the spleen which itself was of normal dimensions. The spleen however showed loss of architecture (Figure 8) in most of its tissue which was replaced by large, poorly differentiated lymphoblastic cells.

Axillary lymphoma. In rat No. 15, the axillary lymphoma had no follicular pattern but consisted of a diffuse mass of mixed-lymphoblastic and lymphocytic-cells in equal proportions.

Bacteriology

Of 7 infected tumours, pus from 5 was available for bacteriological examination. Two yielded no bacterial isolate. Pus from the solitary lymphoma in the neck of rat No. 5, yielded *Klebsiella aerogenes* as did one intra-abdominal lymphoma in rat No. 7. An unidentified *Corynebacterium* species was isolated from one of the mesenteric lymphomas in rat No. 9.

4. Discussion

Spontaneous lymphocytic neoplasms, described as rare in rats[3] have been reported in experimental and wild rats and their occurrence is regarded as strain and colony dependent.[28] The latter authors reviewing the literature on lymphoid neoplasms in the rat reported that the intra-abdominal location was common with lymphosarcoma in Wistar rats, many of them arising in the ileocaecal mesentery. The histological appearances of lymphocytic lymphomas (lymphosarcomas) in the rat as reviewed by Swaen and van Heerde[28] are similar to those in our tumours including the variation in their differentiation from lymphoblastic to lymphocytic with mixed appearances even in the same animal. No splenic tumours were noted in our animals; this compares with reports[13] that the spleen is not involved in chronic rodent lymphomas in contrast to myeloid leukaemias.

Data on the development of malignant lymphomas in humans and animals, naturally or experimentally, suggests several possible pathogenetic mechanisms for the induction of lymphomas in our rats.

(i) The predominance of lymphoreticular tumours amongst the mesenchymal neoplasms in immunodeficient hosts[18,27] led to a modification of the concept of immunosurveillance and its corollary that immunodeficiency predisposes to neoplasia, to regard disordered immunoregulation as the operative mechanism. This view[20,23] considered that in the presence of partial immune-suppression, persistent antigenic stimulation induces lymphomas *via* viral activation and proliferation of transformed lymphocytes.[11,24,26] Habeshaw[9] regarded non-Hodgkin lymphomas as representing abnormal immune responses (see also [14,25]).

In a brief communication Panabokke and Arseculeratne[16] hypothesised that the lymphomas in palmyrah fed rats and their secondary infection resulted from immunosuppression produced by the toxic constituents of the flour. Arseculeratne *et al.*[2] reported aberrations of the immune competence of rats, after 7 and 32 weeks of feeding of a 25% palmyah flour diet. In 7 week fed animals, a depression of humoral and cell mediated immune competence was found; after 32 weeks some rats (Arseculeratne, unpublished data) showed a depression while others showed enhanced humoral and cell mediated responses. Augmentation of humoral responses as found in rats after 32 weeks of palmyrah feeding could conceivably produce antibody or immune complex mediated enhancement of tumours;[10,27] see also.[5] This differential response (enhanced humoral or cell mediated reactions or their depression) may explain the development of malignancy in only some of the test animals of the present series.

Swaen and van Heerde[28] referred to an association between chronic infections as an initiating event and lymphocytic tumours in rodents. In our rats, the chronic infection *supervened* on advanced tumours and was not a determinant or precedent of the tumours; they were probably opportunistic infections with an immunodepressed state. On the other hand, in relation to a possible source of persistent antigenic stimulation as a synergistic factor with disordered states of immune competence in the development of neoplasia, we can only speculate that the chronic hepatic lesions which we have earlier described in palmyrah fed rats (and which we found in some of the tumour bearing rats of the present series) could have resulted in a diminished capacity of the Kupfer cells to sequester antigens from the intestinal tract or to the release of antigens after liver damage [6]

(ii) An alternative hypothesis for the origin of our lymphomas is the activation of latent endogenous viruses by the chemical constituents of the flour as has been suggested of some chemical leukemogens.[13] Gardner *et al*[7] described a C-type virus disease in wild mice, which bears some resemblance to that in our rats - the predominance of malignant lymphomas, the development of fibrosarcoma, hind limb paralysis and spinal cord degeneration. The acute neurotoxic effects produced by palmyrah flour are attributable to its neurotoxin.[8] Although the chronic neurotoxic effects, if any, of this neurotoxin are as yet unknown, it is possible that the hind limb paralysis in addition to the tumours were a part of the disease induced by C-type viruses. Dr. Huebner commented on the absence of ultrastructural evidence of C-type viruses in the thymic lymphoma of rat No. 12 as follows: "The absence of rat Type-C virus is not unusual in carcinogen induced cancers. The rat virus is expressed after 15 or 20 subtransplants into new syngeneic hosts. When cultured *in vitro* the rat virus may appear in the cells after 20 or more subcultures."

The development of lymphomas in the progeny of our palmyrah fed females is consistent with reports of vertical transmission of murine leukemogenic viruses[13], either through gonadal tissue or milk.

(iii) It has also been suggested that chromosomal damage may be an alternative mechanism for the induction of neoplasms by chemical agents.[17] The immunosuppressive agents azothiaprine and 6-mercaptopurine which increase host susceptibility to neoplasia are also known to cause chromosomal damage. In view of the clastogenic effect of palmyrah extracts on human lymphocytes,[12] this mechanism would also remain a possibility in our flour induced tumours.

While it is difficult to identify one mechanism as the basis of the pathogenesis of our lymphomas, it is perhaps more likely that several factors such as aberrations of immune competence, the activation of C-type viruses and clastogenic activity were synergistically involved.

Of what significance are our findings to the human situation? It is in the Northern Province of Sri Lanka that this palm is most extensively grown and its flour consumed. From a study of the geographic pathology of malignant disease during a 5-year period (1973-1977) in Sri Lanka, Panabokke (1980 - unpublished data) found the incidence of malignant lymphomas in the 9 provinces of this country, as shown in Table II. Excluding the data from the Western Province which has the country's

only cancer hospital- data from which may therefore be biased- it appears that the incidence of malignant lymphomas in the Northern Province is approximately 4 times higher than the mean incidence in the 7 other provinces. The natural environmental radiation levels in the Northern Province are not higher than in the rest of the country and the possibility remains to be investigated that the relatively higher incidence of malignant lymphomas in this province is aetiologically related to the high consumption of palmyrah flour, a situation which parallels that in our experimental rats. Plouffe *et al*[19] reported immune suppressive effects of a lectin from the navy bean and noted a clustering of cases of Hodgkin's lymphomas in humans living in the vicinity of a navy bean processing mill.

Acknowledgements

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Effects of Restricting Water to Growing, Lactating and Pregnant Buffaloes Reared in a Hot and Humid Environment

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Abstract: An experiment was carried out to examine the effects on certain physiological indices of heat stress in buffaloes subjected to restriction of water in a hot (Air temperature = 27.6 - 32.8°C) and humid (Relative humidity = 62 - 84%) environment. Five each of growing (Mean age = 10 months), lactating (Mean milk yield = 5 litres/day) and pregnant (8 - 9th month of gestation) Surti buffaloes were grazed under young coconut palms and subjected to three treatments in successive periods, each of three week duration. Each treatment was imposed on all groups of animals simultaneously. In treatment I referred to as the normal management, animals were allowed drinking water *ad libitum* and wallowed for 1.5 hours daily. In treatment II wallowing was denied, and treatment III comprised restriction of drinking water in addition to denial of wallowing. Thermal stress was monitored by measuring rectal and skin temperature, respiration, pulse and cutaneous evaporation rates of each animal several times a day.

All physiological variables studied showed a progressive increase from 0700 hours till 1400 hours and declined towards 1800 hours. The time effect was very highly significant ($P < 0.001$). Under normal management, growing heifers were found to be more stressed than the adults. Denial of wallowing and restriction of drinking water caused an aggravation of heat stress with an average elevation of 0.9 - 1.2°C in rectal temperature and 16 - 18 respirations per minute at mid day over their respective base values. No significant group difference was observed during the latter treatments. The average rate of cutaneous evaporation of 310 ± 15 during treatment I decreased to 271± 15 g/m²/hour in treatments II and III. Heifers generally showed a lower rate of cutaneous evaporation and higher rate of respiration.

The results indicate that despite shade the buffaloes suffered from heat stress as the ambient temperatures increased. Lack of wallowing and restriction of drinking water aggravated the stress. Young animals were possibly more dependent on the pulmonary route for evaporative cooling. Adult buffaloes did show a capacity to lose moisture through the skin at rates comparable to those of zebu cattle.

1. Introduction

Buffaloes in general, show a greater affinity to water than other domestic ruminants. It is believed that the habit of wallowing in water or in wet mud plays a crucial role in the dissipation of excess body heat, while drinking water is also known to play somewhat a

lesser role in thermal regulation. Tropical regions frequently encounter periods of drought when supply of adequate water becomes a problem. The combined effects of hot and humid environments of the tropics and scarcity of water may act as a limiting factor to the survival and productivity of buffaloes maintained in such environments. In view of the envisaged plans to utilise buffalo as a major source of milk and draught power in Sri Lanka, a complete understanding of the interactions of the buffalo with the tropical environment should prove useful. The present study was undertaken to study the effects of restricting water, both for wallowing and drinking, under hot-humid conditions to growing, pregnant and lactating buffaloes of a recognised dairy breed.

2. Materials and Methods

Animals used in the experiment were chosen from the herd of Surti buffaloes on the National Livestock Development Board Farm at Melsiripura. They comprised five each of growing heifers (average age = 10 months, weight = 140 kg), pregnant (mean age = 8 years, weight = 387 kg and in 8th to 9th month of gestation) and lactating (mean age = 8 years, weight = 344 kg and yielding 5 litres of milk per day) cows.

Animals were grazed continuously on cultivated pasture — *Brachiaria miliformis* under young coconut trees which intercepted approximately 70% of the solar radiation. They were also supplemented with cut grass in the night. Lactating animals only were provided with supplementary concentrate feed. Milking was done twice daily at approximately 12 hour intervals. Except when required as a part of the experimental treatment animals had continuous access to drinking water provided in a trough and were also wallowed in a lake between 1430 and 1600 hours each day.

Animals were subjected to the following three treatments, each treatment imposed on all 3 groups simultaneously.

Treatment I:—

All animals were managed as described above; they were allowed drinking water *al libitum* and wallowed for 1.5 hours daily.

Treatment II:—

Same as above but they were not allowed to wallow.

Treatment III:—

Animals were not allowed to wallow. In addition water for drinking was restricted by offering only every other day.

Each of the treatments I and II lasted three weeks while the duration of treatment III was 4 weeks. Measurements were made during the last two weeks allowing one week for adjustment for Treatments I and II and 2 weeks of adjustment in the case of Treatment III.

The following measurements were made on each animal in each treatment at 700, 900, 1200, 1400 and 1800 hours. Rectal temperatures were measured by means of a clinical thermometer and respiration rates by counting flank movements. Skin

temperature was measured on the belly about 7 cm lateral to the mid line using an electric thermometer with a touch thermocouple. Cutaneous evaporation rate was ascertained from a clipped patch on the dorsal lumbar region by using cobalt chloride impregnated paper discs according to Schleger and Turner.[13] On standardising the technique it was found that 11.2 g water/ m^2 paper were required to change the colour of the disc from violet to bright rose.

Respiration rates were measured before disturbing the animals. Thereafter, each animal was tied to a coconut tree and the balance measurements were made, the rectal temperature being taken last. Within a few days, the animals settled down to the procedure and showed no signs of excitement.

Analysis of data

Separate analyses were performed within each treatment-period to ascertain the effects of time of observation within treatment.

Data from each time of observation were subjected to analysis as a split plot in accordance with Gill and Hafs[5] for repeated measurements on the same animal. The model used in this instance included the effects of groups of animals, treatment and group x treatment interaction. Group and treatment means in each case were compared according to Duncan's multiple range test.

3. Results

The ambient temperature and humidity levels that prevailed at the location of the experiment during the study period are presented in Table I. It will be seen that the climatic conditions were not subjected to much variation across 3 treatment periods. The Group — Treatment — Time of day sub class means of the different physiological variables are given in Tables 2 and 3. In all treatments rectal and skin temperatures, respiration, pulse and cutaneous evaporation rates showed a progressive increase up to 1400 hours and showed a decline at 1800 hours (Figures 1 a to 1 e). The time effect was significant ($P < 0.001$) on all variables (Table 4). Although the measurements relate to fixed times of the day, in effect they could be related to variation in environmental temperature and humidity. It is in terms of the latter that the results will be discussed.

3.1 Rectal temperature

Rectal temperature of growing heifers was found to be generally higher than that of adult cows. In Treatment I, heifers also recorded a significantly greater elevation of rectal temperature. There was no significant treatment effect on the base values of the groups. With the restriction of water, although the heifers continued to record higher temperatures at any given time the elevation at higher air temperature was less (0.8%C) than those of pregnant and lactating cows (1.2%C).

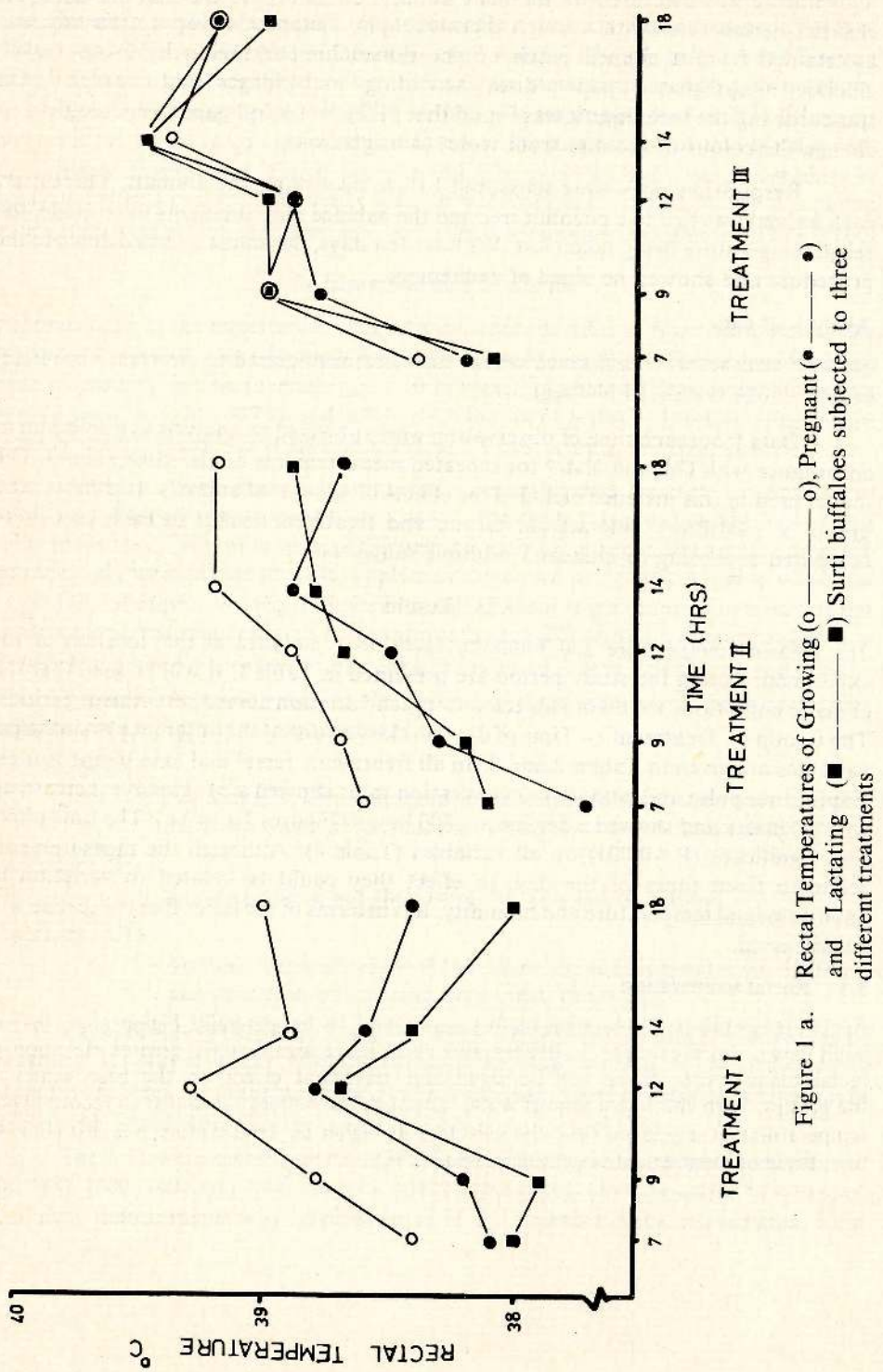

Figure 1 a. Rectal Temperatures of Growing (o ——— o), Pregnant (● ——— ●) and Lactating (■ ——— ■) Surti buffaloes subjected to three different treatments

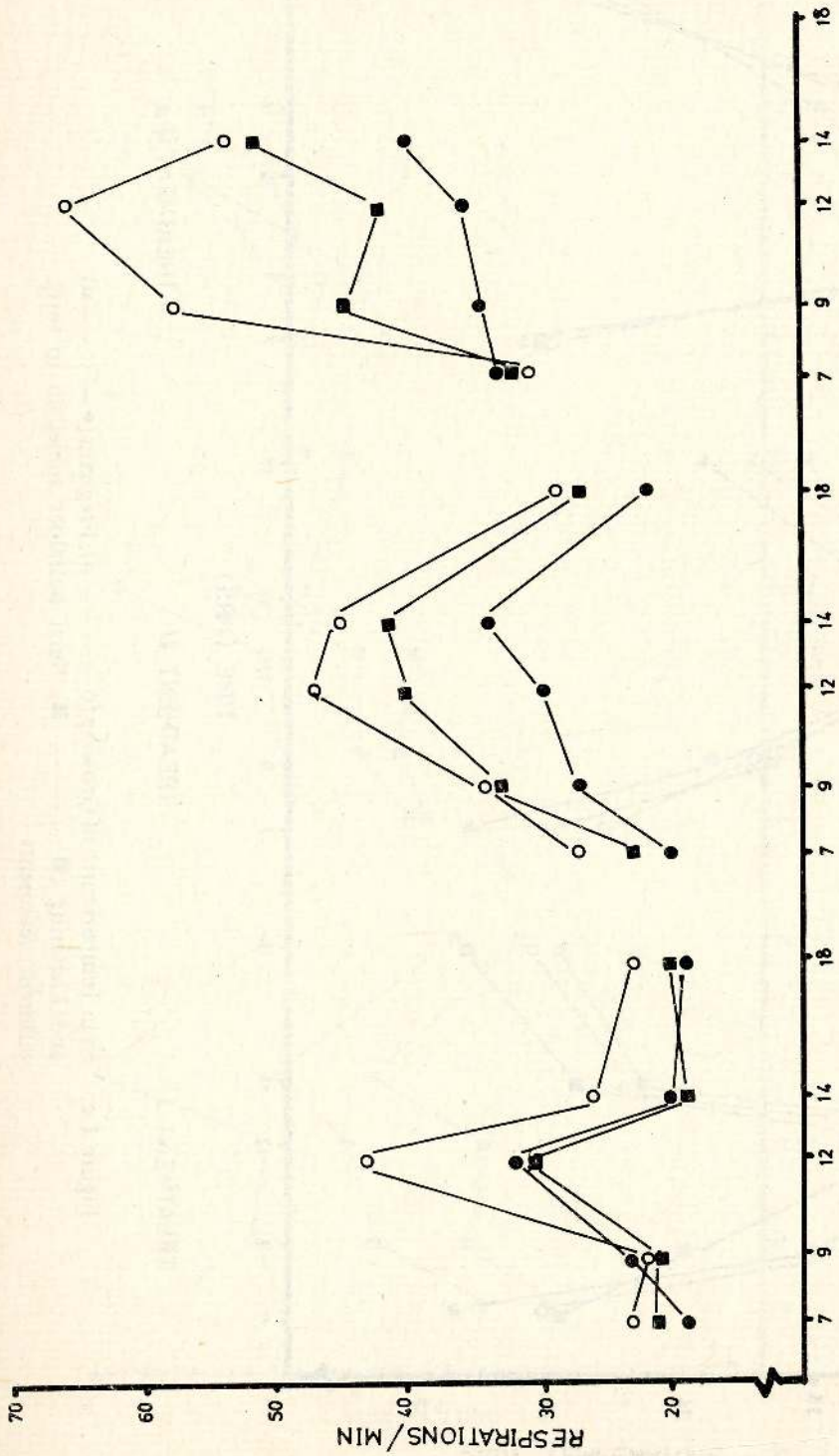

Figure 1 b. Respiration Rates of Growing (o ——— o), Pregnant (● ——— ●) and Lactating (■ ——— ■) Surti buffaloes subjected to three different treatments

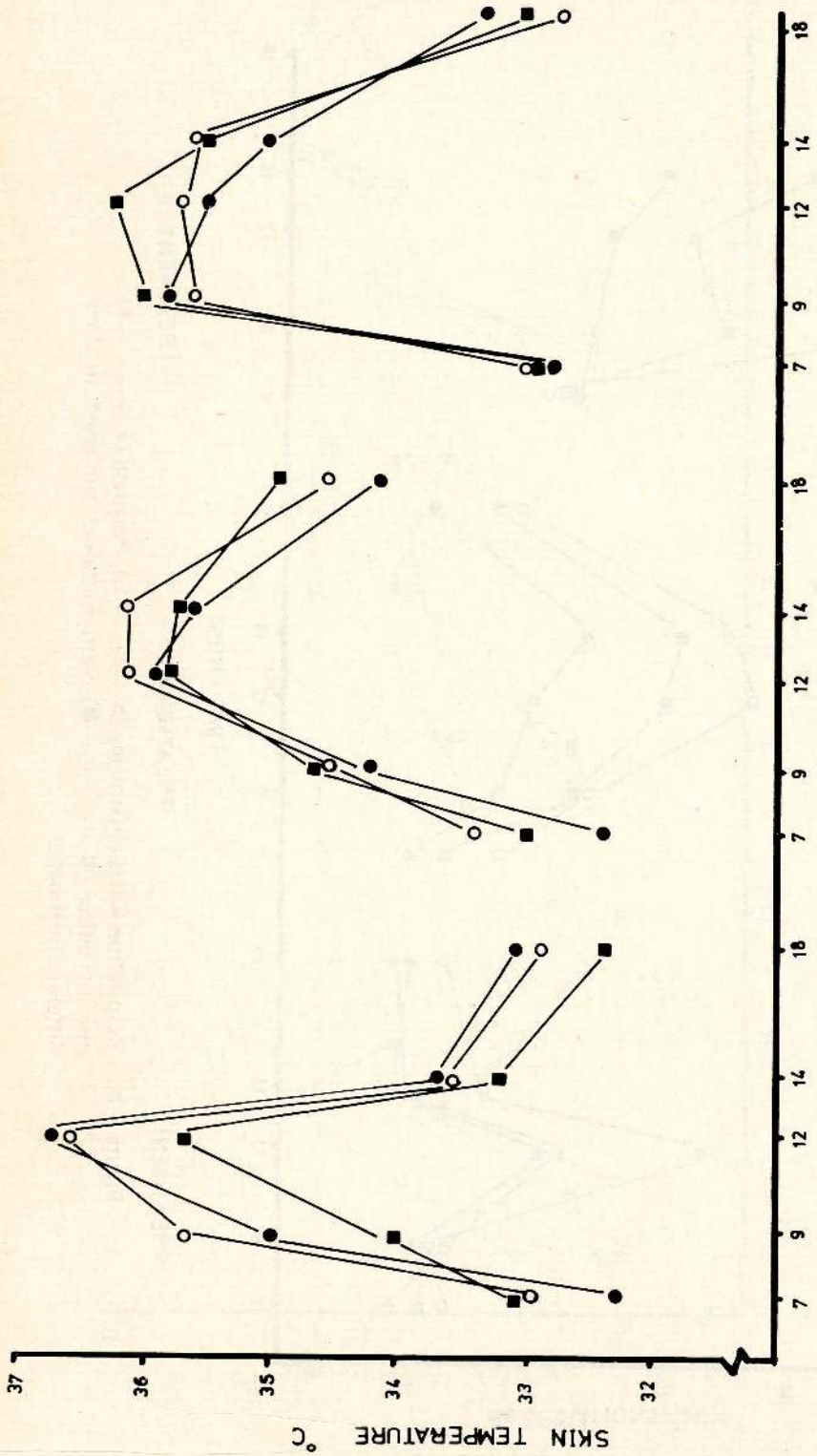

Figure 1 c. Skin Temperatures of Growing (o ——— o), Pregnant (● ——— ●) and Lactating (■ ——— ■) Surti buffaloes subjected to three different treatments

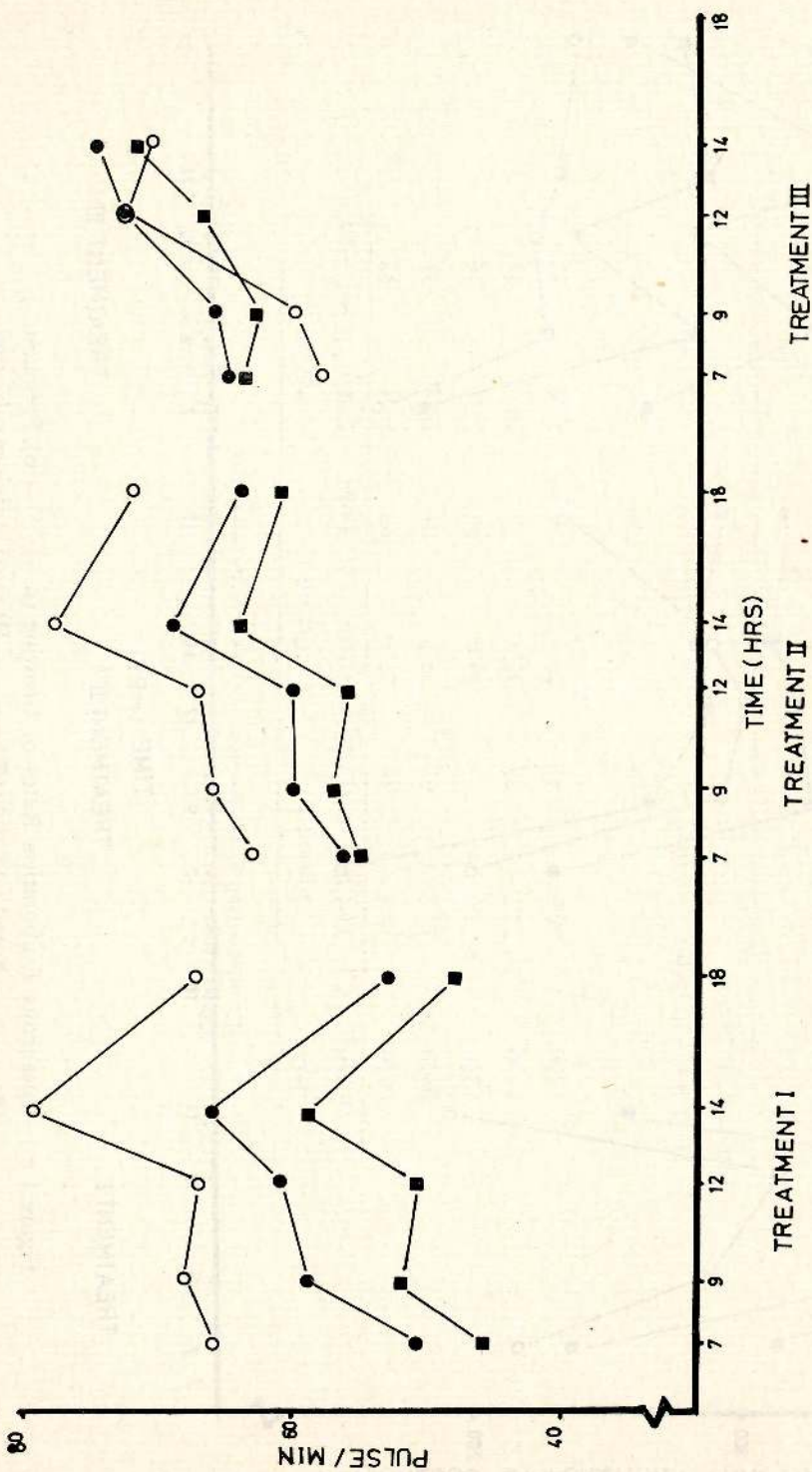

Figure 1 d. Pulse Rates of Growing (o ——— o), Pregnant (● ——— ●) and Lactating (■ ——— ■) Surti buffaloes subjected to three different treatments

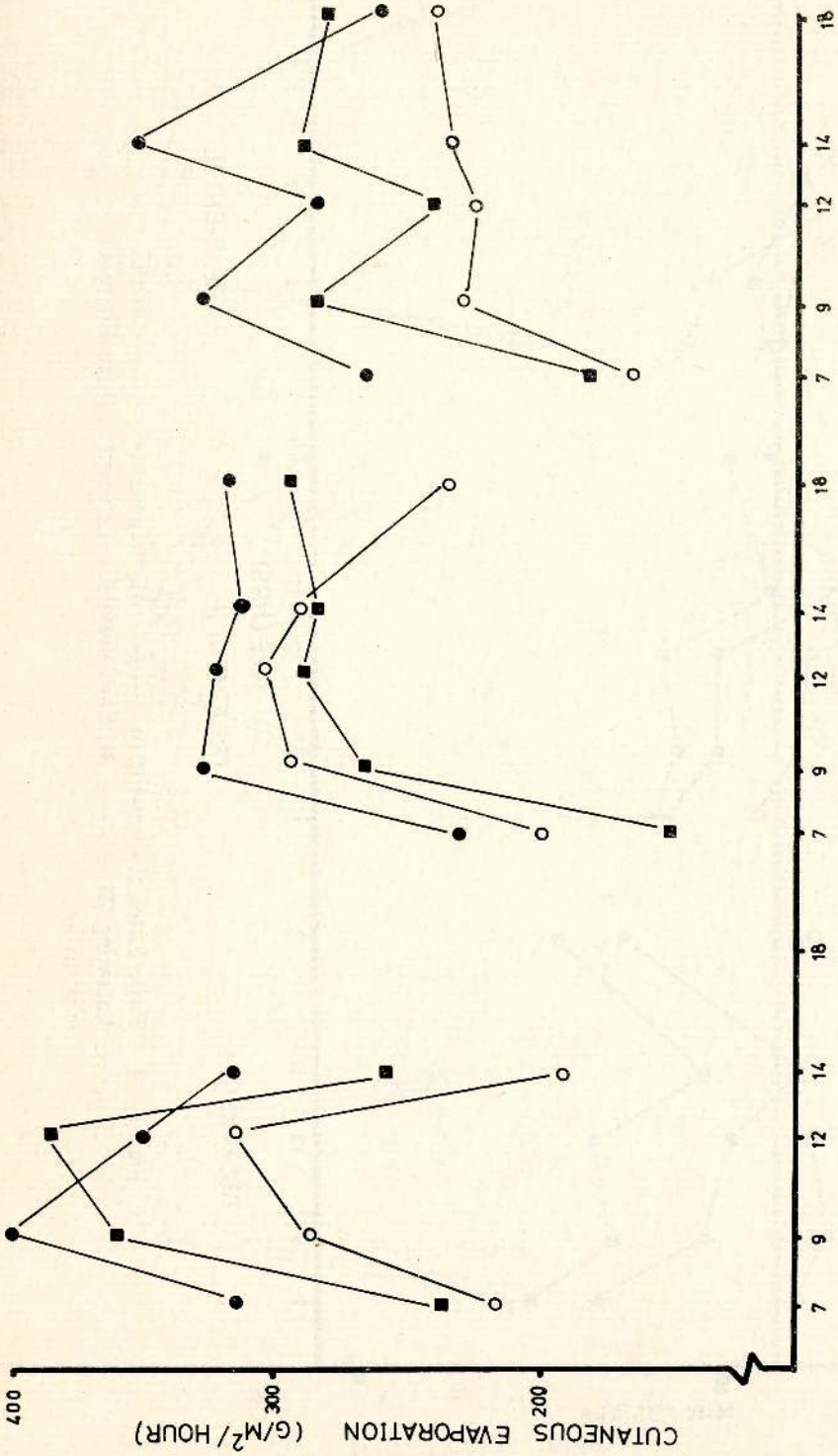

Figure 1 e. Cutaneous Evaporation Rates of Growing (o ——— o), Pregnant (● ——— ●) and Lactating (■ ——— ■) Surti buffaloes subjected to three different treatments

Table 1. Mean air temperature (T) and relative humidity (R.H.) at different times of the day together with total rainfall in each treatment — period of the experiment

time	Period I		Period II		Period III	
(hours)	T(°C)	R.H.(%)	T(°C)	R.H.(%)	T(°C)	R.H.(%)
0600	28.5	86	27.1	90	27.4	77
0900	31.7	67	29.3	81	30.8	71
1200	33.0	63	33.6	58	31.8	64
1500	33.7	52	30.2	73	30.0	71
1800	30.0	81	29.1	74	28.9	82
Total Rainfall (mm) during the period	108		118		70	

Table 2.– Mean Respiration, Pulse and Cutaneous evaporation rates of lactating (L) pregnant (P) and growing (G) buffaloes at different times under three (I, II, and III) treatments.

Time of day	Group of animals	Respiration/Min			Pulse/Min			Cutaneous evaporation g/m²/hr		
		I	II	III	I	II	III	I	II	III
0700	L	21.4	22.6	31.6	46.4^{x}	55.0^{x}	63.8	234^{x}	148	182^{x}
	P	19.4	20.0	32.8	50.6^{x}	56.2^{xy}	65.2	315^{y}	228	266^{y}
	G	22.6	26.8	31.8	66.2^{y}	63.4^{y}	58.0	214^{x}	200	164^{x}
0900	L	21.4	33.4	44.4	52.0^{x}	57.0	63.2	361	265	286^{xy}
	P	22.6	27.4	34.4	59.2^{xy}	59.8	65.8	402	332	330^{x}
	G	22.1	34.2	57.8	67.6^{y}	65.8	59.6	284	295	228^{y}
1200	L	30.8	39.6^{xy}	42.2^{x}	51.4^{x}	56.4^{x}	67.4	385^{x}	290	240
	P	32.0	30.4^{x}	35.8^{x}	61.0^{y}	59.6^{xy}	73.4	350^{xy}	327	285
	G	43.0	47.2^{y}	66.2^{y}	67.2^{y}	67.2^{y}	73.0	315^{y}	305	225
1400	L	19.4	40.8	51.6^{y}	58.8^{x}	64.4^{x}	72.0	257^{xy}	286	290^{xy}
	P	20.2	34.0	40.2^{x}	65.6^{x}	68.6^{x}	75.4	315^{x}	315	355^{x}
	G	26.2	45.0	54.0^{y}	80.2^{y}	77.6^{y}	71.0	192^{y}	287	235^{y}
1800	L	19.4	27.0^{xy}	NR	47.8^{x}	61.0^{x}	NR	NR	295^{x}	281
	P	19.0	22.4^{x}	NR	53.4^{x}	64.4^{xy}	NR	NR	320^{x}	260
	G	22.5	28.6^{y}	NR	67.3^{y}	72.4^{y}	NR	NR	235^{y}	242
Pooled s.e. of mean			3.6			2.9			15	

Figures with different superscripts within treatment – time sub class are significantly different ($P<0.05$)

Table 3. Mean rectal and skin temperatures of lactating (L), Pregnant (P) and Growing (G) buffaloes at different times under three (I, II and III) treatments.

Time of day	Group of animals	Rectal temperature ^{0}C			Skin temperature ^{0}C		
		I	II	III	I	II	III
0700	L	38.0^{x}	38.1^{x}	38.1	33.1^{x}	33.2	32.9
	P	38.1^{xy}	37.7^{y}	38.2	32.3^{y}	32.4^{y}	32.8
	G	38.4	38.6^{z}	38.4	33.0	33.4	33.0
0900	L	37.9^{x}	38.2^{x}	39.0	34.0	34.6	36.0
	P	38.2^{x}	38.3^{xy}	38.8	35.0^{xy}	34.2	35.8
	G	38.8^{y}	38.7^{y}	39.0	35.7^{y}	34.5	35.6
1200	L	38.7^{x}	38.7	39.0	35.7	35.8	36.2
	P	38.8^{xy}	38.5	38.9	36.7	35.9	35.5
	G	39.3^{y}	38.9	38.9	36.6	36.1	35.7
1400	L	38.4^{x}	38.8^{x}	39.5	33.2	35.7	35.5
	P	38.6^{xy}	38.9^{xy}	39.5	33.7	35.6	35.0
	G	38.9^{y}	39.2^{y}	39.4	33.6	36.1	35.5
1800	L	38.0^{x}	38.9^{xy}	39.0	32.4	34.9	33.0
	P	38.4^{y}	38.7^{x}	39.2	33.1	34.1	33.3
	G	39.0^{z}	39.2^{y}	39.2	32.9	34.5	32.7
Pooled s.e. of mean			0.13			0.30	

Figures with different superscripts within treatment – time sub class are significantly different ($P<005$)

3.2 Skin Temperature

The mean basal skin temperature across groups and treatments was 30.0 ± 0.3%C. Except for a significantly lower temperature of the pregnant animals in treatments I and II skin temperature did not differ among groups or treatments at any of the times. There was also a significant group x time interaction showing that the magnitude of change with time was not uniform across groups.

3.3 Respiration

In Treatment I and II the basal respiration rate averaged 22/minute with no significant differences among groups. Denial of wallowing together with deprivation of drinking water caused the basal respiration rate to increase significantly (Mean = 32/min). Heifers had higher rates at higher temperatures. Treatments had no significant effect on the elevation of respiration rates at higher air temperatures. Groups differed significantly in the rise of respiration rates in Treatment III in the order heifers > lactating > pregnant cows.

3.4 Pulse

A significantly higher pulse rate was observed in heifers (Mean = 65.3) compared to adults (Mean = 52.0) in treatments I and II only. A significant rise in the basal pulse rate of the adults, indicating a group x treatment interaction, resulted in the elimination of the group differences in treatment III. Heifers also showed a greater elevation at higher air temperatures. This difference in elevation was significant only at 1400 hours in treatments II and III.

3.5 Cutaneous evaporation

Base values of cutaneous evaporation in treatment I and II showed a significant ($P < 0.01$) group difference with pregnant cows having a higher rate than either lactating cows or the growing heifers. However, at higher air temperatures it was seen that the two adult groups lost significantly ($P < 0.01$) greater amounts of moisture through the skin than the heifers. Restriction of water caused a general decline in the rates of cutaneous evaporation in all three groups.

4. Discussion

Shade is considered to be an important factor in ameliorating climatic stress in buffaloes. However, as reflected by rectal temperature and respiratory responses it was evident that the animals in this study, despite some protection from direct sunlight, were subjected to thermal stress as the environment became warmer.

Evaporation of water through pulmonary and cutaneous routes is known to play a significant role in heat loss[3] in mammals, while Pandey and Roy[12] considered respiratory evaporation to be of greater importance than other mechanisms in

maintaining heat balance in buffaloes. The observed changes in the different physiological parameters in association with changes in air temperature and humidity are therefore to be expected, and agree with those reported for cattle and buffaloes [8,9] exposed to sun at comparable air temperatures.

Trends in rectal temperature and respiration rates in the heifers under normal management (Treatment I) would indicate that they were less efficient in overcoming heat stress. Pal[11] and Asker, Ragab and Ghany[2] have concluded that buffalo calves suffer much more from heat than adults do. However, it has been shown that the increase in heat tolerance of adults is interrupted by lactation and pregnancy. [1,2] Enhanced heat production due to increased metabolism in the latter categories of animals make them more vulnerable to heat stress. Our results, therefore are at variance from expectations. Conditions in treatment I probably had only mild effects for it was seen that the trend reversed in treatments II and III resulting in the adults being equally or much more stressed than heifers.

It is believed that buffaloes have a poor capacity to sweat due to a relative paucity of sweat glands. Hafez, Badreldin and Shafei[6] calculated the area of glandular surface per unit area of skin to be only a third of that in cattle. Nevertheless, rates of cutaneous evaporation in Murrah buffaloes almost similar to certain breeds of zebu cattle have been observed at air temperatures of 40°C.[7] The rates recorded in our study are similar to those of the above study but higher than those of swamp buffaloes reported by Moran.[10] In this context it is also noteworthy that the site of measurement in the present study — the dorsal lumbar region is noted to be the area with the lowest density of sweat glands in the buffalo[6] whereas Moran[10] measured in the shoulder region which has a much greater density. Furthermore our observation of a lower rate of moisture loss in the heifers is in contrast with the reports that the sweat gland density, and therefore the sweating capacity in buffalo decrease with age.[9] Genetic differences of the animals used, differences in site of measurement and in environmental conditions are likely factors responsible for the inconsistencies. However, it is also possible that all of the moisture was not due to true sweating but partly due to insensible loss of moisture by diffusion through the epidermis. Latter has been recognised to contribute significantly to moisture loss in a variety of animals.[4] The decline in cutaneous evaporation associated with restriction of water may also support this explanation. Buffalo calves have a relatively more hairy coat. It is possible that diffusion of moisture is therefore, interfered with to some extent unlike in the adults, and the pulmonary route assumes greater importance in evaporative cooling in the heifers. This may explain the lower rate of cutaneous evaporation and higher respiration rates in the heifers.

It was readily apparent that denial of wallowing caused the lactating and pregnant animals to be more stressed whereas heifers were affected to a lesser extent.

Data on water metabolism showed that there was a dramatic increase in water turnover rates during this period (Ranawana, Tilakaratne, Srikandakumar, unpublished data). This was probably due to increased water intake as an attempt to compensate for the lack of wallowing. Apparently it did not help the animals to a notable degree. Thus the results underline the importance of wallowing to the buffalo as a means of cooling themselves.

In treatment III, when drinking water was restricted along with decline of wallowing it was seen that the heat tolerance was further affected and thermal stress aggravated, no doubt part of it was due to carry over effect from Treatment II. It must also be borne in mind that there is some confounding of treatment effects with the physiological status of particularly the lactating and pregnant cows. The advancing foetus of the pregnant animals would be expected to cause additional heat load while the milk yield of lactating cows was likely to decline with advancing stages of lactation resulting in a lesser heat load. In fact a progressive drop in average milk yield was observed (Period I = 5.24, II = 3.68 and III = 2.39 L/day) with the treatment differences being significant ($P < 0.01$). This decline, however, was evidently brought about by treatment effect since it was noted that the milk yield began to increase a week after the termination of the trial. The effects on milk yield were probably due to reduced feed intake as a result of thermal stress.

Surti is a breed of buffaloes developed in the North Western regions of India where the climate is extreme in both winter and summer. The present results however would indicate that this breed is not well adapted to an environment of high air temperature and humidity. This aspect needs to be considered in the choice of breeds of buffaloes for rearing under such conditions. Climatic stress was aggravated by denial of wallowing and restriction of drinking water which underlines the need for provision of facilities for wallowing or any other means of wetting. Another notable finding of the present study is that in contrast to the accepted concept, buffaloes do lose a significant amount of moisture through the skin. This capacity is relatively less in young animals in whom pulmonary evaporation seems to be more important.

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Mathematical Model of Filariasis

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Abstract: A model of man-parasite-mosquito interaction in filariasis is formulated with a system of differential and integrodifferential equations. The model predicts that when the product of population densities of human beings and mosquitoes exceed a critical value, the system becomes unstable and the number of infectives begins to increase exponentially with time approaching an asymptotically stable equilibrium. When this product is less than the critical value, the starting point is asymptotically stable and the number of infectives decreases exponentially with time. It is suggested that because of the varying weather conditions, the disease does not progress very far in the direction of either of these asymptotic equilibria. Data on incidence of filariasis in the southern coastal belt of Sri Lanka is presented to support the model. The implications of the model on eradication of filariasis is discussed.

1. Introduction

Filariasis is a world health problem. Vast regions of Asia, Latin America, Africa and the Pacific have become a permanent habitat for the disease. Although mosquito control programmes and chemotherapy is reducing its incidence in some areas, the complete eradication seems to be difficult.[4,5,6,11,12]

The life cycle of the filarial parasite is well known.[2,5] The definitive host is man, adult worms harboured in the lymphatic system discharge microfilariae into the blood stream. The intermediate host is a mosquito, in which the microfilariae taken with a blood meal from the definitive host undergo further development and reach the infective stage in 10 - 20 days. When the infective larvae are inoculated into a human being, the sexually matured worms are developed after an incubation period of 6 - 12 months. Here the host-parasite interaction is considerably different from that in malaria.[9] Again in filariasis the immunity to the parasite is low[4] and even with drug treatment, the rate of removal of the infectives is small. In this investigation we take these facts into account and construct a mathematical model of filariasis (mathematical models of host-parasite systems are discussed).[3,7,8] The data on incidence of this disease in the southern coastal belt of Sri Lanka is used to test the model.

2. The Model

We assume that mosquitoes and human beings are distributed uniformly with population densities N and n respectively. A human susceptible is regarded as infected when his blood contains sufficient microfilariae to infect the mosquitoes. If N^* and n^* are the population densities of infected human beings and infected mosquitoes, the

rate at which the latter would interact with the human susceptibles is proportional to $(N - N^*)n^*$. Since the onset of the disease occurs after a period τ from the beginning of exposure to the infected mosquitoes, and the probability of acquiring the infection depends on the integrated intensity of biting by infected mosquitoes during this period. We assume that human infectives are produced at a rate proportional to

$$\int_{t-\tau}^{t} [N(x) - N^*(x)] n^*(x)\, dx$$

As the infectives are also removed (due to development of immunity or drug treatment) at a rate proportional to their number density, we write

$$dN^*/dt = b \int_{t-\tau}^{t} [N(x) - N^*(x)] n^*(x) - rN^* \qquad (1)$$

Where b and r are constants. The rate at which the mosquito susceptibles interact with human infectives is proportional to $(n - n^*) N^*$, and since microfilariae undergo metamorphosis within the mosquito, ready to be inoculated into the definitive host rather quickly ($\sim$10 days, small compared to τ), for the purpose of the model we ignore this time lag and write the rate equation for development of infected mosquitoes as,

$$dn^* / dt = a(n - n^*)N^* - sn^* \qquad (2)$$

Where a and s are constants. It should be noted that in the approach we have adopted here, a separate rate equation is not written for the development of parasites within the hosts. In fact the integrodifferential equation (1) arises from this short circuiting. The present approach where the man-parasite-mosquito interaction is included in two steps is more amenable to mathematical analysis.

It is impossible to obtain exact analytical solutions of coupled integrodifferential and differential equations (1) and (2). However, a great deal can be learnt about the form of the solution by studying the system near the critical points. As a first approximation we assume that the total population densities N and n of human beings and mosquitoes remain constant.

There are two critical points corresponding to $dN^*/dt = dn^*/dt = 0$, a node or a saddle point at the origin $N^* = n^* = 0$ and a node $N^* = N^*_\infty, n^* = n^*_\infty$ approached as $t \to \infty$, given by the equation,

$$b(N - N^*_\infty) n^*_\infty \int_{t-\tau}^{t} dx = rN^*_\infty \qquad (3)$$

$$a/n - n^*_\infty/N^*_\infty = sn^*_\infty \tag{4}$$

whose solution is

$$N^*_\infty = (Nn - rs/ab\tau)(n + r/b\tau)^{-1} \tag{5}$$

$$n^*_\infty = (Nn - rs/ab\tau)(N + a/s)^{-1} \tag{6}$$

The above critical point is an asymptotically stable node (Appendix). Under present day conditions, the hosts-parasite system will not develop very far in the forward direction of such an asymptotic equilibrium and the behaviour near the critical point $N^* = n^* = 0$ more important. Around this point, when N^*, n^* are small, neglecting the second order terms we can write (1) and (2) in the form,

$$dN^*/dt = bN \int_{t-\tau}^{t} n^*(x)dx - rN^* \tag{7}$$

$$dn^*/dt = anN^* - sn^* \tag{8}$$

Eliminating N^* between (7) and (8) we obtain,

$$d^2n^*/dt^2 + (s + r)dn^*/dt + (sr)n^* = abnN \int_{t-\tau}^{t} n^*(x)dx \tag{9}$$

The linear equation (9) will have solutions of the form $n^* = (\text{constant})e^{kt}$ if,

$$k^2 + (s + r)k + sr = (abnN)(1 - e^{-k\tau})k^{-1} \tag{10}$$

The characteristic equation (10) has two and only two roots both real (Figure 1)

$$k_1 < 0, k_2 > 0 \text{ if } nN > sr/ab\tau \tag{11}$$

$$k_1 < 0, k_2 < 0 \text{ if } nN < sr/ab\tau \tag{12}$$

and the solutions of (7) and (8) can be written in the form,

$$n^* = Ae^{k_1 t} + Be^{k_2 t}$$

$$N^* = (1/an)[A(k_1 + s)e^{k_1 t} + B(k_2 + s)e^{k_2 t}] \tag{13}$$

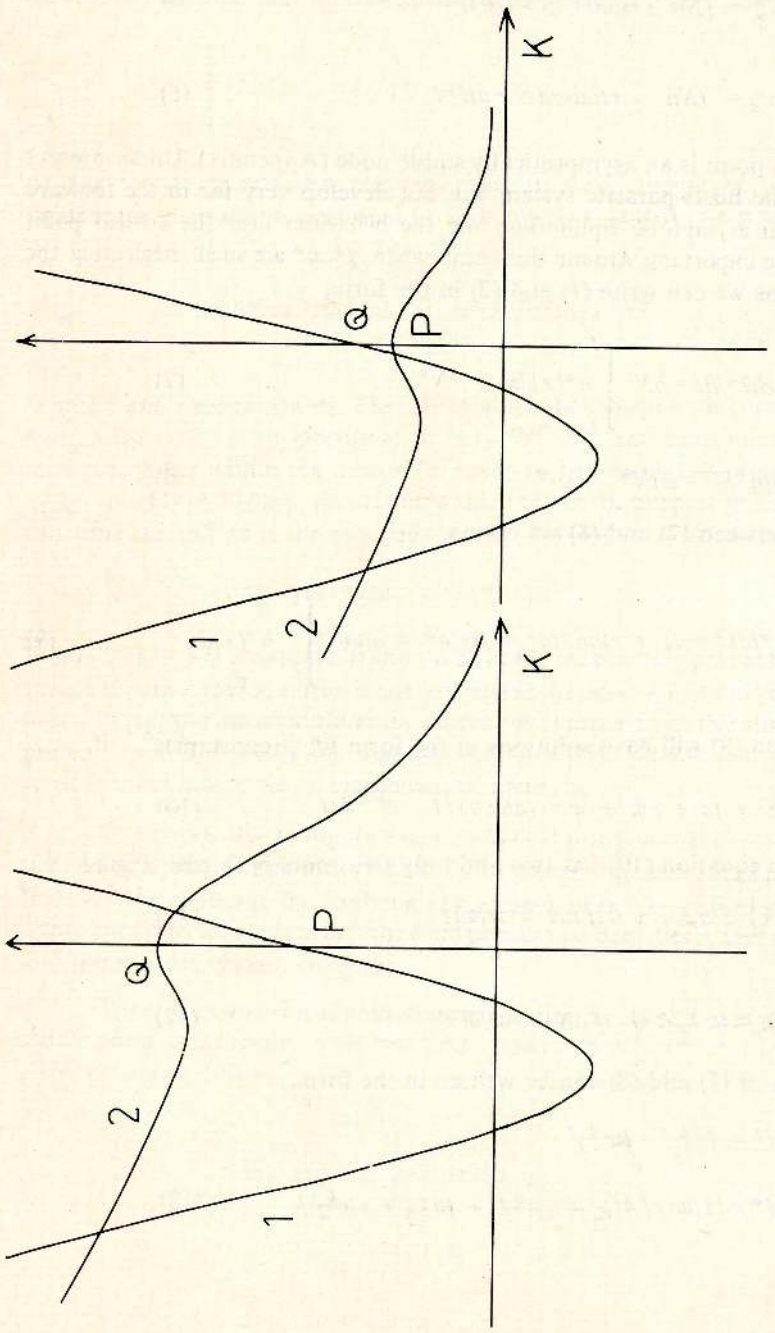

Figure 1. The sketches of the functions on left-hand (1) and right-hand (2) sides of the equation (10). P, Q are the points (0, sr), *(O, abnNτ)* respectively (a) $abnN\tau > sr$ (b) $abnN\tau < sr$.

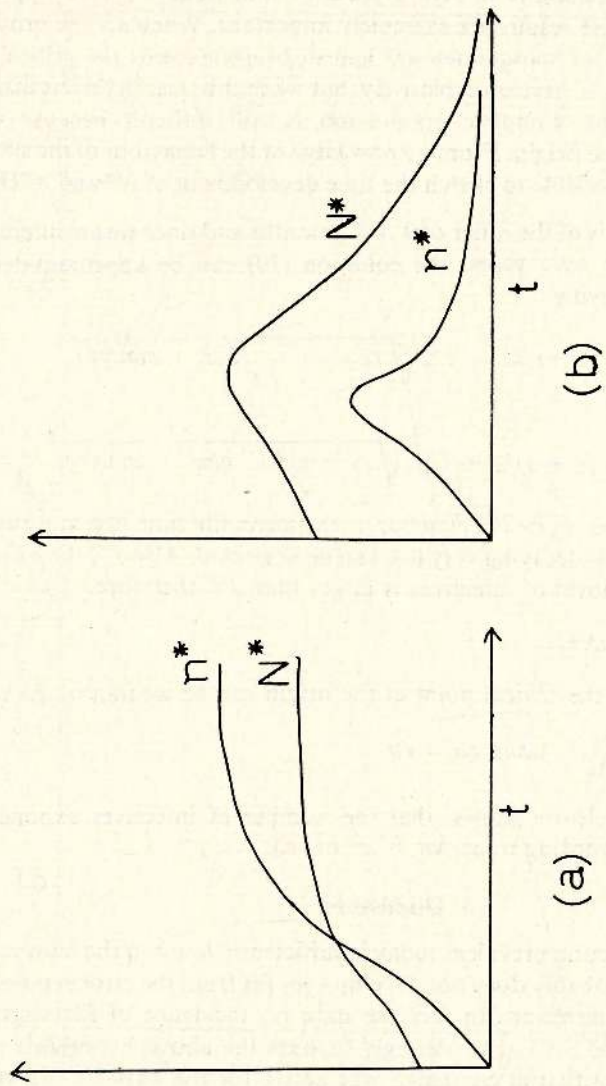

Figure. 2. A sketch of the time development of N^* and n^* for the initial condition $n^* = 0, N^* \neq 0$.
(a)abnNτ *> sr (b)abnN < sr. Vertical axis N* or n**

Where A and B are constants. When (11) is satisfied, the critical point $N^* = n^* = 0$ is a saddle point and the system becomes unstable [11]. In the second case when both roots are negative, this critical point is an asymptotically stable node [11] (see Appendix). The consequences of these results are extremely important. When nN the product of the population densities of mosquitoes and human beings exceeds the critical value $c = sr/ab\tau$, filariasis begins to develop explosively, but when this quantity is less than c the disease decays, however, complete eradication is still difficult because of the asymptotic stability at the origin. From a knowledge of the behaviour of the system at the critical points it is possible to sketch the time development of N^* and n^* (Fig. 2).

The parameter τ is of the order of 9 - 12 months and since we are interested in progress of the disease over years, the equation (10) can be approximated to a quadratic for $k\tau < 1$ giving,

$$k_1 = -(s+r)/2 - 1/2\sqrt{(s+r)^2 - 4(sr - abnN\tau)} \tag{14}$$

$$k_2 = -(s+r)/2 + 1/2\sqrt{(s+r)^2 - 4(sr - abnN\tau)} \tag{15}$$

Again as $s \sim t_m^{-1}$, where $t_m (\sim 20 - 30\ days)$ is the mean life time of a mosquito, the term $e^{k_1 t}$ in equation (13) decaying very fast can be neglected. Also r^{-1}, the mean time associated with the removal of infectives is larger than s^{-1}, therefore,

$$k_2 \simeq abnN\tau/s - r \tag{16}$$

Thus the solution near the critical point at the origin can be written in the form

$$N^* \simeq N_o^* e^{(abnN\tau/s - r)t} \tag{17}$$

The above expression clearly shows, that the number of infectives exponentially increase or decrease according to as $Nn > c$ or $Nn < c$.

3. Discussion

The level of filarial infection prevalent today is sufficiently low and the man-parasite-mosquito ecosystem probably does not develop very far from the critical point at the origin in the forward direction. In fact the data on incidence of filariasis in the southern coastal belt of Sri Lanka strongly favours the above hypothesis. In this region a continuous antifilarial campaign was active for the past 10 - 15 years. A significant portion of the population is being kept screened for filariasis (night blood test[4]) and the positive cases are given drug treatment. Under these conditions, the constant r in equation (1) takes a value larger than its natural value resulting purely from immunological factors. Though not very successful mosquito control programmes are also carried out, this is roughly equivalent to increasing the value of the constant s. The plots of lnN^* vs t for several urban and suburban areas in this

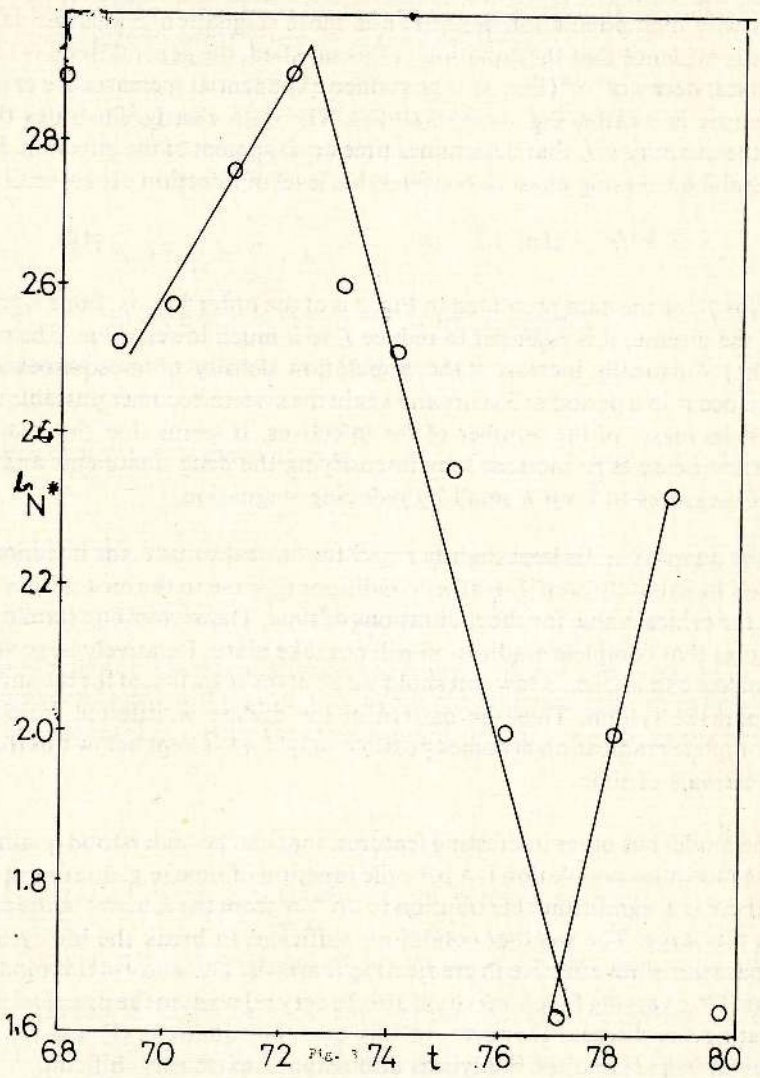

Figure 3 – A plot of the natural logarithms of the number densities of filariasis cases detected per year from 1967 - 1980 in a suburban region of area 36 km^2 and average population 37.000. The decay time of N^* corresponding to the straight line portion in the middle is 5.1 years.

region contain straight line portions with negative and positive slopes (Fig. 3). The lines with negative slopes corresponding to exponential decay of N^* continues for longer intervals of time. Furthermore the numerical values of slopes are smaller for those areas with high population densities and more stagnation (e.g.,larger value for nN). There is evidence that the equation (17) is satisfied, the general trend is towards an exponential decay of N^* (Fig. 3). The sudden exponential increases are caused by abrupt changes in weather e.g., heavy rainfall. The data clearly illustrates the role played by the quantity nN, that determines time development of the infection. Even in the exponential decreasing phase, a considerable level of infection occurs until a time,

$$T = (r - abnN\tau/s) - 1 \qquad (18)$$

The value for T for the data presented in Fig. 3 is of the order 5 years. For a significant control of the disease, it is essential to reduce T to a much lower value. The weather changes that drastically increase n the population density of mosquitoes can be expected to occur in a period of 5 years and again the system becomes unstable with an exponential increase of the number of the infectives. It seems that the best way to eradicate the disease is to increase r by intensifying the drug treatments and taking permanent measures to keep n small by reducing stagnation.

If the quantity nN is kept slightly above the critical value c, the infection could sustain itself indefinitely even if weather conditions adverse to the mosquitoes, lowers nN below the critical value for short durations of time. The asymptotic stability of the origin ensures that complete eradication will not take place. Relatively large values of r^{-1} and τ makes c small, i.e., a low threshold value of nN is sufficient for the survival of the host parasite system. Thus the pattern of the disease is different from that in malaria complete eradication becomes possible only if nN is kept below this threshold for long intervals of time.

The model has other interesting features, that can be understood qualitatively. Even if the mosquito population is a periodic function of time (e.g. due to wet and dry seasons) there is a significant contribution to dN^*/dt from the integral in the equation (1), when τ is large. The weather conditions sufficient to break the life cycle of the malarial parasite is not effective in eradicating filariasis. The study of this model when n and N are time varying functions could also be very relevant to the practical problem of eradicating the disease. However, in this case the equations (1) and (2) become nonautonomous [12] and the analytical discussion is extremely difficult.

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Appendix

To study the nature of the critical point $N^* = N^*_\infty$, $n^* = n^*_\infty$ we put $N^* = N^*_\infty + Y$, $n^* = n^*_\infty + y$ in (1) and (2), where Y, y are the deviations of N^*, n^* from the steady values. After neglecting the second order terms in y, Y we obtain,

$$dY/dt = b \int_{t-\tau}^{t} [py(x) - n^*_\infty Y(x)]\, dx - rY \qquad \text{(A1)}$$

$$dy/dt = aqY - uy \qquad \text{(A2)}$$

Where $p = N - N^*_\infty$, $q = n - n^*_\infty$, $u = aN^*_\infty + s$.

Elimination of Y between (A1) and (A2) yields,

$$d^2y/dt^2 + (u+r)dy/dt + ury = abq(p - n^*_\infty u/aq) \int_{t-\tau}^{t} y(x)dx - bn^*_\infty [y(t) - y(t-\tau)] \qquad \text{(A3)}$$

Equation (A3) will have solutions of the form $y = (\text{constant})e^{kt}$ provided

$$k^2 + (u+r)k + ur = (aqb/k)(p - n^*_\infty u/aq)(1 - e^{-kt}) - bn^*_\infty (1 - e^{-kt}) \qquad \text{(A4)}$$

The above equation has two and only two roots, both real and negative (This can be easily shown, exactly in the same way as for the equation (10), by sketching curves similar to that in Fig.1) Thus the critical point (n^*_∞, N^*_∞) is an asymptotically stable node.

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Carbon dioxide Concentration in the Atmosphere of Isthripura Cavern, Central Province, Sri Lanka

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Abstract: The atmosphere of a more or less horizontal C - shaped limestone cavern at Isthripura, Sri Lanka, showed a gradient of CO_2 concentration from nearly 3% at the closed end of the cavern to 0% at the open end. The O_2 concentrations were everywhere above 18%. The dyspnoea which is experienced inside the cavern seems to be partly due to hypercapnia. The full explanation for the occurrence of marked dyspnoea at certain points in the cavern remains to be found.

1. Introduction

There are a number of crystalline limestone caves in Sri Lanka.[2] Two of the larger caves situated in the central region of the country are both called Isthripura. This term is said to be derived from two Sanskrit/Sinhalese roots: sthri, woman; pura, town. The present account is about the Isthripura cavern situated at 80°54′ E, (longitude) and 7° 10′ N (latitude). The Mahaweli river flows in the valley about 2 km away from the cavern. The cavern is expected to be inundated when the Randenigala dam is built across the river within the next few years. It is hardly visited except occasionally by Buddhist religious groups who meditate in the grotto.

The cavern, situated on hilly ground, consists of three large caves and three small caves, connected by passages (Figure 1). The system is shaped like a horizontal C lying in an east-west direction. Three large caves form the ends and middle of the C. The small caves lead off from the passages which connect the large caves. The first large cave, at the east end of the system, is a grotto, open to the exterior, forming the entrance to the cavern. All the other caves and passages are subterranean and black. The mouth of the grotto is about 20 m wide while its floor is about 55 m wide. Its long axis lies in a north-south direction. A vertical shaft, about 2.5 m deep, leads into the rest of the cavern from a point near the north end of the grotto floor. The middle cave, about 85 m long, is at the lowest level in the cavern system. It contained a pond of clear water in August 1981 (which is a dry season); the sheet of water was about 30 m long and its depth about 1.5 m. The shore of the pond contained a brownish-black soil, soft to the touch, and teeming with bag worms, crickets and slender red millipedes, all of which started moving about when the light of the lantern fell on them. The roof of the cave contains chandelier-like stalactites. The passage between the first and second large caves (site 4 in the figure) contains a 1 m tall dagoba-shaped stalagmite. The third large cave is about 70 m long, and 12 m wide and 10 m high in the centre. It forms the

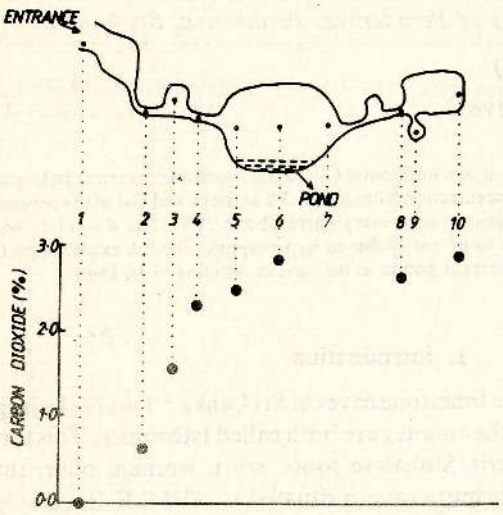

Figure 1 – Carbon dioxide concentration in the atmosphere of the Isthripura cavern.

The sketch above indicates the general plan of the cavern. It is not drawn to scale. The points on the graph represent the CO_2 concentrations at the sites indicated directly above them in the sketch.

far western end of the cavern system. It is the home of a population of bats whose odour first strikes one strongly as one enters the passage leading to the cave.

The cavern is hot and uncomfortable. Respiratory distress in the form of dyspnoea, that is, a conscious awareness that one's breathing is increased and laboured, is experienced, especially at certain points in the natural system of caves and tunnels. It seemed likely that the dyspnoea was due to hypercapnia or hypoxia or both. Deraniyagala[3] stated that the cavern "air is so deficient in oxygen, that the observer is attacked by a faint sense of dizziness". Gas analysis was not done on that occasion.

2. Method

The cavern was visited on 10.8.81 and sites were selected for later study. On 29.8.81 gas was collected into football bladders at the pre-determined sites. This was done by a man who went in alone with an electric torch. The bladders were brought out to the entrance to the cavern and the gas within them was analysed on the spot with a Lloyd-Haldane gas analyser. Each row of figures in the table of results represents a single analysis on gas from a single bladder.

Subjective sensations were recorded for 3 persons who went into the cavern immediately after the gas samples had been collected. After the three men had returned from the cavern they were asked to make a list of the sensations they had experienced. The composite list was found to be as follows: heat, sweating, breathing difficulty, fear, oppression, fatigue, headache, slipperiness. Each person was then asked to record subjectively the strength of each of these sensations. This was done on a 5-point rating scale: 0, no sensation; 1, slight, mild; 2, moderate; 3, marked; 4, very marked, severe. The results for the three persons were then averaged.

Results are shown in Table 1 and Figure 1.

Table 1.– Carbon dioxide and oxygen concentrations in the atmosphere of the Isthripura cavern

Site at which the gas sample was collected (See Figure 1)	Bats	CO_2 (%)	O_2 (%)	Discomfort score (0 - 4 scale)	
				Dyspnoea	Heat
1. Entrance to the cavern (a large open cave)		0.0	20.89	0.0	0.0
2. First tunnel		0.64	19.59	0.0	2.5
3. Second cave		1.55	19.25	1.2	2.5
		1.58	18.99		
4. Second tunnel		2.31	18.28	3.7	2.1
		2.23	18.19		
5. Lake, eastern end (near 4 above)		2.50	18.38	1.7	0.0
6. Lake, near middle		2.87	18.08	1.7	0.0
7. Lake, western end				1.7	0.0
8. Passage		2.67	18.16	3.1	3.1
9. Cave via a tortuous passage				4.8	4.8
10. Large cave at South-western end of cavern	Abundant	2.93	18.18	2.1	1.2

3. Discussion

There is no rule that is generally applicable to the gas composition of caverns. Quite apart from sulphurous caves which are suffocating because of hydrogen sulphide (such as in the Death Valley in the Yellowstone of the USA), the CO_2 concentration varies enormously. The Grotto of the Fairies at St. Moritz, Switzerland, is said to contain 2% CO_2 and the grotto of Büdösbarlang, Transylvania, 95% CO_2. The term 'foul air' in caves usually denotes air containing much CO_2[6].

In the Isthripura cavern there was a more or less distinct gradient of carbon dioxide concentrations, with highest levels, nearly 3%, at the western closed end of the cave complex, and decreasing progressively eastwards to the entrance. The open cave at the east end which forms the entrance to the cavern had no more CO_2 than ordinary atmospheric air.

The reason for this gradient is not known. We may suppose that CO_2 is generated within the cavern and diffuses outwards through the only main exit to the air at the eastern end of the cavern. In other words, the cavern air, laden with CO_2, is diluted by atmospheric air the closer it gets to the opening to the atmosphere at the cave entrance. Vertical diffusion gradients of CO_2 in vertical shafts is well recognized.[5] The Isthripura cave is more horizontal than vertical.

The mechanism by which CO_2 is generated is undetermined. It could be from the action of acidic water percolating into the cavern, liberating CO_2 from the calcium carbonate of the limestone rock. The western end of the cavern, rich in CO_2, was found to have the wettest rock and soil. Presumably underground water seeps into the cavern especially from the western end at the time of year at which the study was done (August, a non-rainy month for the region). Another important source of CO_2 could be the exhalation of bats. Bats were seen emerging from the entrance but none were seen within the caves near the eastern end of the cavern complex. The western caves, on the other hand, had a large population of bats. The bats were medium-sized microchiropterans.[7]

The effect of the cavern atmosphere upon human breathing seemed to be due to several factors, some but not all of which could be identified. The oppressively hot and stuffy atmosphere was probably due to heat and high humidity, although we did not measure these. The dyspnoea was partly due to CO_2. CO_2 concentration, which is 0.03% in ordinary open air, must rise to about 1% in the inspired air at atmospheric pressure before any measurable increase in the breathing occurs, and this increase is too small to be noticed by the person himself who breathes the air.[4] Dyspnoea, in the sense of awareness that one's breathing is increased, is known to set in with a CO_2

concentration of about 2%. The atmosphere in most of the Isthripura cavern, especially its western three-quarters, had CO_2 concentrations of the order of 2 - 3%.

The dyspnoea cannot, however, be fully explained on the basis of the CO_2 concentration alone. The dyspnoea was most marked at two sites in the cavern, neither of which gave the highest CO_2 readings. The oxygen concentrations were throughout 18% or more. These are too high to cause dyspnoea. The full explanation for the oppressive dyspnoea therefore remains to be elucidated. A combination of heat and humidity with excess CO_2 and lack of O_2 might be the causative agent.

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Preliminary Laboratory Studies on Increasing Phosphorus Availability In Eppawala Apatite

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Abstract: Preliminary investigations to increase the availability of phosphorus in Eppawala apatite were carried out. Samples of an ultisol (Reddish Brown Latasolic soil) and an alfisol (Reddish Brown Earths) amended with animal manure or straw or sulphur at 2% were incubated separately with finely ground apatite at 50% field capacity or under flooded condition. Olsen's P of the incubated soil samples determined at fortnightly periods indicate that the release of phosphorus in apatite is increased by straw and animal manure under unflooded conditions. Under flooded conditions only animal manure was effective. Straw did not show any significant influence.

1. Introduction

Phosphate rock is one of the primary raw materials of the world's chemical fertilizer plants. Apatite is an important phosphate rock of igneous origin and deposits of this material in various forms occur in a number of countries.[17] In Sri Lanka, large deposits of apatite are known to occur in Eppawala in Anuradhapura District. The plant available P in apatites is generally low [11,21] and hence, processing of this material to increase its P availability is usually carried out. As this process involves energy and other raw materials the final product tends to be more expensive.

Various methods of increasing the P availability in apatite materials such as applying the fertilizer material a few weeks before planting the crop[20], incorporation of sulphur[3] or animal manure[18] along with apatite are shown to be effective. As availability of P in apatite is usually greater in acidic soils,[1] studies were carried out to examine the influence of mixing Eppawala apatite with acidifying materials on P availability under upland and lowland conditions.

2. Materials and Methods

Soil samples (< 2 mm in diameter) of two tropical soils viz. Reddish Brown Latasolic (RBL) and Reddish Brown Earths (RBE), finely ground sulphur and lightly ground particles (< 2 mm) of straw and animal manure (cattle dung) were used in the study. The phosphate rock material used was a finely ground sample of apatite deposits found in Eppawala located in the North Central Province of Sri Lanka. The total and Olsen's P of the materials used are indicated in Table 1.

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Experiment 1

Samples of Reddish Brown Latasolic (RBL) and Reddish Brown Earth (RBE) were mixed separately with dried animal manure (cattle dung), dried straw or powdered sulphur at 2%. The apatite material was also incorporated with these mixtures at the same rate and incubated at room temperature and at 50% field capacity over a period of 12 weeks. Controls (soils alone and soils mixed with cattle dung or straw or sulphur) were similarly incubated. At fortnightly intervals, samples taken from the incubating mixtures were analysed for Olsen's phosphorous[13] by blue colour method.[10] Each treatment was triplicated.

Experiment 2

Soil mixtures except those with sulphur, prepared as in Experiment 1 were incubated under flooded conditions (1" water maintained above the soil level) at room temperature. Olsen's P was determined as in Experiment 1.

3. Results and Discussion

Olsen's P or $NaHCO_3$ extractable P is considered a good indicator of the plant available phosphorus in a soil.[13] During incubation of a soil, available P content tends to increase due to mineralization of organic phosphorous by soil micro-organisms.[15] Some of these organisms are capable of dissolving P containing minerals[19] secreting organic acids such as α — ketoglutonic[8], lactic and acetic.[18] Available P tends to decrease due to chemical factors.[12] Thus, the available P content, indicated by Olsen's P,[13] at any moment depends on the net effects of these processes. Dissolution of phosphate rock depends to a great extent on the nature of the material itself[4,5,7] and also on soil factors.[1,6]

Experiment 1

Results of the first experiment (Tables 2 & 3) indicate that during incubation, Olsen's P in soil and apatite mixtures have increased gradually in the first 4-6 weeks and thereafter remains more or less constant in RBE or tends to decrease in RBL. As could be expected, incorporation of apatite has increased Olsen's P over the control although the differences are not significant. Available P in soils incubated with straw or cattle-dung also show a tendency to increase similar to that in the previous treatments. There is a significant increase in available P in soils incubated with cattle-dung in RBL soils during the 4th - 8th week and RBE soils during 2nd - 6th week. This increase is likely to be due to high P content in cattle-dung (Table 1) which may have got partly solubilised during incubation. In soil-straw mixture, Olsen's P has not significantly increased during incubation. This could be due to low P content of straw (Table 1) and microbial immobilization which is known to take place with an increase in the microbial population[2] brought about by the incorporation of carbohydrate rich material such as straw.[14]

Table 1.– P contents of the materials used in the study (Average of 3).

	Total P mg/100g	Olsen's P -ppm
Reddish Brown Latasolic soil	12.2	6.7
Reddish Brown Earth soil	8.4	12.4
Apatite	1280.0	0.6
Cattle-dung (dried)	176.1	0.8
Straw (dried)	12.4	—

Table 2.– Olsen's P of RBL samples incubated at 50% field capacity in ppm (Average of 3).

	Weeks						
	0	2	4	6	8	10	12
Soil	6.6	8.9	9.6	9.7	10.5	10.2	9.8
Soil + A	6.6	10.1	10.4	11.1	11.4	10.9	10.2
Soil + ST	6.7	7.1	8.1	10.5	11.6	11.6	11.0
Soil + CD	7.4	10.2	12.8	12.6	12.7	12.6	11.7
Soil + S	6.9	8.7	9.4	8.6	9.8	9.2	9.0
Soil + A + ST	6.6	10.3	11.1	13.1	13.5	11.4	12.1
Soil + A + CD	7.6	11.7	14.6	15.2	13.7	13.9	12.4
Soil + A + S	6.8	8.8	10.2	9.8	9.6	10.1	10.2
LSD 5%	1.4	1.6	1.4	1.6	1.3	2.7	2.4

A — Apatite
ST — Straw
CD — Cattle-dung
S — Sulphur

Table 3.– Olsen's P of RBE samples incubated at 50% field capacity in ppm (Average of 3).

	Weeks						
	0	2	4	6	8	10	12
Soil	12.2	14.3	14.7	15.3	15.7	15.4	15.7
Soil + A	12.8	15.5	16.1	16.2	16.0	16.3	16.0
Soil + ST	12.4	13.1	13.8	15.7	16.7	15.9	15.1
Soil + CD	12.2	17.1	17.8	18.4	18.8	18.9	18.8
Soil + S	12.3	15.2	14.9	15.4	16.2	16.1	16.4
Soil + A + ST	12.9	18.2	19.0	19.3	19.5	19.3	19.6
Soil + A + CD	12.4	19.2	20.7	21.0	20.8	21.6	20.6
Soil + A + S	13.1	15.3	16.5	16.4	16.5	16.4	16.8
LSD 5%	1.8	1.6	2.5	2.3	2.5	2.9	2.1

A — Apatite
ST — Straw
CD — Cattle-dung
S — Sulphur

Effect of organic matter

In treatments where soil-organic matter mixtures are incubated with apatite, Olsen's P has significantly increased over the corresponding controls. This increase is observed in the case of cattle-dung apatite mixture during the periods 4th - 6th and 2nd - 6th week in RBL and RBE respectively. Mixing apatite with straw also has increased the available P content significantly during the 2nd - 8th and 2nd - 12th week periods in RBL and RBE respectively. These results show that decomposing straw and cattle-dung have a solubilisation effect on apatite probably due to increased microbial activity which is known to cause production of acids.[19] However, this effect appears to be more with straw than with cattle-dung and more in RBE than in RBL. Singh and Datta[18] also reported that mixing farmyard manure with phosphate rock increased P utilization by paddy.

Effect of sulphur

In soils incubated with sulphur, available P has increased but not significantly. This is so even when apatite is incorporated, indicating that incubating with sulphur has no net influence over P availability. Singh and Datta[18] also did not get consistent results in a P utilization study in rice with sulphur but Bromfield[3] found that incorporation of S increased P uptake in ground nut.

Experiment 2

Under flooded conditions (Tables 4 and 5) too, available P has increased during incubation even more than at 50% field capacity. When a soil is kept flooded, anaerobic conditions develop, red-ox potential drops and more soluble phosphorous compounds form.[16] The increase in P availability under flooded conditions could be attributed to the above factors.

Effect of organic matter

Incubating with added organic materials enhance these factors resulting in an increase in available P due to solubilisation effect of the decomposing organic materials. With straw, Olsen's P has significantly increased in RBL after the 6th week and in RBE after the 8th week. With cattle-dung in RBL and RBE, available P has significantly increased after the 2nd week. In soil organic matter mixtures incorporated with apatite, available P has increased significantly over the corresponding controls only in the case of soil cattle-dung mixture. These observations indicate that during anaerobic decomposition of cattle-dung, insoluble P compounds in soil and apatite tend to get dissolved but when straw undergoes decomposition under flooded conditions, only soil P compounds tend to get mobilized.

Table 4.– Olsen's P of RBL samples incubated under flooded conditions in ppm (Average of 3)

	Weeks						
	0	2	4	6	8	10	12
Soil	7.3	9.6	10.5	11.2	11.6	12.2	12.6
Soil + A	7.4	11.2	14.0	14.2	15.1	15.9	16.0
Soil + ST	7.5	9.5	12.2	15.9	15.2	16.7	17.5
Soil + CD	8.1	13.5	14.5	14.5	16.6	16.3	15.7
Soil + A + ST	7.4	10.2	12.3	14.4	14.5	15.2	16.1
Soil + A + CD	8.5	15.4	16.5	18.1	19.7	18.7	20.0
LSD 5%	1.6	1.7	1.8	2.1	1.6	2.1	2.0

A — Apatite
ST — Straw
CD — Cattle-dung

These results indicate that incorporation of organic materials such as cattle-dung and straw tend to increase availability of phosphorous in Eppawala apatite under unflooded conditions. As this increase takes place only for a limited period,

applications of organic materials may have to be timed in order to obtain the maximum benefit of enhanced P availability. Under flooded condition, only cattle-dung appears to be effective in increasing P availability in Eppawala apatite.

Table 5.– Olsen's P of RBE samples incubated under flooded conditions in ppm (Average of 3).

	Weeks						
	0	2	4	6	8	10	12
Soil	12.4	15.4	16.2	17.4	17.6	16.9	17.1
Soil + A	12.8	16.4	17.4	18.2	18.9	18.4	18.5
Soil + ST	13.2	14.8	16.4	18.8	21.4	20.8	21.4
Soil + CD	13.1	17.5	19.5	19.8	20.1	20.4	20.3
Soil + A + ST	12.9	14.5	16.3	18.2	20.8	20.4	20.6
Soil + A + CD	12.6	20.4	21.8	21.9	22.8	23.8	24.2
LSD 5%	1.8	2.0	2.2	2.0	2.4	2.6	2.6

A — Apatite
ST — Straw
CD — Cattle-dung

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Biotype Distribution of Vascular Wilt Pathogen *Pseudomonas solanacearum* in Sri Lanka

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Abstract: Pathotypes of *Pseudomonas solanacearum*, Smith were collected from various agroecological regions of Sri Lanka. Only two biotypes sensu Hayward, namely biotype 2 and 3 were found.

Biotype 2 was isolated from potato plants grown in the central highland and it was found to be delimited to isotherm 16°C. Biotype 3 which was pathogenic to all solanaceous crops, was isolated from almost all the sampling sites throughout the island. The wet and dry zone climatic regions did not, apparently have any effect on the distribution of biotypes.

Many samples of *P. solanacearum* in the hill country dry zone were found to carry *P. marginalis*, which had a synergistic effect on the production of wilt disease. *P. marginalis* showed similar biochemical reactions as biotype 4 of *P. solanacearum*.

1. Introduction

The bacterial wilt caused by *Pseudomonas solanacearum* E. F. Smith is one of the major diseases of solanaceous crops. The disease occurs mostly in warm climates. It is known to infect various other hosts such as Banana[11] Peanuts[9], Caster[12], Winged bean[1] and has an erratic distribution in soil.[8] Also variation within the species based on morphological, physiological properties has been well documented.[2,4,7,13,15]

Hayward[5] grouped *P. solanacearum* into four biotypes. This classification was based on their ability in oxydizing disaccharides-lactose, maltose, cellobiose and hexose alcohols - mannitol, sorbitol and dulcitol. Seneviratne[10] reported an occurrence of biotypes 2, 3, and 4 in the hill country of Sri Lanka. Further studies were done to establish the distribution of biotypes throughout major agricultural areas of the island. An attempt was made to relate it to environmental factors.

2. Materials and Methods

2.1 Field survey

Solanaceous crops infected with *Pseudomonas solanacearum* Smith were collected from various agroecological regions of Sri Lanka. Whole plant samples were brought to the laboratory and vascular tissues were used for the isolation of pathogen from infected tomato, potato, capsicum and brinjal plants. Potato tubers were also used for the isolation of bacterium.

Selection of sampling locations were based on the previous cropping history, soil type, altitude, rainfall and temperature of the region.

The popular climatic division of the island is classified into two major divisions "wet" and "dry" zone. This expresses the regional hygro-climatic differentiation based on climatic reality which also reflects a land use and crop cultivation pattern. Although the wet and dry zones (Figure 1) are not internationally valid terms defined by climatic indices, they are realistic to climatic situation in the island. Of course viewed from the other dry regions of the earth the "Driest" in the dry zone - Mahalewaya - saltern in Hambantota still records an average rainfall of 929 mm per year.

In the present study agro-ecological regions classified according to 75% expectancy values of annual rainfall and elevation (Land and Water in 1979) was used for the selection of sampling locations. This apparently coincides with the wet and dry zone classification proposed by Wickramatilaka (1963) on effective dry period basis (Figure 1).

The land area under wet and dry zones are 1.6 million and 4.9 million ha respectively. The average annual rainfall in wet zone is about 32 million acre feet (1 Ac.ft. = 760 mm/ha) and 57 million acre feet in the entire island, that is rainfall in the wet zone is 72% higher over dry zone.[3]

2.2 Dry Zone

In the dry zone, wet and dry periods alternate once a year. The rainy period is only 3 - 4 months (Oct./Nov. to January) but the rains are disproportionately high. The dry period, maximum of 8 months (Feb. to Sept./Oct.) is extremely dry. The 75% expectancy value of annual rainfall is around 508 - 762 mm.

Soils in the dry zone are mainly reddish brown earths. But red yellow latosols and regosols, low humic gley soils and solodized solonitz are also found in some regions (DL_4).

The annual average temperature however does not relate to dry and wet conditions. The average annual records reveals homogenous temperature in the lowlands and the rapidly decreasing temperature in the highlands. In the lowland dry zone up to 150 m the temperature varies from $26.5^0$to 28^0C, the spatial variations of temperature in the region are slight.

These climatic conditions have produced a suitable niche to many crops and a wide variety of vegetation in the dry zone. Many grain crops, pulses, vegetables of various families, tubers and industrial crops are the major economic crops grown in the area. Among the common annual crops, rice is by far the most important crop during Maha. Although the soils are flooded for 3 - 4 months during paddy crops, solanaceous vegetables mainly capsicum, tomato and brinjal are grown under irrigation in these fields during the Yala season. However, in Jaffna potato crop is given high priority.

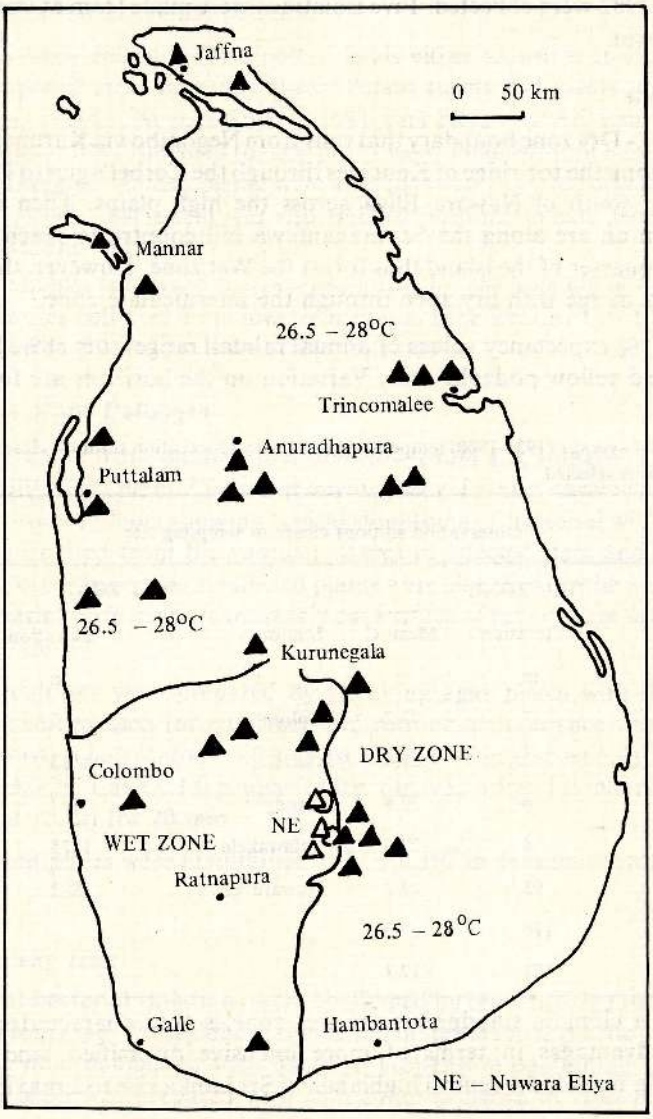

Fig. 1. The distribution of **Pseudomonas solanacearum** biotypes in Sri Lanka.

▲ – Biotype 3 (1979–1982)
△ – Biotype 2 (1979–1982)
○ – Biotype 2 (Seneviratne 1969)

Samples of naturally infected plants of potato (*Solanum tuberosum* L) and tubers from Jaffna - Thirunelvely, 1981 and Trincomalee - Kuchchavely and Uppuvely 1980, brinjal plants (*Solanum melongenae* L) from Jaffna - Kondavil, 1979, Trincomalee - Pankulam, 1980, Mannar - 1979, Vanathavillu - 1981, Puttalam - 1981, Monaratenne, Divlana - 1981, Bingiriya - 1981, capsicum (*Capsicum annum* var. *grossum*(L)) from Kandalama - 1980, Madatugama 1980, Mahailluppallama 1980, Kalawewa - 1982 were collected. Five isolations were made from at least 4 specimens from each farm.

2.3 Wet Zone

The Wet zone - Dry zone boundary that runs from Negombo via Kurunegala, and then to Matale, along the top ridge of Knuckles through the Corbet's gap to Pidurutalagala massif to go south of Nuwara Eliya across the high plains. Then it goes round Balangoda in an arc along the Sabaragamuwa hill country to reach Matara. The South West quarter of the island thus forms the Wet zone. However, the boundary is not rigid and merge with dry zone through the intermediate zone.

The 75% expectancy values of annual rainfall range from 889-3175 mm. Soils are mainly red yellow podzolic type. Variation on the horizons are found.

Table 1.– Annual average (1931-1960) temperature at various observation stations, closer to the sampling locations selected.

Observation stations closer to sampling site					
	DRY ZONE			WET ZONE	
Station	Elevation	Mean C	Station	Elevation	Mean C
	m			m	
Puttalam	2	27.2	Colombo	7	26.9
Batticaloa	3	27.4	Galle	13	26.5
Mannar	4	27.8	Kandy	477	24.4
Jaffna	4	27.6	Talawakele	1375	18.6
Anuradhapura	93	27.2	Nuwara Eliya	1882	15.4
Kurunegala	116	27.0			
Hakgala	171	17.3			

From a climatic standpoint, the wet zone is thus characterized by greater cultivation advantages in terms of more intensive diversified land use. In the Pidurutalagala massif, the central highlands of Sri Lanka rise to a maximum altitude

of 2,524 m, which produces a considerable vertical thermal contrast between highlands and lowlands. Temperature variations are very prominent, it falls quickly as the altitude increases (Table 1).

Because of the thermal requirements, the optimum condition for wetland rice occurs in the hill country only up to about 1,200 m (4,500 ft). However, other crops such as potato, tomato, brinjal and capsicum are grown. New areas have been cleared for potato cultivation in the hill country.

Samples were collected from potato fields either grown in traditional potato fields, newly opened areas or paddy fields. Potato tubers and plants were collected from Hawaeliya – 1981. Nuwara Eliya – 1981, Sita Eliya – 1981, Rahangala – 1981 and Yalapatwela – 1981. Infected tomato plants were obtained from Kandy, University farm – 1980. Diseased tomato plants were also collected from Rahangala – 1981, and Bandarawela – 1981. Bacterium was also isolated from the tomato samples collected from Mirahawatte and Welimada – 1981.

Several samples from each location were used for the isolation of the pathogen. The tomato samples collected from low country wet zone Weboda (1979), Mawanella 1979 , and Mapalana 1980 were also used for this study.

2.4. Isolation of the Pathogen

Isolations were made from potato (*Solanum tuberosum* L.), tomato (*Lycopersicon esculentum* Mill), Egg plant (*Solanum melongenae* L) and capsicum (*Capsicum annum* var. *grossum*) plants showing typical symptoms of bacterial wilt in the field. Bacterium was isolated from the vascular tissues of infected stem and was used to streak plants. Potato tubers from infected plants were also used for the isolation of the pathogen. Bacterial ooze from clean freshly cut surface of tubers were taken in sterile water as inoculum.

Axenic cultures were prepared by streaking agar plates with the bacterial samples. The medium used for culturing and routine maintenance was as follows: (calcium carbonate agar) peptone 5.0 g; yeast extract 0.5 g; glucose 5.0 g; K_2HPO_4 0.2 g; $MgSO_4.7H_2O$, 0.2g; $CaCO_3$, 1.0 g; agar 18.0 g; distilled water 1 L. Nutrient medium was sterilized at 15 psi for 20 min.

Inoculated plates were maintained at 21 ± 0.1°C in precision low temperature incubators.

2.5 Pathogenicity tests

Pathogenicity of bacterial isolations were confirmed by reinoculating tomato plants. Five weeks old tomato cv. Marglobe plants raised in sterile soil in plastic pots (15.5 cm diameter) were stem inoculated with bacterial suspension containing 10^6 cells/ml. Bacterial suspension was prepared with 48 h cultures grown in calcium carbonate agar. Three 10 μl drops of the suspension was placed on the axil of the third leaf from

the top, and the stem was then pricked with a syringe needle (gauge 25) through the inoculum drop.

Inoculated plants were placed in the green house (24^0C night, 28^0- 33^0C day). Plants were observed for the wilt and yellowing after 3 days from inoculation.

2.6 Biotype separation

All isolations were subjected to biochemical tests for their ability to oxidize disaccharides and hexose alcohol proposed by Hayward[5] Bacterial cultures were inoculated to culture tubes (1 x 12.5 cm) containing the following medium.

Basal medium per litre: $NH_4H_2PO_4$, 1.0 g; KCL 0.2 g; $MgSO_4.7H_2O$ 0.2 g; yeast extract 1.0 g and Bromothymol blue 0.3 ml of 1% W/V solution in 50% ethanol. Medium was adjusted to pH 7.1 with 1N NaOH before adding 1.5 g agar.

To 9 parts of sterile, cooled basal medium added 1 part of membrane filter sterilized 10% (w/v) of each carbon source.[5] Medium was then dispensed aseptically in a horizontal Laminar Floor Cabinet (Environmental Control INC.) to sterile plugged tubes to a depth of about 4 mm.

Inoculated slopes were incubated at 27^0C for 14 days. Slopes were observed for acid production on the 3rd, 7th and 14th day before discarding.

3. Results and Discussion

It was found that in the Yala season (N. E. monsoon, December - February) *Solanum melongenae* L. (egg plant) was the dominant solanaceous crop grown in the Dry Zone farms visited. *Pseudomonas solanacearum* isolated from diseased plant from almost all the sites except Kuchchavely in Trincomalee were pathogenic strains. The wilting of potato samples collected at Kuchchavely was due to *Fusarium oxysporum* and other *Fusarium spp.*

In the biochemical tests, the development of a yellow colour in the medium indicated production of acid from the oxidation of carbon sources. In most cases where there is positive acid production slight yellow colour appeared around inoculum by the 3rd day and it was yellow throughout the medium after 1 week of growth at 27^0C.

The distribution of biotypes in various agroecological regions is summarized in Figure 1. Heyward grouped *P. solanacearum* into 4 biotypes. Biotypes 3 and 2 were recorded in both dry and wet zone of Sri Lanka. However, biotype 2 was restricted to hill country.

Potato samples mainly tubers collected at Uva basin 1200 - 1400 M, rice fields (Rahangala - 80%, Boralanda - 30%, Yalapatwala - 85% and Mirahawatte - 30%) and samples from Sita Eliya - 20% and Hawaeliya - 15%, showed positive response to biotype 4 in biochemical tests.

Although this confirms to the results previously reported by Seneviratne[10] from the samples collected at Gorandiyatenna, it was decided to subject the bacterium for further biochemical and taxonomical study.

The biochemical tests used were Oxidase test with a platinum loop[6], Arginine dihydrolase test[14] Nitrate reduction and Carbon source utilization in Ayers *et al.* mineral salts medium in addition to Acid production tests.[5] Results are summarized in table 2.

Table 2.–Differentiation of *Pseudomonas solanacearum* isolates from Uva basin, Sita Eliya and Hawaeliya.

Test	*Pseudomonas solanacearum* isolates						
	Biotype 2	Biotype 3	Standard Biotype 4	R	B	Y	HE
Arginine hydrolase	ND	ND	ND	V^+	+	+	V^+
Oxidase test	+	+	+	V^+	+	+	+
Nitrate reduction	-	-	-	V^+	+	+	V^+
Carbon source for growth							
Cellobiose	-	-	-	-	-	-	-
Trehalose	-	+	+	+	+	+	+
Mannitol	-	+	+	+	+	+	+
Sorbitol	-	+	+	+	+	+	+
Acid production tests							
Lactose	A	A	-	V	V	V^+	V^+
Maltose	A	A	-	V	V	V^+	V^+
Mannitol	-	A	A	A	A	A	A
Sucrose	A	A	A	V	V^+	V^+	V
Sorbitol	-	A	A	A	A	A	A

ND—Not detected
V —Variable
R —Rahangala
B —Boralanda
Y —Yalapatwela
HE—Hawaeliya

\+ Definite positive response
V^+Slight positive response
\- No response or no acid production
A Acid producing.

Although the carbon source utilization and acid production tests indicated a presence of biotype 4, it is evident from table 2 that the results are not conclusive enough. Therefore all isolates were then grown at 27^{0}C in King's medium B agar (oxidase positive), composed of proteose peptone (Difco) 20.0 g; $K_2HPO_4.3H_2O$ 2.5 g; $MgSO_4.7H_2O$ 6.0 g; agar 15.0 g; glycerol 15.0 ml in 1 L of distilled water and examined with a long wave (375 nm) ultra violet lamp Gelman, universal UV unit for fluorescence. Green fluorescence was detected.

Fluorescent and the non-fluorescent were later separated out carefully for pathogenicity tests. Non-fluorescent bacteria was then identified as pathogenic *Pseudomonas solanacearum* biotype 3 whereas fluorescent bacteria was identified as *Pseudomonas marginalis*. When artificially inoculated tubers showed soft rot, and slight wilting of plant with browning of leaf margins. However when both strains were inoculated to potato plants wilting was severe and prominent, with conspicuous vascular wilt symptoms.

It is evident from these results that in the hill country wet and intermediate zone (IV_2 & IV_3) *Pseudomonas marginalis* prevails in association with *Pseudomonas solanacearum*. Probably it has a synergistic effect in wilt production.

Although Seneviratne (1964) reported the presence of biotype 4 in the hill country, I have found only 2 biotypes namely 2 and 3 among the samples collected. The distribution of biotype 2 was restricted to potato and within the 16^{0}C isotherm (Figure 2). Absence of biotype 2 in potato crops in the low land dry zone holds evidence for the effect of temperature on the survival. Figure 3 represents the thermal diurnal climate of two representative stations Colombo - Low country and Nuwara Eliya for hill country. Thermo isopleth diagrams of Colombo and Nuwara Eliya show the corresponding course of the isopleths. However, the order of temperature magnitudes are different. The maximum and minimum temperatures are shown during the period from December to May. Lowest temperatures are early in the mornings and highest at 12 - 14 hrs. However, onset of rains has minor effect on the diurnal course. The temperature remains constant from 12 - 17 hrs in the hill country Nuwara Eliya region it is about 18 - 23 ^{0}C and in Colombo 29 - 31.3^{0}C in December - January. However in Nuwara Eliya range is 11 - 17^{0}C during the rest of the year whereas it remains high around 22 - 29.2^{0}C.

During the main potato cropping season in the hill country October/November to February and February/March to July has relatively low temperature periods compared to 11 - 23^{0}C during February/March period. It is possible that 11 - 17^{0}C is favourable for epiphytic development of the bacteria in the field. Although the temperature could go up to about 23^{0}C during February/March it is only for a period of 2 hours (12.00 to 14.00 hours). Therefore it is possible that the population of biotype 2 restricted to potato crop could survive in the areas without much losses during land preparation and planting in February - March.

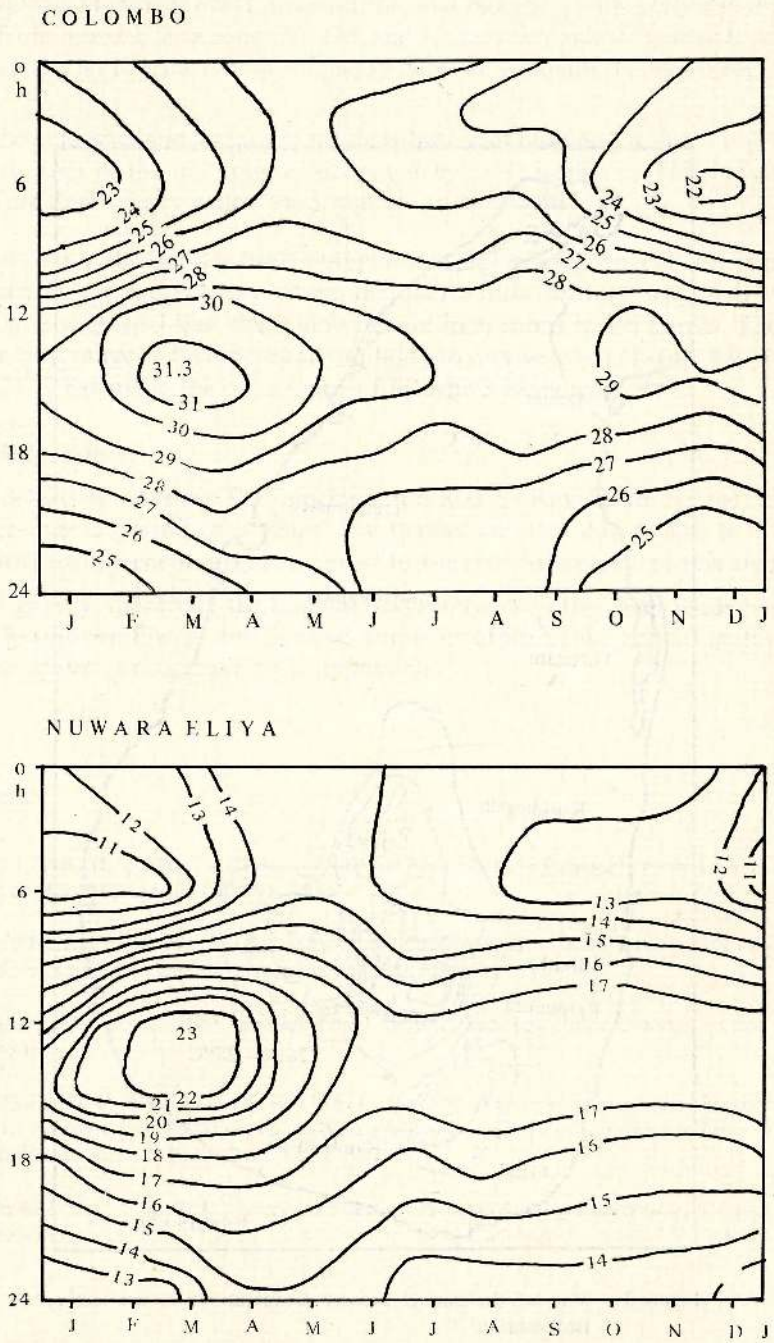

Figure 2. Thermo-isopleths diagrams for Colombo and Nuwara Eliya.

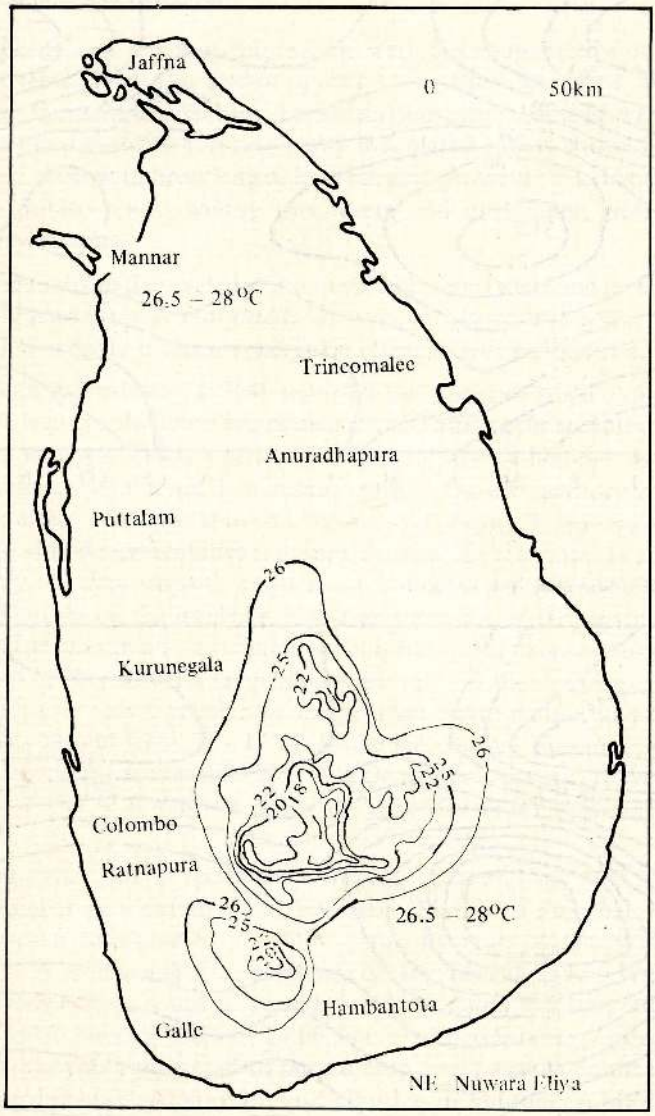

Figure 3 – Map of the annual average temperatures in Sri Lanka, isotherms in °C.

Seneviratne[10] suggested a correlation between cropping history, soil type and biotype occurrence. The samples collected from the farms in new clearings of the Kalawewa and Madatugama (Capsicum) showed biotype 3 only. Only biotype 3 was isolated from intermediate zone $1V_3$, $1M_3$ and $1L_1$ agroecological regions. Even in the new clearings and in potato crops in paddy fields at Yalapatwela only biotype 3 was detected.

The characteristic feature of the distribution of biotype 2 is that it is restricted to a small area in the hill country delimited by 16^0C isotherm. This indicated its temperature dependency rather than rainfall or soil types.

In view of the fact that both biotypes 2 and 3 were found in new clearings and its occurrence in the hill country where the distribution through irrigation water is unlikely it is suggested that these biotypes are indigenous to Sri Lanka. The broad spectrum host range of biotype 3 and its ability to survive even at higher temperatures such as 31^0C has made the occurrence of biotype 3 islandwide.

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Textural Studies of some Granites and Gneisses from the Precambrian Vijayan Complex of Sri Lanka

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Abstract: Microcline rich granites and gneisses occur abundantly in the Precambrian Vijayan Complex of Sri Lanka. These bodies forming the cores of plunging domes and folded structures show abrupt and gradational contacts with the country rocks. Textural studies of granites and gneisses reveal magmatic and metasomatic origins for these bodies.

1. Introduction

The Precambrian of Sri Lanka consists of metamorphic and igneous rocks belonging to three divisions:- Highland Group, Southwest Group and Vijayan Complex.[4] Highland Group consists of metasedimentary and metavolcanic rocks such as quartzites, marble, granulites, gneisses and charnockites. Southwest Group is formed of calciphyres, quartzites, cordierite gneisses and charnockites. Vijayan Complex terrain is underlain by granites, granitic gneisses, hornblende biotite gneisses, migmatites, calc gneisses, quartzites and doleritic bodies. The structure of the Highland Group of rocks is characterized by overturned parallel, upright and double plunging folds. These rocks as well as those of the Southwest Group show a consistent linear structural trend. The structure of the Vijayan terrain is very complex and is dominated by plunging domes, synforms and antiforms (Figure 1).

So far, not much petrological work has been carried out on the Vijayan rocks and the available papers deal mostly with the interrelationship between the Vijayan Complex and the Highland Group. Vijayan Complex terrain has long been regarded as the basement on which Highland Group sediments had been deposited.[1,3,7,8] Cooray[5] considered the Vijayan as amphibolite facies rocks formed due to migmatisation and granitization of pre-existing granulite facies Highland Group. Age data[6] seems to confirm a period of cooling and uplift concurrent with migmatization and granitization, about 1150 Ma ago, when perhaps some of the charnockites of the Highland Group were also formed.

The western boundary between Highland Group and Vijayan Complex is represented by a passage of metasediments into dominantly gneissic, granitic and migmatitic terrain. However in the east, the contact is demarcated by shearing at points along the course of Mahaweli river[14] and this structural feature extends into the

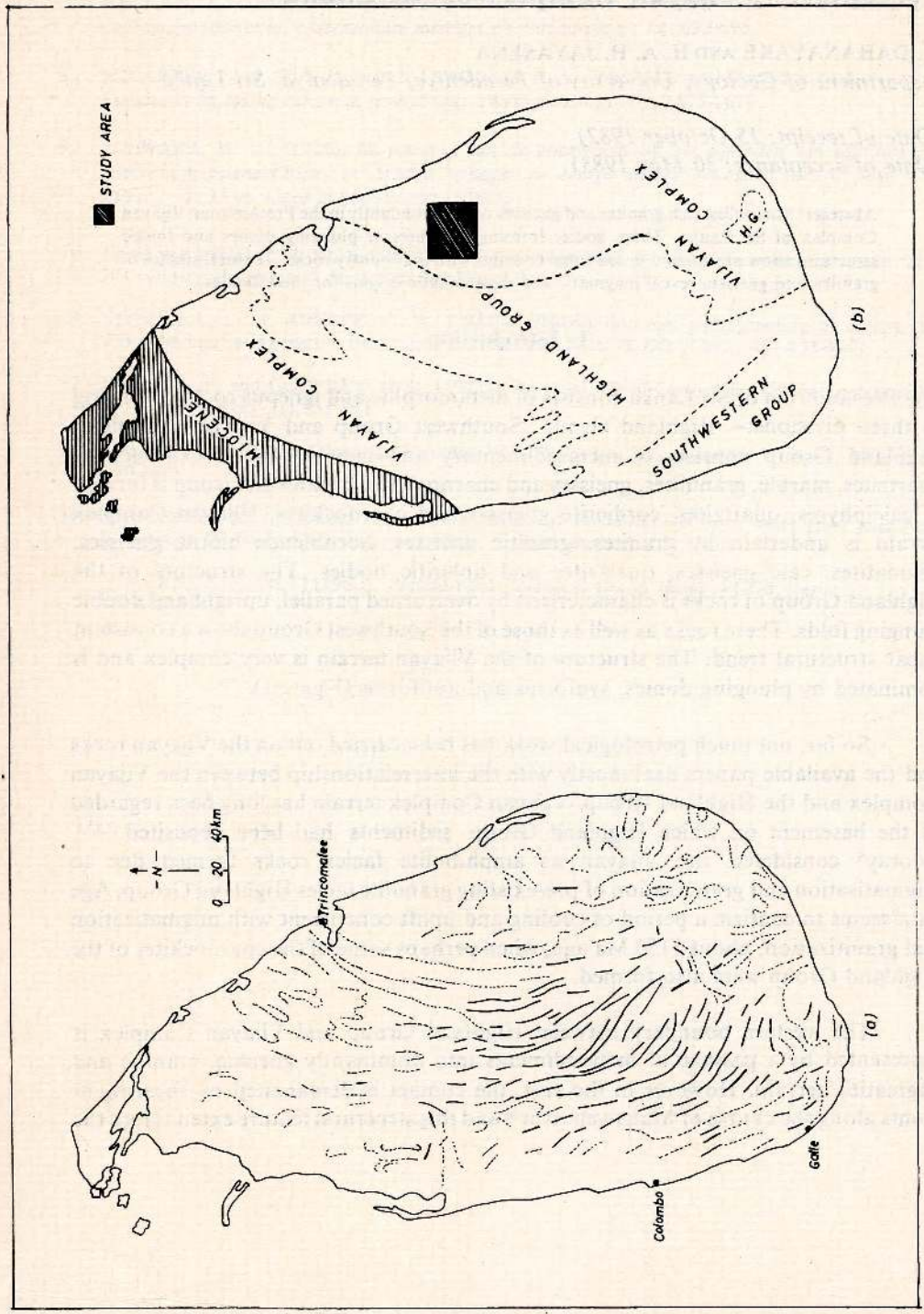

Figure 1 : Maps of Sri Lanka showing (a) general structure (b) major geological divisions and the location of the study area.

northeast towards a deep submarine canyon.[2] The contact zone is characterized by a train of hot water springs and a series of basic intrusions.[12] The same authors recognized a Precambrain plate boundary at the contact zone where sediments and volcanic deposits had been metamorphosed consequent to collision of eastern and western Vijayan "plates".

In this paper the writers discuss the petrology and textural characteristics of granites and granitic gneisses with a view to understand the complex geological history of these rocks. For this purpose, an area of about 1000 km^2 from the Vijayan Complex was selected in Eastern Sri Lanka (Figure 1b).

2. Methods of Study

The aerial photographs of the area on the scale of 1: 20,000 were studied for structural observations. Laboratory studies were supplemented by field mapping of the area on the scale of 1: 63,360. The laboratory and field observations were computed to produce a geological map of a smaller scale (Figure 2) so as to obtain a better structural and geological picture of the area. About 40 thin sections from granites and gneisses of the area were studied for their petrology and texture.

2.1 General Geology of the Study Area

The study area forms a vast peneplained surface interrupted by isolated inselberg type ridges rising to about 150 m above MSL and sluggish streams, prominent among them in the area being Maduru Oya. The area is characterized by north plunging dome and antiform/synform structures. The cores of domes and folds are formed of microcline granites and gneisses which pass laterally into either migmatites or augen gneisses. These lithologies underlie mostly the rounded hills, isolated massifs and elongated ridges whereas hornblende biotite gneiss - the dominant rock type of the area - form most of the peneplained surface. Thin bands of calc gneiss, amphibolite, quartzite are found interbanded with hornblende biotite gneiss which is often associated with sill-like thick pegmatitic bodies.

The contact of microcline granites and gneisses with the surrounding migmatites and augen gneisses can either be abrupt or gradational. At abrupt contacts, the granitic body shows a shattered appearance with as many as five joint systems and mylonitic breccia is also associated. Pockets of hornblende are also noted at the contact area and silicified potash feldspar occurs within the cracks and joints of both the intrusion and the country rock. At gradational contacts which are more common, schlieren structures of basic to intermediate compositions are seen to grade into migmatites and gneisses.

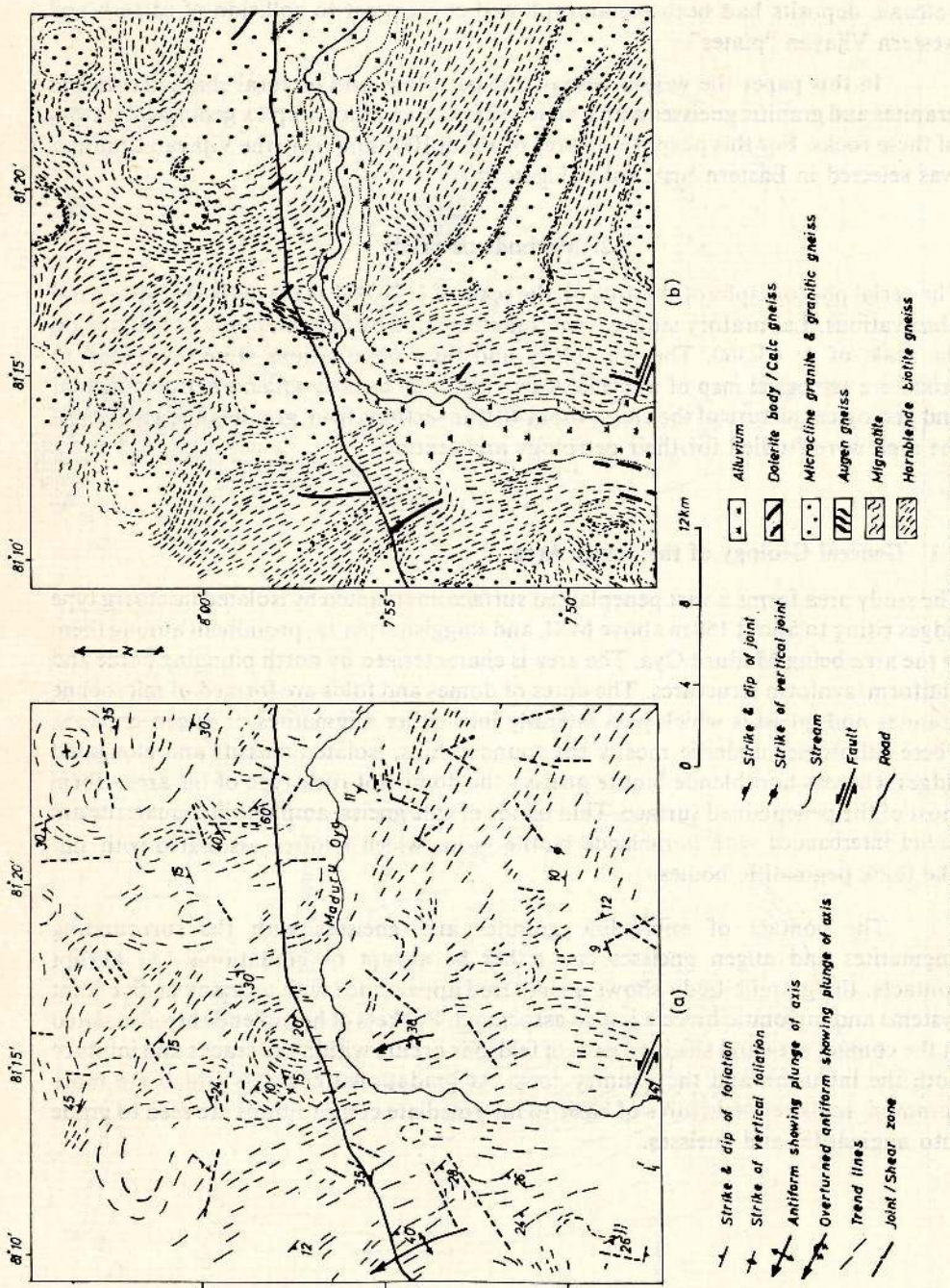

Figure 2 : (a) structural map of the study area, (b) geological map of the study area.

2.2 **Textures of Granites and Gneisses** (See Figures 3 & 4)

The granites and gneisses of the study area consist mainly of microcline, plagioclase and quartz in that order of abundance with subsidiary biotite, hornblende, magnetite and apatite. The granites are generally coarse grained and when the gneissic character is well defined the rock tends to be medium grained with biotite and hornblende aligned parallel to local foliation. Pegmatitic aggregates are found along and across foliation. Most of the granites and gneisses fall under the granite or quartz syenite fields of the classification of Streckeisen (1967).

Microcline with sizes ranging from 0.5 to 3 mm occurs dominantly in the granites and gneisses as independent grains and perthitic intergrowths or it is observed in association with plagioclase. Cross hatched twinning is present prominently in microcline which occurs as anhedral grains locally clustered in patches and interstitial to large plagioclase grains. When in contact with plagioclase, microcline is found to protrude into the former as tongues and lobes. Plagioclase replaced by a cross hatched microcline phase is common in the rocks studied and diffused margins characterize the microcline plagioclase contact. Sometimes, ghost plagioclase twins are observed in microcline. The early plagioclase grains surrounded by microcline show deformed twins and sericitization products riddled inside them. Microcline at points occur as tiny blebs in plagioclase giving a pseudo-antiperthitic texture. At the interfaces of larger microcline grains, intergranular albite is observed as the double row variety or the wart shaped type. At microcline plagioclase boundaries, swapped rims of albite are observed. A whole range of perthitization products from the incipient type to the dominantly exsolved phase is characteristic of the granites and gneisses. Thus string, flame and rod type perthites are commonly observed. The perthitic growths are intense at the cores of domes and at points of shear such as the contacts of augen gneiss bodies. Granulated quartz is closely associated with such growths. Bleb-like perthites bear a resemblance to the swapped albitic rims in appearance whereas the braid type shows relict material similar to that in sericitized plagioclase grains.

Plagioclase grains range in size from 0.5 to 5 mm and are anhedral for the most part due to embayment by microcline and quartz. Idiomorphic quartz grains are occasionally observed in plagioclase grains. Three distinct types of plagioclases are noted. The early formed plagioclases are identified by their corroded character. They are often engulfed or cross cut by younger plagioclases whose compositions tend to be those of albite or oligoclase. The third type occurs as rims or integranular albite at plagioclase-microcline and microcline-microcline interfaces as referred to earlier. Plagioclase of earlier origin are found as inclusions in later formed grains. The early type possesses coarse albite twin lamellae and are sericitized with accessory muscovite, calcite and epidote. The most common twins in plagioclases are those of albite type. The twins are either coarse and rare or multiple with extremely fine lamellae. Both carlsbad and albite twinning are encountered together with occasional pericline twinning. Some albite twin lamellae characteristically extend all the way across the grains but terminate abruptly at fractures. Plagioclase forms borders and relict

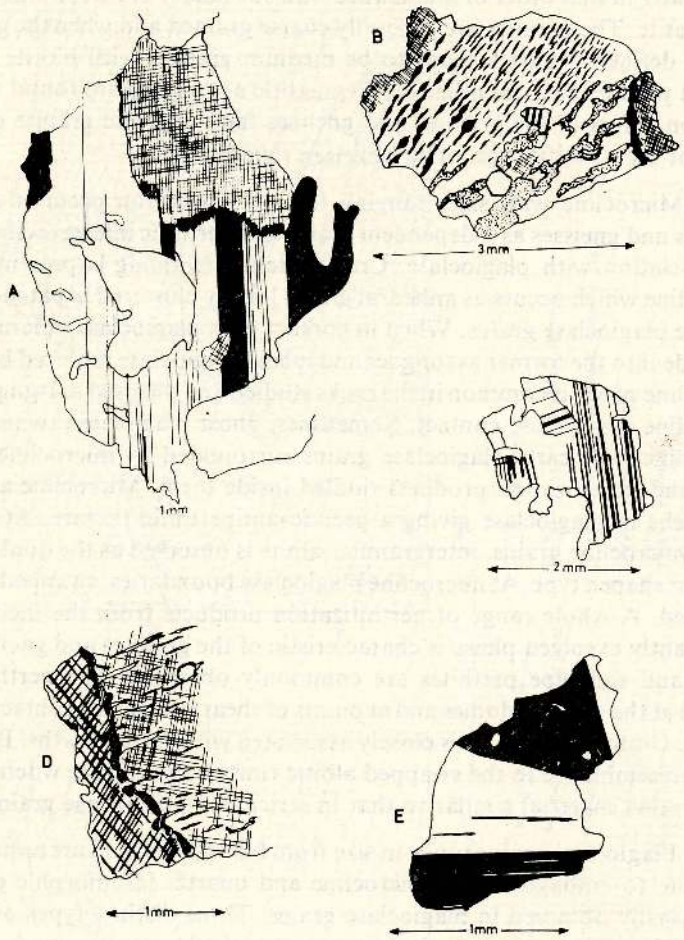

Figure 3 : A — diffusive boundary between plagioclase and microcline (Sample No. MO/75)

B — development of perthites, relict plagioclase (in the centre) and sericitization (stippled) (Sample No. MO/6).

C — two generations of plagioclase (Sample No. MO/96)

D — formation of intergranular albite (double row type - close ruled) (Sample No. MO/79)

E — Combined carlsbad - albite twinning (Sample No. MO/10).

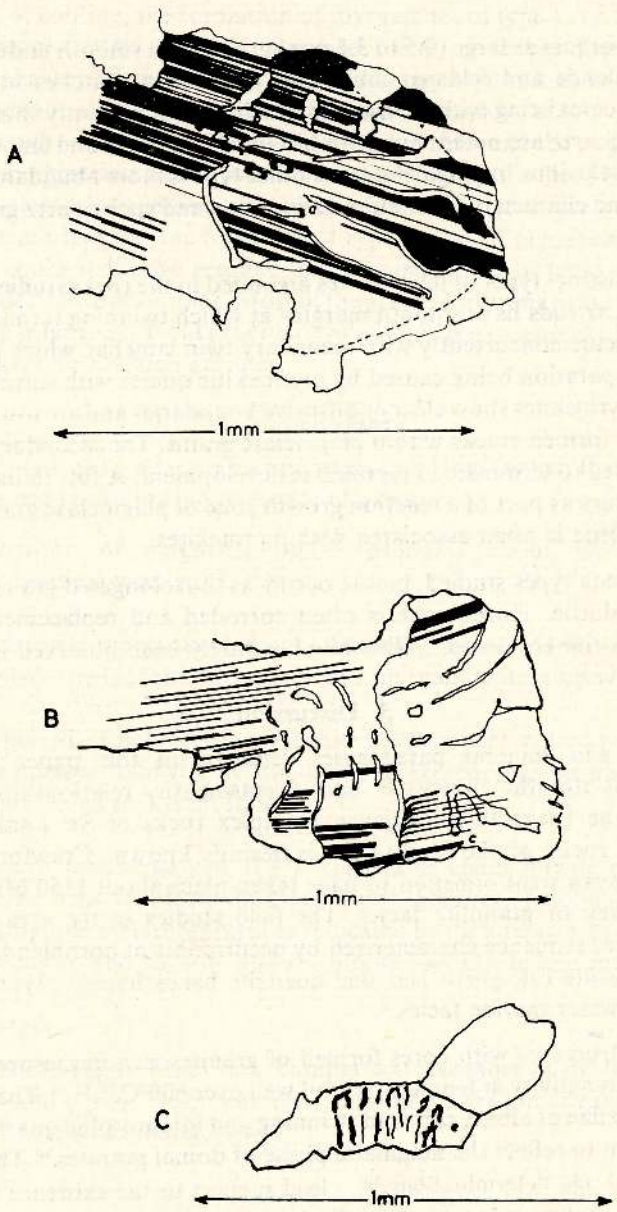

Figure 4 : Development of different types of myrmekites.

A — (a) Type I
(b) Type II
B — (c) Type II
(d) Type III
C — (e) Type IV

patches at the edges of microcline and at points narrow veinlets of pseudoperthite also are noted. Differently twinned enclaves of plagioclases are observed within later formed grains.

Quartz occurs as large (0.5 to 3.5 mm) grains with smooth undulating borders. Biotite, hornblende and feldspar are found engulfed as patches in quartz grains. Quartz grains co-existing with perthitic microcline display faintly shattered margins. Two types of quartz are noted: one with hexagonal outlines and smooth boundaries occurring as inclusions in plagioclase; the other type is more abundant with irregular morphology and characteristic undulose extinction and such quartz grains embay the adjacent grains.

Three distinct types of myrmekites are noted in the rocks studied. In the type I, worm-like quartz rods have smooth margins at which twinning terminates abruptly. The type II occurs concurrently with secondary twin lamellae which are continuous without any separation being caused by myrmekitic quartz with sutured boundaries. The type III myrmekites show clear or diffusive boundaries and are usually distributed along the later formed cracks within plagioclase grains. The secondary twin lamellae are also observed to terminate in myrmekite development. A fourth indistinct type of myrmekite occurs as part of a reaction growth zone of plagioclase grains enclosed by microcline. Biotite is often associated with myrmekites.

In the rock types studied, biotite occurs as thin elongated grains and are often replaced by chlorite. Hornblende is often corroded and replacement products of biotite and chlorite are noted. Sillimanite has rarely been observed in the gneisses.

3. Discussion

The textures and mineral parageneses reported in this paper provide some information as to the intrusive and metasomatic relationships which had characterized the Precambrian Vijayan Complex rocks of Sri Lanka. The early history of the rocks of the study area is scantily known. Crawford and, Oliver[6] considered Vijayan transformation to have taken place about 1150 Ma within a pre-existing lithology of granulite facies. The field studies in the area do indicate a metasedimentary sequence characterized by occurrences of hornblende biotite gneiss with rare sillimanite calc gneiss and thin quartzite bands implying perhaps an earlier Archean deep water marine facies.

Dome structures with cores formed of granites rich in mesoperthite suggest intrusive igneous activity at temperatures of well over 600°C.[10,11,13] The occurrence of broad twin lamellae of albite, carlsbad twinning and idiomorphic quartz inclusions in plagioclase seem to reflect the magmatic phase of domal granites.[10] The petrological observations and age determinations,[5,6] lend support to the existence of a relatively long period of cooling subsequent to the igneous phase. Such conditions were per-

haps conducive to the non perthitic microcline development and replacement of plagioclase by microcline resulting in decalcification and sericitization.[9] Towards the later stages of cooling, the formation of myrmekites of type I and late albite rims could be envisaged. The cooling processes were probably interrupted by a deformational phase resulting in the growth of deformed twin lamellae. Consequently the cooling magmatic body had fractured initiating emanations of K-rich fluids, which had seeped through cracks and joints of both the intrusion and the country rock. The ensuing K-feldspathization would form microcline devoid of relict plagioclase along cracks within plagioclase grains and also perhaps initiated the replacement of plagioclase by microcline and the formation of types II and III myrmekites. The potash metasomatism could well have resulted in the granitization of rocks which are now observed to be perthite free or poor. Most of the granites forming folded structures are believed to be so originated. Field observations of schlieren structures also attest to the metasomatic character of such granites.

4. Conclusions

The textural studies of some granites and gneisses of the Vijayan Complex lead the authors to propose the following sequence of events.

(a) Intrusion of magmatic bodies probably about 1150 Ma into a metasedimentary suite.

(b) Relatively long period of cooling characterized by plagioclase replacement, albite formation and myrmekite development.

(c) A period of deformation with the development of fine twin lamellae of plagioclase followed by fracturing of the cooling magmatic body and emanations of K-rich fluids.

(d) Potash metasomatism at PT conditions characteristic of amphibolite facies with the formations of some granites. (probably a phase of retrograde metamorphism as indicated by the alterations; (a) hornblende →biotite and chlorite and (b) biotite →chlorite and muscovite.)

Acknowledgements

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Studies on the Physical and Chemical Properties of Different Varieties of Rice Hulls Available in Sri Lanka

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Abstract: Rice hull is a by-product in paddy milling and is largely a waste material. It has been found that rice hull can be used as a raw material in a number of industries. On developing the utilizations of rice hull, it is very essential to study physical and chemical properties of rice hull. In the present study physical properties and chemical properties of six different varieties of rice hull have been investigated.

External appearance, dimensions and weight per grain are very important to identify the different varieties of paddy grains. Calorific value of rice hull is 4127 cal/g and hence it can be used as a fuel. Specific gravity and bulk density of rice hull are 1.32 and 165.3 mg/ml respectively. Silica is the major inorganic constituent of rice hull and is 9.94% by weight. Moisture, organic matter, K_2O, Na_2O, CaO MgO, Al_2O_3, Fe_2O_3, MnO, P_2O_5, $SO_3$and Cl of the different varieties of rice hull are 9.4%, 87.8%, 0.69%, 0.027%, 0.081%, 0.09%, 0.183%, 0.014%, 0.034%, 0.24%, 0.082% and 0.007% respectively. A variation of these constituents among the different varieties of rice hull was observed, which is attributed to the factors such as soil condition, type of fertilizers used and climatic conditions etc. The presence of amorphous silica in rice hull was detected by scanning electron micrograph and differential thermal analysis. Therefore rice hull can be used for making pozzolanic type of cements. The amorphous silica in rice hull converts into a crystalline form at higher temperatures. This indicates that to get active rice hull, rice hull should be burnt under 700° C.

1. Introduction

Rice hull, the outer covering of the rice grain is a by-product in paddy milling and forms 20 per cent by weight of the paddy milled. It is now largely a waste product. Only about 20 per cent of the available rice hulls are used as a fuel in some of the larger paddy mills.

Rice hulls are composed of 70 per cent organic matter, 20 per cent ash and 10 per cent moisture. At present research is in progress to make use of the ash obtained by burning rice hull under controlled conditions as a starting material for making cementitious binders by mixing with lime or portland cement. Rice hull ash consists

essentially of silica and this should be in an amorphous form if cementitious properties are to be developed by the binder. For the development of these products details of the chemical and physical properties of the hull are essential.

In 1928 Joachim [1] has analysed some of the varieties of rice hulls available in Sri Lanka. Subsequent to this no systematic work has been carried out to determine the physical and chemical properties of different varieties of rice hulls available in Sri Lanka. The present investigation was undertaken in order to make a systematic study of the physical and chemical properties of six different varieties of rice hulls available in Sri Lanka, namely BG 11-11, BG 94-1, BG 34-8, BG 90-2, BG 400-1 and BG 3-5.

2. Experimental

2.1 The specific gravity of the different varieties of rice hull were determined by evacuation method.[2]

2.2 The calorific values of the different varieties of rice hull were determined using an automatic adiabatic bomb calorimeter. Model of the instrument is autobomb CB-100.

2.3 The alkali oxides K_2O, Na_2O contents, CaO, MgO contents and Al_2O_3,[3] Fe_2O_3,[3] MnO,[4] P_2O_5,[4] contents were determined by Flame Photometer, Atomic Absorption Spectrophotometer and UV - Visible Spectrophotometer techniques respectively. Models of the instruments are Spectromom 381 L, Spectromom 190 A and Spectromom 361.

2.4 The SO_3 content was determined by a gravimetric method[5] (SO_4^{2-} as $BaSO_4$).

2.5 The chloride content was determined by a titrimetric method[6] (Cl^- as AgCl).

2.6 The Scanning Electron Micrographs of the rice hull samples were studied using a JSM 25 S Scanning Electron Microscope.

2.7 The differential thermal analysis and thermogravimetric curves of two varieties of rice hull were obtained using a differential thermal analysis equipment. Model of the instrument is MOM, Q - Derivatograph.

3. Results and Discussion

3.1 External Appearance, Dimensions and Weight per grain

Six different varieties of paddy were used for this study and the results are given in Table I. It was found that the paddy grain of variety BG 11-11 is the smallest one and it can be clearly identified from the others. Grains of BG 94-1, BG 90-2 and BG 400-1 are almost same and difficult to identify from each other. Weight per grain of BG 90-2 is the highest value.

3.2 Specific Gravity, Bulk Density and Calorific value of rice hulls

The specific gravity, bulk density and calorific value of six different varieties of rice hull are tabulated in Table II. Variation of these properties among the different varieties of rice hull are 1.17 - 1.40, 140.2 - 212.4 mg/ml and 4080.6 - 4199.9 cal/g respectively. The specific gravity and bulk density of BG 34-8 variety is the lowest with 1.17 and 140.2 mg/ml respectively.

3.3 Chemical Analysis of different varieties of Rice Hulls

The chemical analysis of different varieties of rice hull indicates that the organic matter is the major constituent. Out of the varieties analysed the organic matter content of BG 11-11 was the lowest with 86.2 per cent, whereas BG 90-2 contains the maximum amount about 91.4 per cent of organic matter.

The major inorganic component in rice hull is silica. The other constituent which were found in appreciable quantities are K_2O, Na_2O, CaO, MgO, Al_2O_3, Fe_2O_3, MnO, P_2O_5, SO_3 and Cl. BG 11-11, BG 94-1 and BG 34-8 which are mainly grown in the dry zone where the soil contains high alkali showed a high percentage of K_2O and Na_2O.

BG 34-8 which is mainly grown in dry zones like Polonnaruwa, Anuradhapura and Kurunegala shows a higher percentage of MnO. The variation of chemical constituents in these varieties of rice hull can be attributed to the soil conditon, climatic condition and type of fertilizers used.

Table 1.–External appearance, dimensions and weight per grain of different varieties of paddy grains.

Variety	Colour	Shape/Size	Length/ mm	Width/ mm	Thick-ness/ mm	Weight per grain mg/ grain
BG 11-11	Dark straw	Nearly round, small	5.48	2.85	2.00	12.71
BG 94-1	Dark straw	Oval, large one sharp end	9.19	2.73	2.04	23.30
BG 34-8	Dark straw	Oval, medium	7.47	3.05	2.14	23.13
BG 90-2	Dark straw	Oval, large	9.47	2.83	2.12	28.64
BG 400-1	Dark straw	Oval, large	8.48	3.06	2.13	26.89
BG 3-5	Straw	Oval, medium	7.70	2.63	1.88	17.94

Table 2.– Specific gravity, bulk density and calorific value of different varieties of rice hulls.

Variety	Specific gravity	Bulk density mg/ml	Calorific value cal/g
BG 11-11	1.33	152.4	4080.6
BG 94-1	1.36	212.4	4110.6
BG 34-8	1.17	140.2	4144.6
BG 90-2	1.33	175.7	4123.1
BG 400-1	1.34	164.1	4199.9
BG 3-5	1.40	146.9	4101.1

Table 3.– Chemical composition of different varieties of rice hull.

Variety	BG 11-11	BG 94-1	BG 34-8	BG 90-2	BG 400-1	BG 3-5
H_2O	8.7079	8.8004	9.9438	9.4619	9.0888	10.5338
Organic	86.2287	86.4432	87.1062	91.3466	90.1561	86.7337
SiO_2	10.8515	11.6061	10.3958	6.5866	8.7730	11.4362
K_2O	1.0080	0.7586	0.9638	0.5029	0.3023	0.5744
Na_2O	0.0347	0.0215	0.0186	0.0210	0.0181	0.0462
CaO	0.0850	0.1020	0.0779	0.0653	0.0738	0.0805
MgO	0.1174	0.0707	0.0910	0.1230	0.0652	0.0730
Fe_2O_3	0.0027	0.0188	0.0084	0.0321	0.0050	0.0177
Al_2O_3	0.2840	0.1502	0.2823	0.0758	0.2775	0.0254
MnO	0.0161	0.0201	0.0729	0.0358	0.0346	0.0265
P_2O_5	0.2775	0.1917	0.2408	0.3758	0.1082	0.2180
SO_3	0.2096	—	0.1363	0.0767	—	0.0690
Cl	0.0016	0.0207	0.0104	0.0015	—	0.0103
Total	99.1415	99.4036	99.4044	99.2431	99.8118	99.3119

Chemical constituents - per cent by weight moisture free basis.

The chemical analysis of the six different varieties of rice hull studied are given in Table 3.

3.4 Scanning Electron Microscope Studies

A study of the electron micrographs show the cellular structure of the different varieties of rice hull and the presence and distribution patterns of amorphous silica in the cellular structure. The distribution pattern of amorphous silica varies from variety

to variety and this is useful to characterize the different varieties of rice hull. Another significant feature of each variety of hull is the silica fibres arising from the surface of the cellular structure in different varieties. White areas of these photographs indicate the amorphous silica.

The scanning electron microphotographs of the different varieties of rice hull studied are given in Figure 1.

3.5 Differential Thermal Analysis (DTA) and Differential Thermogravimetric (DTG) studies of different varieties of Rice Hull

DTA curve of BG 11-11 shows a broad exothermic phase transformation of amorphous silica to crystalline silica and completes at 700°C (973 K).

The DTA curve of BG 94-1 is also similar to BG 11-11 but the complete transformation of amorphous to crystalline occurs at a higher temperature of 760°C (1033 K).

These results clearly indicate that the transformation of amorphous silica in rice hull to a crystalline form occurs with increase of temperature.

DGT curves of BG 11-11 and BG 94-1 show two significant peaks at 100°C (373 K) and others at 250°C (523 K) and 260°C (533 K) respectively. The peak, at 100°C is due to the loss of moisture. The peaks at 250°C and 260°C are broad and indicate the loss of organic matter during a long range of temperature.

The DTA and DTG curves of the rice hull of the varieties BG 11-11 and BG 94-1 are given in Figure 2.

4. Conclusion

The present study clearly shows the variation of physical properties and chemical composition of the six different varieties of rice hull.

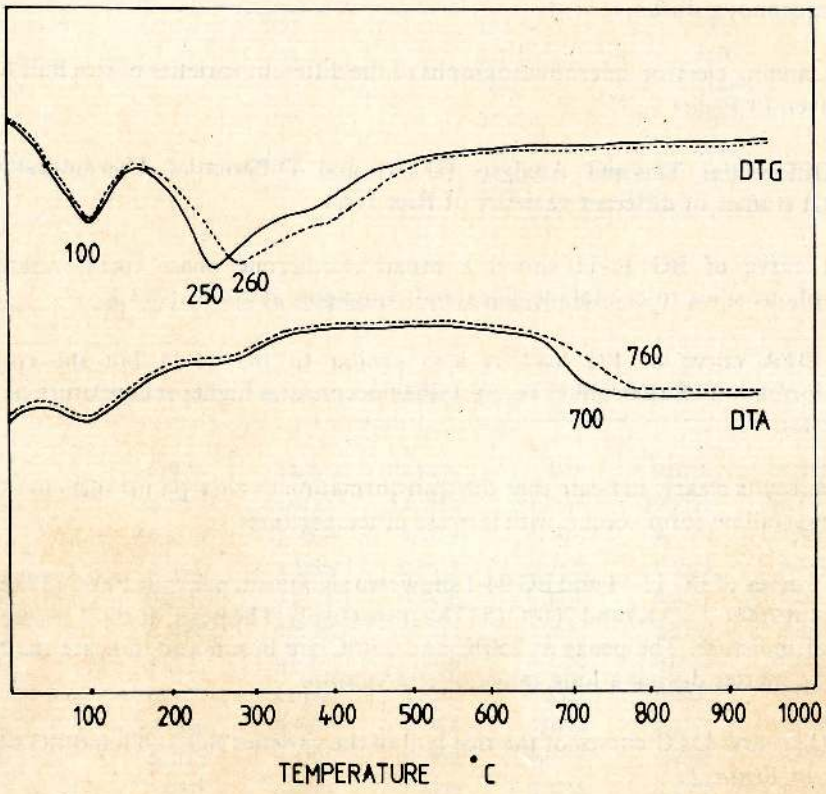
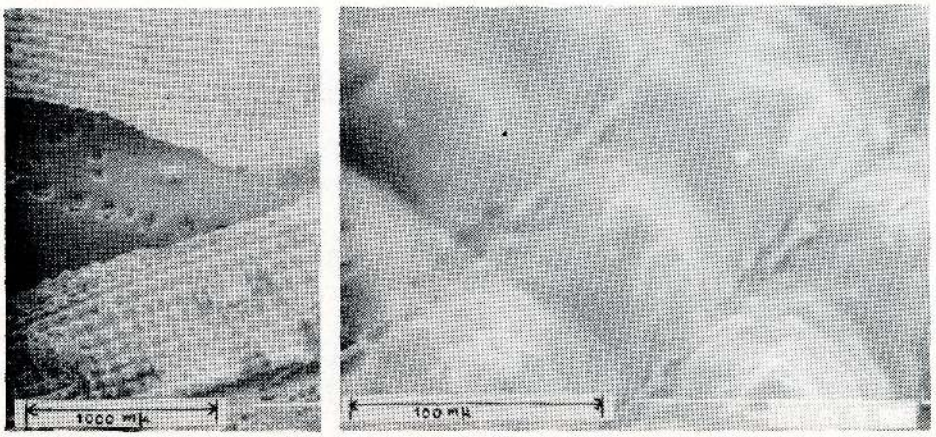
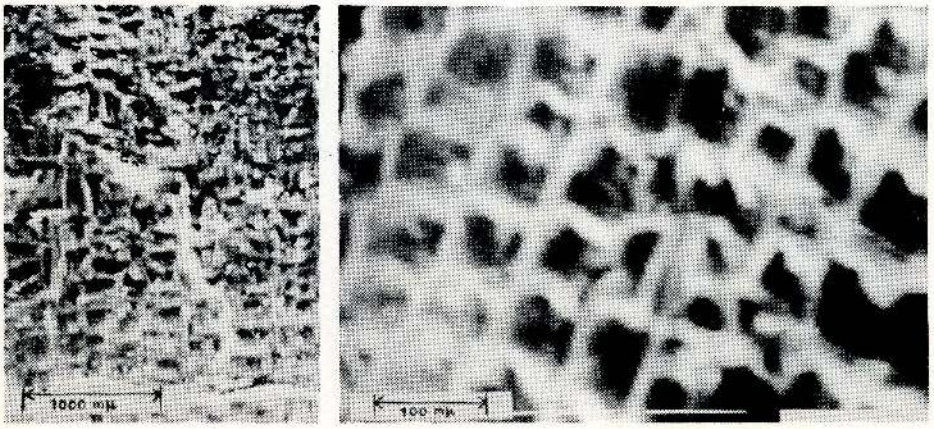


Figure 1. DTA and DTG curves of rice hull

——— BG 11-11
-------- BG 94-1

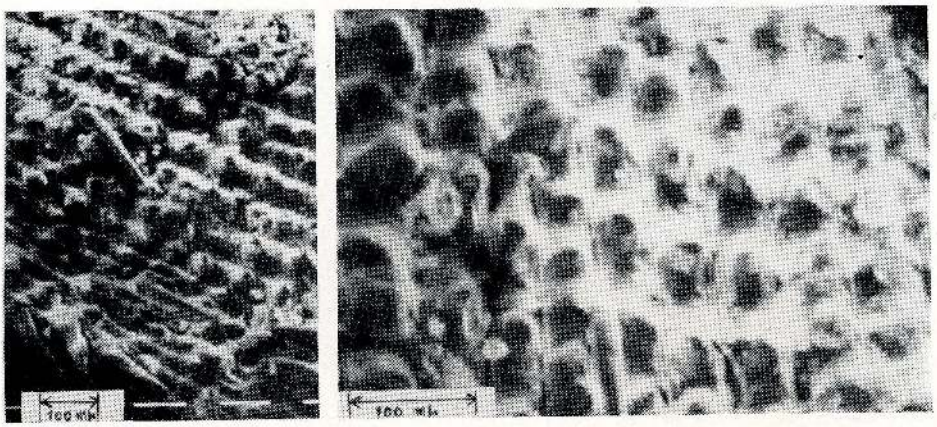


VARIETY BG 11-11

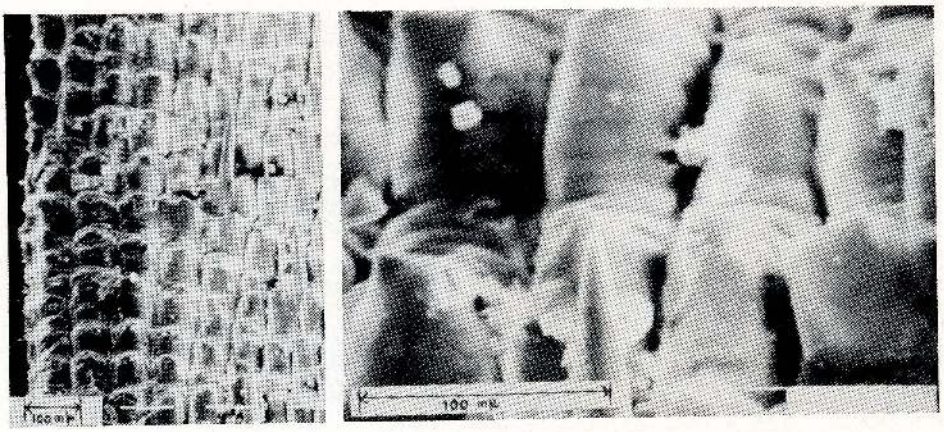


VARIETY BG 94-1

Figure 2. Scanning electron micro photographs of rice hull

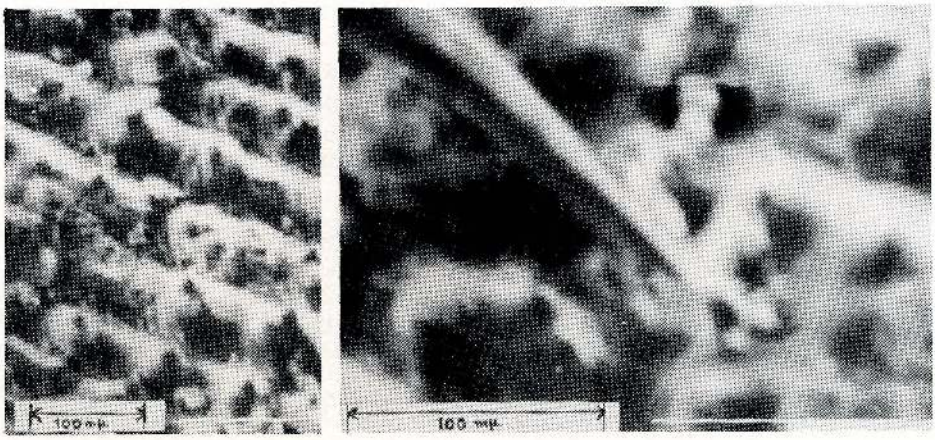


VARIETY BG 34-8

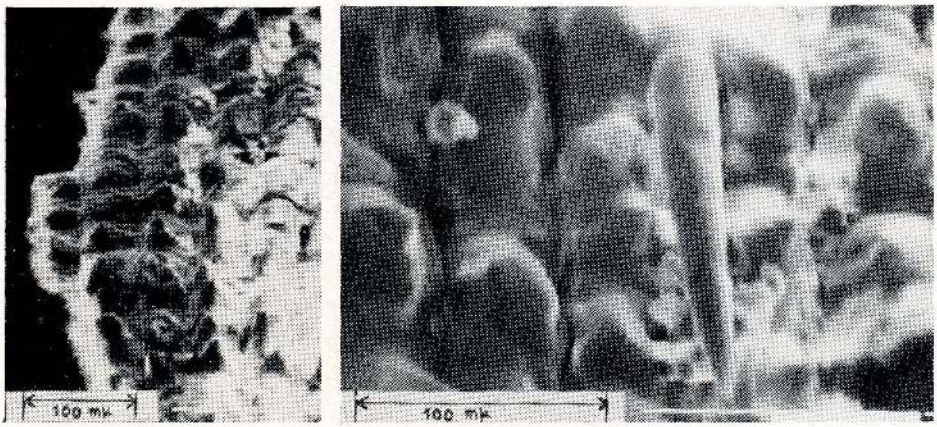


VARIETY BG 400-1

Figure 3. Scanning electron micro photographs of rice hull



VARIETY BG 90-2



VARIETY BG 3-5

Figure 4. Scanning electron micro photographs of rice hull

4.1 External Appearance, Dimensions and Weight per grain

These results are very important to identify the different varieties of paddy grains. The grains of BG 11-11, BG 34-8 and BG 3-5 can be clearly identified from the others. Average value of weight per grain is 22.1 mg/grain.

4.2 Specific Gravity, Bulk Density and Calorific Value

The average calorific value of rice hull is 4127 cal/g. The hull with high percentage of organic matter BG 400-1 shows the highest calorific value of 4200 cal/g.

The specific gravity and the bulk density of BG 34-8 variety is the lowest with 1.17 and 140.2 mg/ml respectively.

Average values of specific gravity and bulk density are 1.3211 and 165.3 mg/ml respectively.

Individual values show a slight variation from the average values.

4.3 Chemical Composition of different varieties of Rice Hull

Moisture content of the different varieties of rice hull varies from 8.7% to 10.5%. The major constituent of rice hull is the organic matter and that varies from 86.2% to 91.4% among the varieties and has an average value of 88%. Silica (SiO_2) is the major inorganic constituent of the rice hull and varies from 6.6% to 11.6%. Average value of silica of the different varieties of rice hull is 9.94%. Other inorganic constituents K_2O, Na_2O, CaO, MgO, Al_2O_3, Fe_2O_3, MnO, P_2O_5, SO_3 and Cl are also found in detectable amounts in the different varieties of rice hull. The variations of these constituents among the different varieties of rice hull are 0.3% - 1%, 0.2% - 0.05%, 0.07% - 0.1%, 0.07% - 0.12%, 0.03 - 0.28%, 0.003% - 0.03%, 0.02% - 0.07%, 0.11% - 0.38%, 0.07-0.21% and 0.002% - 0.02% respectively. The average values of each constituent are 0.69%, 0.027%, 0.081%, 0.09%, 0.183%, 0.014%, 0.034%, 0.24%, 0.082% and 0.007% respectively. These average values clearly indicate that there is a significant variation of the constituents K_2O, Na_2O, Al_2O_3, Fe_2O_3, MnO, P_2O_5, SO_3 and Cl of the different varieties of rice hull. Therefore it is important to know the variation of this kind of constituents in rice hull before studying the strength of cements obtained from the different varieties of rice hulls. The constituents SO_3 and Cl are not found in all the varieties. The variation of these constituents in different varieties of rice hull mainly depends on factors like soil condition, climatic condition and type of fertilizers used etc.

4.4 Scanning Electron Microscope Studies

The Scanning Electron Microscope studies indicated the presence of amorphous silica and that its distribution pattern could be utilised to distinguish the different varieties of rice hull. The distribution pattern of amorphous silica in each variety of hull is characteristic and could possibly be a genetical feature.

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The Genesis of Thorium-Rich Monazite Placer Deposits in Sri Lanka

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Abstract: The monazite placers of Sri Lanka are among the world's most thorium rich sediments. This study of the stream sediments and rocks from an area in the southwest of Sri Lanka shows that the highly metamorphosed aluminous schists and gneisses and also granitoid rocks of the Highland and South-west Groups of the Precambrian of Sri Lanka are the probable source rocks for the thorium-rich monazite. The magmatic fluids known to have pervaded the aluminous sediments during the intense folding and metamorphism under granulite facies conditions are considered to have been thorium rich. The P-T conditions of metamorphism proved to be ideal for the formation of a variety of gem minerals including gem monazite and other associated heavy minerals.

1. Introduction

Gems, and to a lesser extent gold, are increasingly being found in the sediments of streams draining the central Highland Group of rocks in Sri Lanka. Due to the recent large-scale gem mineral discoveries the study of gemstones of Sri Lanka has been the subject of several recent studies.[4, 11, 13, 17] It has also been found that in some sediments gems are closely associated with gold.[5] Whereas much emphasis has been placed on gemstones as a useful export commodity, the thorium bearing monazite stream sediments of Sri Lanka have not been given the same consideration and indeed their potential is great as shown by the recent work of the Geological Survey of Sri Lanka.

This paper deals with the genesis of thorium-rich heavy minerals, particularly monazite, in the stream sediments of the Bentota River, in the southwest of Sri Lanka. This stream drains an area containing abundant gemstones and some alluvial gold. The area under consideration is a mineralized terrain and large alluvial or 'beach' deposits of monazite are found at the mouth of the Bentota River. Uranium and thorium are known to be found in relatively high concentrations in this area. Using

the abundance of the heavy mineral suites supplemented by petrographic studies of rock thin sections, an attempt has been made to trace the source rocks of the thorium-rich monazite.

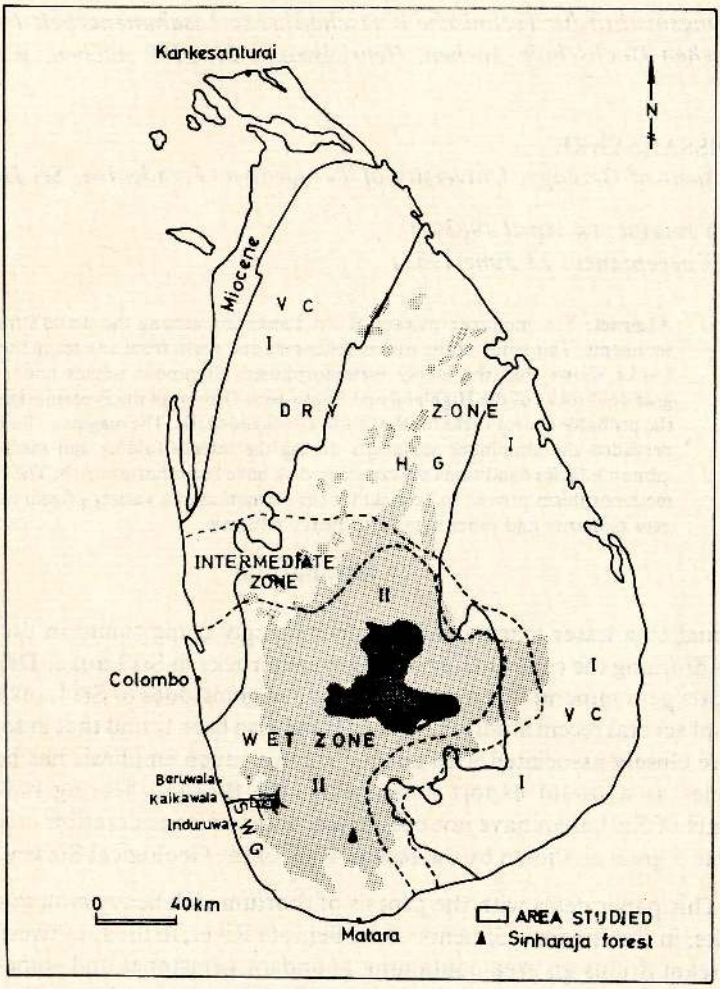


Figure 1 – Map showing the area studied. VC-Vijayan Complex; HG - Highland Group; SWG - Southwest Group. 1 - Lowlands II - Uplands III - Highlands.

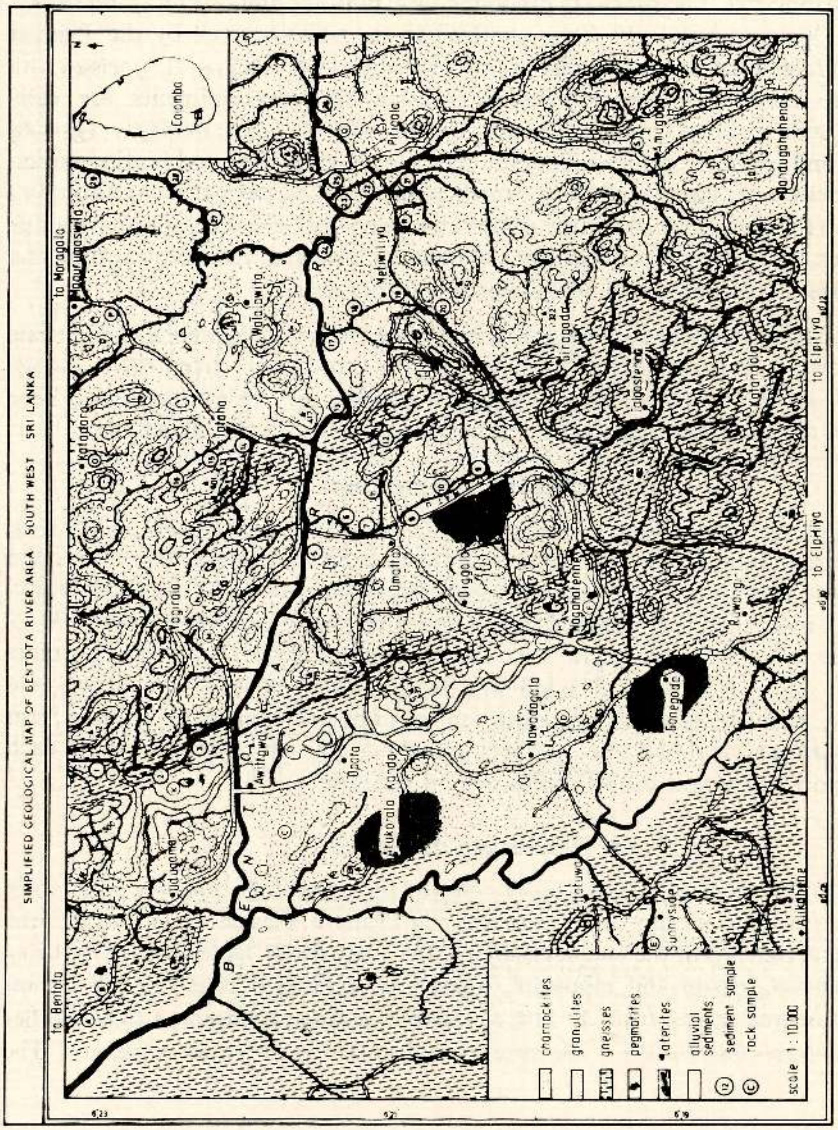


Figure 2 – The geological map of the area studied and the sampling points. The inset shows the location of the area.

2. General geology of the area

Figure 1 illustrates the location of the area studied with respect to the general geology and physiography of Sri Lanka. The area lies within the Southwest Group of rocks comprising mainly of wollastonite bearing calciphyres, cordierite gneisses with sillimanite, corundum and sapphirine as accessory minerals. Migmatites, charnockitic gneisses and granitoid rocks are also common in the Southwest Group.

The major part of the area is drained by the Bentota river and its complex system of tributaries. The rocks are predominantly plutonic and of Precambrian age, superficial Quaternary deposits being confined to the valleys carved by the Bentota river. The Precambrian rocks comprise mainly of charnockites and granitic gneisses with subordinate metasedimentary bands.[3,16] Among the metasediments are calc-granulites and gneisses, quartzites and quartz schists, quartzfeldspar (garnet) granulites and gneisses, garnet-sillimanite (cordierite) granulites and biotite-garnet-graphite gneisses. As noted by Cooray,[3] small granitic bodies, pegmatites and dolerites intrude into the crystalline rocks, the pegmatites being both charnockitic and granitic in character. It has been found that some of the granitic pegmatites carry thorium and uranium bearing minerals such as monazite and thorianite.

Monazite occurs as a seasonal beach sand deposit at Kaikawala and Beruwala (Figure 1) where it is associated with ilmenite, garnet, rutile and zircon. Even though monazite is mined on a small scale at Kaikawala beach, very little attention has been paid to the monazite bearing stream sediments as studied in this paper.

3. Materials and methods

Figure 2 illustrates the sampling locations. A total of 31 sediment samples and 19 rock samples were obtained. The sediments were taken from tributaries very close to the main Bentota river since a very dense mangrove vegetation prevented the accessibility. Close to the main river the distance between sampling points was between 300 - 400 m and further away from the main river the distance between the sampling points increased as shown in Figure 2. The sediment samples were obtained by making a hole 1 m^2 in the sand and cutting a thin groove so as to obtain composite samples from different stratigraphic horizons. Approximately 5 kg of sediments from each sampling point were sent to the laboratory for analysis.

4. Results and discussion

The screened fractions of the total sediments and the percentage of heavy minerals in the various fractions are illustrated graphically in Figure 3. Figures 4a-4d illustrate the heavy mineral contents of the samples analysed, the major heavy minerals observed being ilmenite, garnet, zircon and monazite. Ilmenite in general is found in the highest concentration and ranges from 30-71% of the total sediment. Based on these studies the heavy mineral distribution in the streams studied can be shown as in Figure 5. The

highest heavy mineral concentrations are found in the regions of Gonagala and Omatu Ela and also Pitigala Ganga (Figure 2), all the heavy minerals studied showing a similar pattern of distribution.

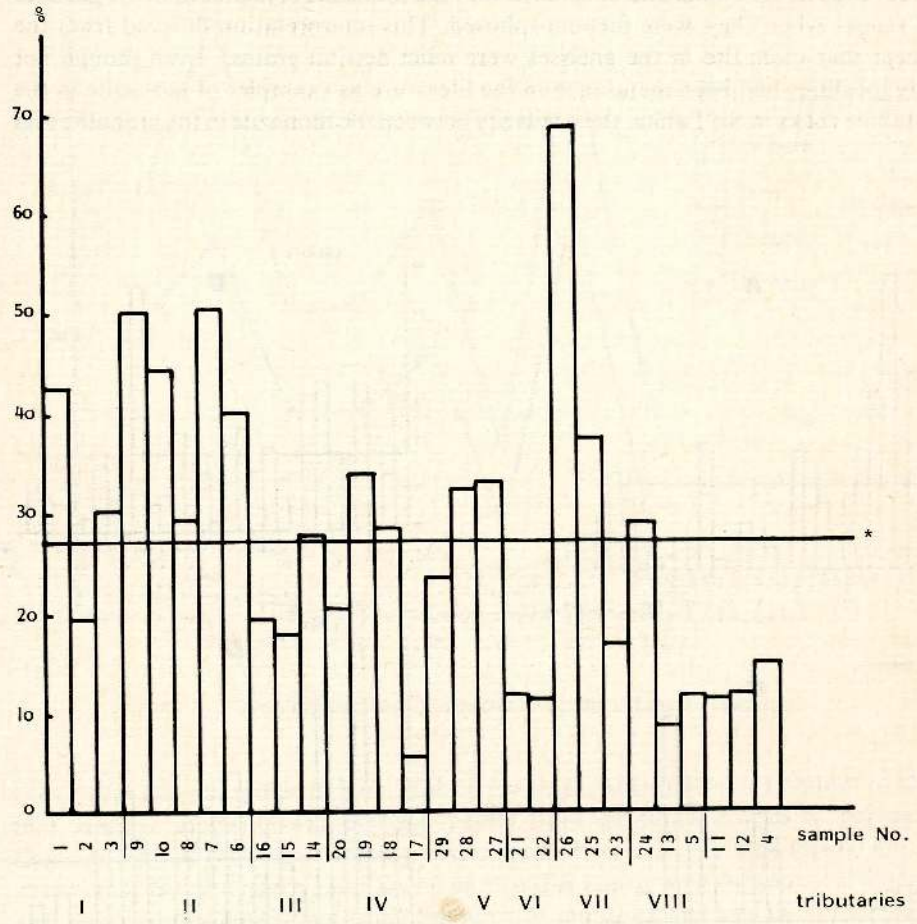
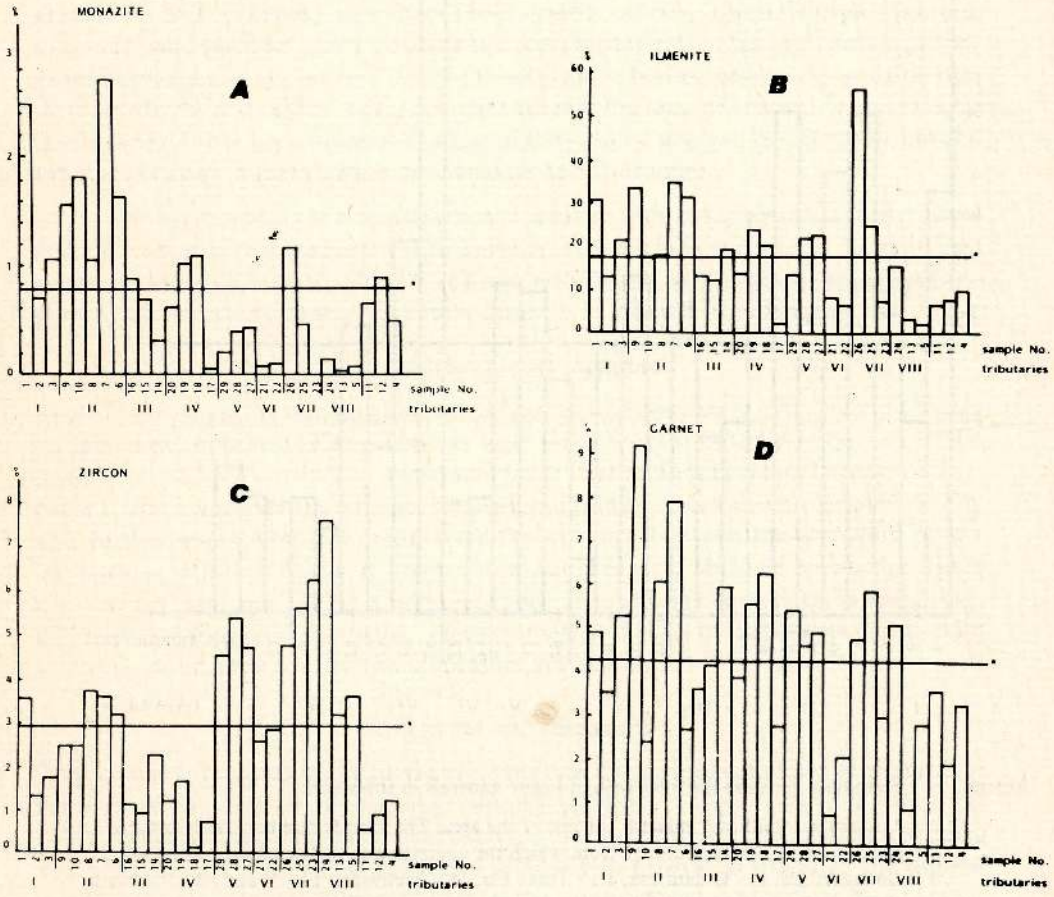


Figure 3 – Histogram showing the total wt% of heavy minerals in tributaries.

* Average total heavy mineral content of the area. The sample numbers refer to those as given in fig. 2. The tributaries from which the samples were collected are as follows. I - Gonagala Ela, II - Omatu Ela, III - Totas Ela, IV - Metiwiliya Ela, V and VI - Palawatta Ganga VII - Pitigala Ganga VIII - Bentota River.

Monazite in particular was well known as forming placer deposits in Sri Lanka as far back as 1903.[2,6] A further point of interest was the fact that this monazite contained an average of 10% ThO_2, which was higher than the average of commercial monazite from sources elsewhere in the world.[15] Overstreet[15] interpreted this high average for ThO_2 in the monazite to reflect the uniformly plutonic character of the source rocks in Sri Lanka and concluded that the monazite crystallized in the gneisses and schists when they were metamorphosed. This interpretation differed from the concept that monazite in the gneisses were relict detrital grains.[1] Even though not many localities had been mentioned in the literature as examples of monazite in the crystalline rocks in Sri Lanka, the similarity between the monazite in the granulite and



Figures 4a-d — Histograms showing the heavy mineral contents of the samples analyzed.

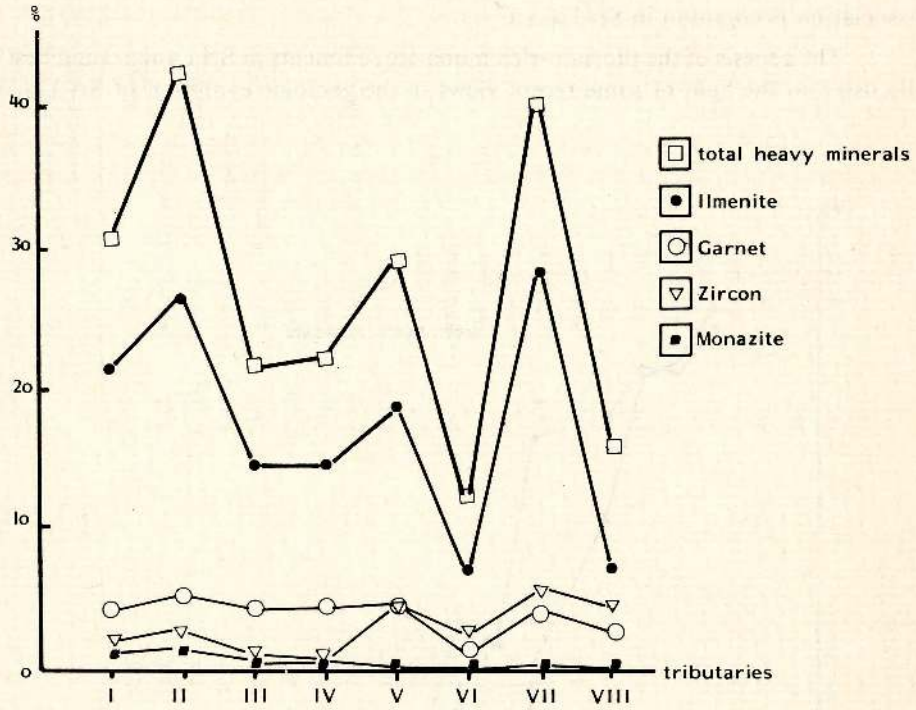


Figure 5 – Distribution of heavy minerals along the tributaries studied.

the typical alluvial monazite was used by the Imperial Institute of London[9] to show that alluvial monazite was derived mainly from granulite instead of pegmatite. Dunstan[7] showed that the schists, gneisses, granulites, acid charnockites and granitic rocks in the Southwestern and Central parts of Sri Lanka were the source of ilmenite-rich concentrates containing small amounts of monazite and variable quantities of zircon and rutile. Cooray[3] in his study of the geology of the Alutgama region found that monazite was introduced into the host rocks during widespread granitization that affected the area in the later stages of its plutonic history.

A study of nearly 20 thin sections of rocks from the area investigated showed that the gneisses and the granulites in particular, contained the heavy minerals observed in the alluvium. It is of interest to note that sillimanite was also found in the area studied could also be rich in heavy minerals. Coates[1] considered this source to have supplied much of the monazite to the streams and beaches of Sri Lanka. One advantage of identifying a source terrain and working from it toward the placer deposit is that the same source terrain may contribute to several types of residual and

placer deposits.[8] Indeed, the high grade metamorphic rocks of the southwestern and central parts of Sri Lanka could well be the source rocks for a variety of placer deposits including the gem and gold bearing gravels.[13] Some minerals of gem quality such as zircons, like monazite are considered to be invariable associates of gold and this association is common in Sri Lanka.

The genesis of the thorium-rich monazite sediments in Sri Lanka could best be discussed in the light of some recent views in the geologic evolution of Sri Lanka.

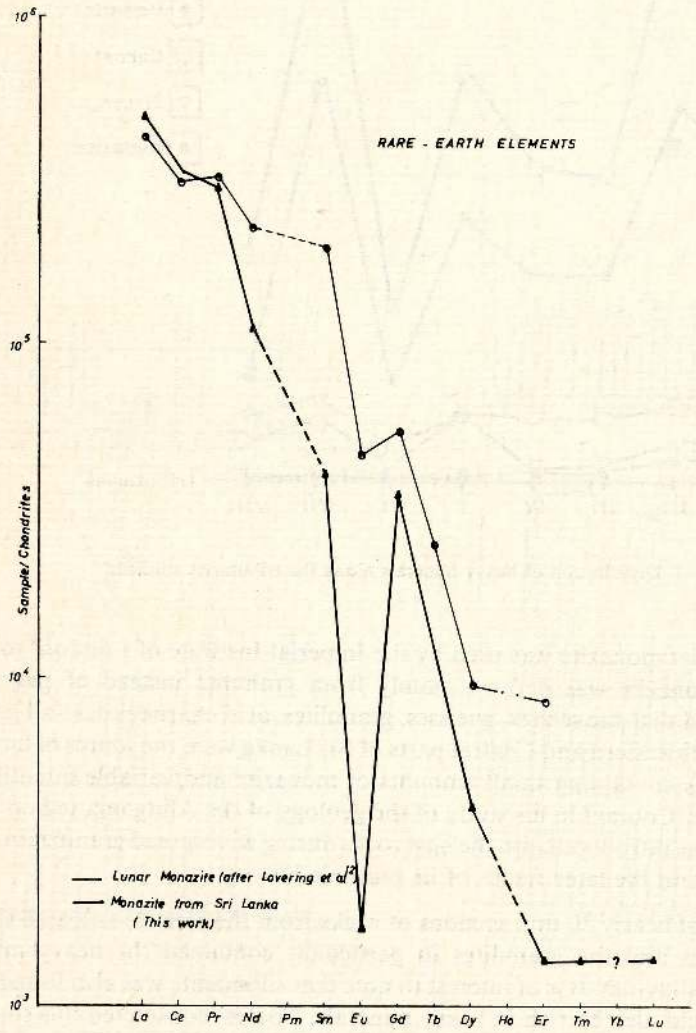


Fig 6: Chondrite normalized rare-earth elements of the monazite samples.

Table 1. – Chemical analyses of monazite.

	A				B		C	D	
	Wt%				Wt%			ThO_2 in monazite from metasedimentary rocks	
	1	2	3	4					
ThO_2	8.98	9.64	9.77	9.47	SiO_2	0.4	Ce_2O_3	30.45%	*Facies*
Ce_2O_3	26.87	28.03	27.30	27.55	ThO_2	11.6	P_2O_5	24.50%	Greenschist 0.4%
La_2O_3	28.26	29.79	30.79	31.45	U_3O_8	0.4	La_2O_3	14.56%	Alb-epidote-amphi. 3%
Y_2O_3	1.37	0.74	0.74	0.87	Ce_2O_3	28.7	Nd_2O_3	12.48%	Amphibolite 4.9%
TiO_2	1.34	0.48	0.32	0.32	La_2O_3	21.7	ThO_2	9.49%	Granulite 8.9%
ZrO_2	0.82	0.29	0.14	0.13	Nd_2O_3	6.0	Pr_6O_{11}	3.62%	
Al_2O_3	0.96	1.44	1.00	0.50	Pr_6O_{11}	1.9	Sm_2O_3	1.64%	
CaO	0.72	0.76	0.44	0.25	Sm_2O_3	0.6	K_2O	1.21%	D: After Overstreet (1967)
MgO	0.05	0.07	0.10	0.09	Gd_2O_3	0.09	ZrO_2	1.35%	
Fe_2O_3	0.89	0.51	0.67	0.59	Dy_2O_3	0.2	Gd	7500 ppm	
PbO	0.09	0.05	0.11	0.22	Ho_2O_3	0.05	Ba	5000 ppm	
SnO_2	n.d	0.07	0.01	0.02	Er_2O_3	nt.fd	U	3640 ppm	
MnO	0.01	nil	nil	nil	Y_2O_3	nt.fd	Cr	2000 ppm	
P_2O_5	28.06	26.74	27.09	27.25	Al_2O_3	0.02	Cl	2000 ppm	
SiO_3	1.02	1.48	1.57	1.21	Fe_2O_3	nt.fd.	Dy	1032 ppm	
U_3O_8	n.d	n.d	n.d	0.08	Cr_2O_3	nt.fd	Na	538 ppm	
					V_2O_3	nt.fd	Tb	437 ppm	
Total	99.44	100.09	100.05	100.00	CaO	1.0	Er	230 ppm	
					MgO	nt.fd	Yb	123 ppm	
					Pb_3O_4	0.1	Eu	104 ppm	
					P_2O_5	27.1	Co	100 ppm	
							Mn	85 ppm	
						100.16	Lu	35 ppm	
							Sb	25 ppm	
							Sc	2 ppm	

A: After Cooray (1965)
1: beach sand, Induruwa
2: beach sand, Kaikawala
3: beach sand, Beruwala
4: beach sand, Beruwala
n.d: not detected.

B: After Jobbins *et.al* (1977)
nt.fd: not found

C: This work; neutron activation analysis. (Std. dev. ± 7%)
Analyst: M. S. Rupasinghe

The central Highland Group is considered to be a former oceanic basin flanked by the eastern and western parts of the Vijayan Complex (Figure 1), representing two Precambrian microplates which were closing up at varying rates.[14] The oceanic basin was continuously filled with sediments of the sandstone-shale-limestone sequence. An increase in the rate of subduction caused the metamorphism of the sediments in the part of the basin lying closer to the trench at the eastern part. This was followed by the formation of granulite facies metamorphic rocks in the basin and the further convergence of the microplates deformed the basin producing tight folds, particularly in the Southwest Group where monazite bearing rocks occur. The deformed and metamorphosed oceanic crust penetrated parts of the metasedimentary cover producing different facies of the Southwest Group. This was accompanied by the emplacement of magmatic fluids produced by the basement remobilization associated with collision.

Overstreet[15] outlined many features of monazite in schists and gneisses that show that it is of metamorphic origin. These features as given below are of particular significance in the genesis of monazite in the metamorphic terrain of Sri Lanka.

(a) Direct relation between amount of monazite in metamorphic rock and grain size of original sediment.

(b) Inverse relation between the range in grain size of particles of monazite in paraschists and paragneisses and the possible size range in the original sedimentary rock.

(c) Correlation between physical properties of monazite and metamorphic grade of host rock.

(d) Inclusions in monazite identical with metamorphic minerals in host rock.

(e) An inverse relation between monazite, allanite and other thorium bearing minerals in metamorphic rocks and a direct relation between the amount of thorium in monazite and the grade of regional metamorphism.

In the area studied and in the rocks of the Southwest Group of Sri Lanka in general, monazite occurs primarily as an accessory mineral in a variety of gneissic and granitoid rocks associated with migmatites. Cooray[3] and Rupasinghe[16] observed the occurrence of monazite in pegmatites and in migmatized charnockites. In the light of the above mentioned facts it seems probable that monazite was introduced into the host rocks during the intense magmatic activity associated with the metamorphism of the aluminous sediments under granulite facies conditions. These conditions proved very favourable for the genesis of minerals of gem quality such as garnet, sillimanite, andalusite, cordierite, zircon, corundum, etc. It is of interest to note that monazite of gem quality had also been found in Sri Lanka.[10]

The thorium content of Sri Lanka monazite is very high and is exemplified by a comparison with the average ThO_2 contents for different metamorphic facies (Table1). As shown in Table 1, apart from high thorium contents the rare-earth element concentrations are also extremely high. As shown in Figure 6, it is of interest to compare the rare-earth element contents of monazite from Apollo 11 basalt[12] 11047, 68 and those of monazite from Sri Lanka (this work). A general similarity is seen with a more pronounced Eu anomaly in the Sri Lanka monazite samples. It is seen from the chondrite normalized REE fractionation pattern that the light REE's (La to Sm) are highly enriched relative to the heavy REE's (Gd to Lu). Lovering *et al*[12] concluded that crystallization of monazite from late-stage liquids formed during crystallization of lunar igneous rocks could lead to these liquids to become increasingly depleted in the light REE's relative to the heavy REE's.

5. Conclusions

The foregoing study shows that thorium-rich monazite has been derived from a variety of gneisses and granitoid rocks in the Southwest and Highland Groups of Sri Lanka. The P-T conditions of metamorphism and the introduction of magmatic fluids during the deformation and metamorphism of the aluminous sediments resulted in the introduction of thorium-rich fluids and the formation of monazite. The extensive weathering under humid tropical conditions and subsequent transportation localized the heavy mineral-rich alluvial placers in Sri Lanka as exemplified by the area of this study. As shown by Goldsmith and Force[8], geologic maps that show metamorphic zones and describe the kinds of rocks that make up a metamorphic terrain should serve as useful prospecting tools. The Southwest Group of Sri Lanka provides a good case in point and detailed mapping of the area would certainly prove worthwhile in the discovery of mineral deposits useful for Sri Lanka.

Acknowledgements

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Effect of Storage (in small Packages) on Volatile Oil and Piperine Content of Ground Black Pepper

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Abstract: The composition of the essential oil of Sri Lanka black pepper and changes in composition on grinding and storage in various packaging materials are reported.

1. Introduction

Pepper *(Piper nigrum L.)* is one of the more important spices grown in Sri Lanka. Sri Lanka pepper is reported to have special characteristics[6] (high volatile oil and piperine) which gives it a special position in world trade. Traditionally, pepper has been exported as whole black pepper, however with increasing competition in the world market the need for product diversification has arisen. Among the new forms of pepper for the export market are: ground pepper (black and white), canned and pickled green pepper, buff and white pepper (containing pericarp) and dried green pepper.[8]

The original systematic study of the volatile constituents of pepper by Jennings and co-workers[8,9,11,12,13,15] was carried out using Sri Lanka pepper. However, these studies were directed mainly towards the confirmation of the presence and identification of the constituents of the volatile oil. Although one study[16] gave a quantitative picture of the oil of Sri Lanka pepper, the report is nearly 20 years old. Indian varieties, on the other hand, have been extensively studied and the subject has been given much prominence in a recent review.[6]

Thus there is a case for investigating the composition of volatile constituents of Sri Lanka pepper based on gas-liquid chromatography notwithstanding the fact that the subject was considered in part in a paper on quality control.[15]

Past studies[1,2,3,4] on the packaging of ground black pepper have revealed that polyethylene alone does not fully meet the requirements of a ground pepper and in order to retain volatiles, select laminates must be used. Chinenova *et al.*[4] reported reduced losses in lacquered cellophane, while Balsubrahmanyam *et al*[3] found that low density polyethylene (LDPE) and high density polyethylene (HDPE) were poor barriers for volatile oil while ground pepper in a polyester / polyethylene lined carton

lost the least oil. Balsubrahmanyam and Kumar[2] reported a 5 month-shelf life using a paper / aluminium foil / polyethylene laminate as well as a cellophane / LDPE double pouch. Balsubrahmanyam*et al* [1] also reported that high temperature storage in LDPE and HDPE resulted in 'sticky' packages and oil deposition on the surface of the packaging material.

Despite this knowledge, ground pepper continues to be marketed in Sri Lanka in single pouch LDPE.

Our study on packaging of this material appeared important for two reasons :-

(i) To our knowledge the effect of storage in various packaging material on essential oil composition has thus far not been reported.

(ii) It was of interest to determine in more detail the shelf-life of ground pepper in LDPE as this was the packaging material currently in use in this country.

In this paper we report the following:

(i) A glc analysis of Sri Lanka pepper oil,

(ii) The effect of commercial grinding on volatile oil content and composition,

(iii) An analysis of volatile oil of selected ground pepper samples found in the local market,

(iv) The effect of storage of ground pepper in different gauges of single pouch LDPE packs, an Al foil laminate and tinned cans on the composition of pepper oil,

(v) The effect of storage (in these packages) on piperine (the pungent principle of pepper).

2. Experimental

2.1 Raw material

Graded black pepper (FAQ) meant for the export market was purchased from G. S. Chatoor and Co.,Ltd. Other samples were collected from Wariyapola Group Estate, Matale (a plantation of genuine and unmixed Sri Lanka pepper). The latter was dried at 50-60°C in a forced draft oven for 48 h. Ground pepper samples from different sources were purchased from the open market.

Table 1. – Volatile constituents of Sri Lanka pepper and effect of grinding

Component	r.r.t	Export sample (g/kg pepper)	% oil	Export sample after commercial grinding (g/kg pepper)	Estate sample g/kg pepper	% oil
1. ∝- pinene	0.51	9.3	17.0	0.4	9.4	11.2
2. camphene	0.60	0.2	0.4	+	0.1	0.1
3. β-pinene	0.70	5.6	10.2	0.5	10.3	12.1
4. Sabinine	0.14	9.2	16.8	0.8	15.5	19.2
5. ∝ & β phellandrene	0.82,0.87	4.8	8.7	0.6	4.1	4.8
6. myrcene	0.92	1.1	2.0	0.3	2.4	2.9
7. limonene	1.00	9.6	17.4	1.5	16.5	19.5
8. δ - terpenine	1.17	0.2	0.4	0.2	1.5	1.7
9. unidentified	1.21	0.1	0.2	+	0.5	0.5
10. p-cymene	1.30	0.4	0.1	0.1	+	+
11. terpinoline	1.35	0.2	0.4	0.1	0.7	0.9
12. unidentified	2.75	0.2	0.4	+	+	+
13. unidentified	2.85	+	+	+	+	+
14. l-terpenin-4-ol	3.02	0.3	0.6	0.7	0.3	0.4
15. β- elemene	3.10	1.5	2.7	0.9	1.1	1.3
16. linalool	3.35	0.6	1.1	0.4	1.2	1.5
17. unidentified	3.62	0.7	1.3	0.1	3.1	3.7
18. β-caryophyllene	3.81	6.0	10.9	8.7	10.6	12.5
19. unidentified	3.89	0.1	0.2	+	—	—
20. β-farnesene	4.09	0.8	1.5	0.5	0.7	0.9
21. humulene	4.15	0.3	0.5	0.1	0.3	0.4
22, 23. unidentified	4.29, 4.0	0.8	1.5	0.9	—	—
24. β-bisobolene	4.50	0.2	0.4	0.6	1.8	2.1
25. unidentified	4.58	0.8	1.5	0.6	0.3	0.4
26, 27 cis & transcarveol	4.71, 4.81	+	+	+	0.1	0.1
28-31. unidentified	4.96-5.48	0.3	0.5	0.7	0.3	0.4
32. methyl eugenol	5.59	0.5	0.9	+	0.7	0.8
33-48. unidentified	5.65-8.42	0.4	0.8	1.9	1.9	2.2

Results are expressed in terms of g component/kg dry wt. black pepper and % pepper oil. Retention time of limonene = 420 Sec.

Percentage of oil on dry weight pepper for (1) Export sample, (2) Export sample after grinding and (3) Estate sample were 5.5, 2.0 and 8.5% respectively.

Operating conditions of glc : Instrument model, Varian 2440; recorder model, Varian 9176; Integrator model, Pye Unicam-DP 88 (computing integrator); Detector, FID; Column length (m) 3; Column diameter (mm), 3; Programming, 60 - 80°C (2°C min^{-1}). 80 - 200°C (4°C Min^{-1}) and hold; Injector temperature, 200°C; Detector temperature, 240°C; Carrier gas (Helium), 30 ml min^{-1}; Hydrogen supply, 25 ml min^{-1}; Air supply, 55 ml min^{-1}; Recorder, 1 mV; Chart speed, 5 mm min^{-1}.

2.2 Grinding and packing

Black pepper was ground in a commercial hammer mill and sieved (150 μm sieve). The ground pepper (250g) was immediately packed in the following packages:

(i) LDPE - 25, 50, 75, 100, 125 and 175 μm (ii) HDPE - 15 μm (iii) Al foil (0.1 mm) / LDPE 75 μm laminate (iv) lacquered tinned cans. These packages were stored in a wooden cupboard at ambient temperature (27-31 ^{0}C).

2.3 Moisture content

Moisture content was determined by the Dean and Stark (toluene) method.[5]

2.4 Oil content

Oil content was determined using Clavenger light oil arm after hydro-distillation for 4h. For the determination of oil content grinding was preceded by freezing. This procedure prevented oil loss.

2.5 Oil composition

Oil composition was determined using a Varian 2440 gas chromatograph. Operating and other conditions are given in a footnote of Table 1. Identifications were made using retention data and peak enrichment techniques only. This has been considered adequate as all the components tentatively identified have been previously reported in pepper oil.

2.6 Piperine content

Pepper was extracted with CH_2Cl_2 and pepper oleoresin produced as described previously.[7,9] Piperine was estimated by the two methods detailed previously: (i) tlc-uv densitometric method[7] and (ii) the tlc-uv spectrophotometric method.[11]

3. Results

3.1 Oil composition of Sri Lanka pepper oil

Oil composition of an export sample and a sample collected from an estate is shown in Table 1. As reported previously[6,16] monoterpene hydrocarbons were present in relatively large proportions. A significant peak appeared immediately prior to β-

caryophyllene (r.r.t = 3.62) conspicuous in Sri Lanka pepper and sometimes occurring in very large proportions. The peak, not reported previously, was unidentified. Beyond r.r.t. = 5.6 were 15-20 minor components whose total contribution was < 8%. No effort was made to identify these components.

3.2 Effect of Grinding

Table 1 also shows the effect of grinding where the levels of monoterpene hydrocarbons declined to the greatest extent. It appears that some caryophyllene or a chromatographically similar sesquiterpene was formed during grinding.

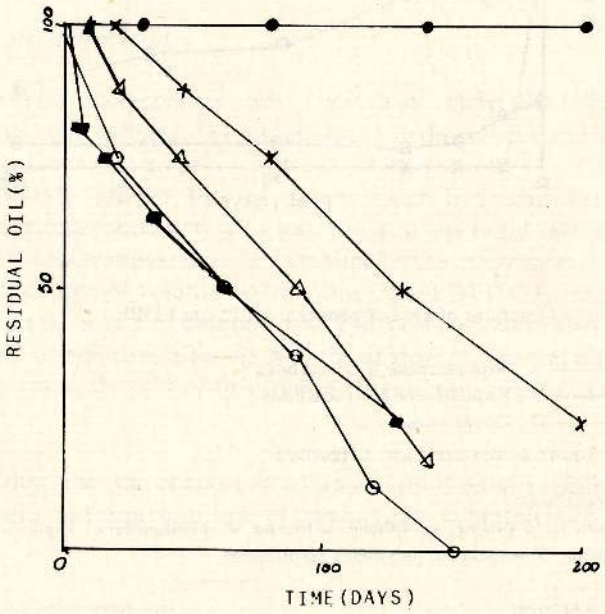

Figure 1 — Effect of storage in polythene on oil content of ground pepper

■ ——— ■ , 50 μm LDPE ;
O ——— O , 15 μm HDPE ;
Δ ——— Δ , 100 μm LDPE ;
x ——— x , 175 μm LDPE ;
• ——— • , Al foil laminate.

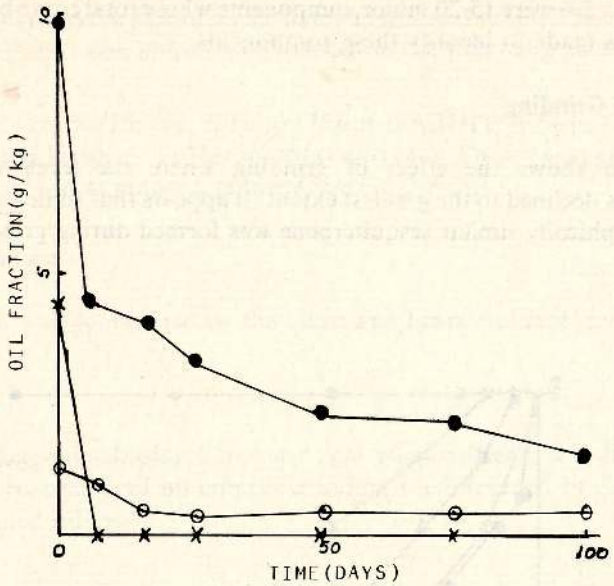

Figure 2 — Loss of oil fractions of ground pepper from 25 μm LDPE

x ——— x , Monoterpene hydrocarbons ;
• ——— • , Sequiterpene hydrocarbons ;
O ——— O , Oxygenates.

Only known components are categorised

Monoterpene hydrocarbons:
α-pinene, β-pinene, camphene, sabinene, α-phellandrene, β-phellandrene, myracene, limonene, γ-terpenene, p-cymene, terpinolene

Sesquiterpene hydrocarbons:
β-caryophyllene, β-farnesene, humulene, β-bisobolene, β-elemene

Oxygenates:
l-terpenin-4-ol, linalool, cis and trans carveol, methyl eugenol

3.3 Analysis of samples of ground pepper from the market

Four samples were analysed. Samples 1-3 were ground black pepper contained in 50 micron LDPE while sample 4 was contained in a bottle fitted with a crown cork. The latter sample contained 0.6% oil while the other samples contained 0.1% oil or less. On glc analysis it was found that monoterpene hydrocarbons were absent in all cases.

3.4 Storage experiments using ground pepper

3.4.1 Preliminary observations

Moisture content was initially 8%. After the various stages of storage, moisture content rose to 9-14%. Mouldiness was not visually observed.

3.4.2 Effect on oil content

Oil content declined markedly under all LDPE and the HDPE storage conditions but remained constant in the aluminium foil laminate and in the tinned can. Some of the results are expressed in Figure 1. (50μm, 100μm and 175μm LDPE, 15μm HDPE and Al foil laminate).

3.4.3. Effect on oil composition

Here selected known components were combined under the following categories: (1) monoterpene hydrocarbons, (ii) sesquiterpene hydrocarbons and (iii) oxygenates.

In all cases a greater loss of monoterpene hydrocarbons was observed. Sesquiterpene hydrocarbons were also lost, but at a less rapid rate. On a percentage basis the smallest losses appeared to be exhibited by the oxygenates. Figures 2, 3 and 4 describe the rate of loss of volatile oil fractions from LDPE (25μm) LDPE (175μm) and HDPE (15μm). Losses of monoterpene hydrocarbons were also shown in the Al foil laminate and tinned cans after six months of storage; as total oil content did not decline in these cases, the loss of this fraction is probably due to its conversion into other volatiles.

Table 2 describes the changes in composition of oil after different treatments and illustrates that the degree of loss of constituents is preferential.

3.4.4. Effect on piperine content

Both methods of assay of piperine used in this study gave very closely concordant results.

The only significant decline in piperine content was in the 25μm LDPE (Figure 5). The figure also shows the loss of volatile oils from the same package. Volatile oil and piperine losses closely parallel one another.

Table 2.— Effect of storage on some oil components of ground pepper

	Black pepper	ground black pepper	LDPE 25 μm 7 days	LDPE 50 μm		LDPE 75 μm		LDPE 100 μm		LDPE 125 μm		HDPE 15 μm		Al foil. laminate 6 mths	Tinned can 6 mths
				7 days	2 mths	7 days	2 mths	10 days	3 mths	10 days	3 mths	19 days	2 mths		
∝ -pirene	17.0	2.13	0.05	0.05	0.09	0.27	0.31	0.19	0.09	0.24	0.14	0.92	0.02	2.6	0.30
β -pinene	10.2	2.39	0.03	0.01	0.06	0.26	0.62	0.05	0.06	0.25	0.09	0.59	0.03	2.8	1.55
sabinene	16.8	3.85	0.04	0.04	0.07	0.42	0.13	0.21	0.07	0.36	1.10	0.87	+	3.90	1.16
∝ & β phe-llandrene	8.7	2.97	0.05	0.05	0. 08	0.54	0.13	0.17	0.08	0.24	0.12	0.72	0.30	4.10	1.02
linonene	17.4	7.39	0.02	0.16	0.18	0.72	1.09	0.38	0.21	0.51	0.31	0.36	0.36	3.0	0.50
terpinolene	0.42	0.39	0.17	0.01	0.01	0.06	+	0.03	+	0.04	+	0.10	0.09	0.59	0.29
1-terpenin-4-ol	0.59	3.52	6.07	5.60	5.03	4.09	4.44	3.38	4.19	4.59	5.63	5.55	3.98	8.35	11.70
β-caryophyllene	10.9	43.7	51.5	49.2	41.9	47.3.	43.9	52.1	32.5	52.1	40.1	46.1	31.3	37.0	42.6
β-bisobolene	0.37	2.92	3.72	3.56	5.30	3.34	4.71	3.78	4.98	3.44	4.86	3.90	5.67	2.71	3.45
Vol. of oil (% dry wt pepper)	5.5	2.0	0.8	1.6	4.0	2.0	1.0	2.0	1.0	2.0	1.0	1.5	1.0	2.0	2.0

Only identified constituents, present in significant amounts, are shown. Constituents are expressed as a % of total oil.

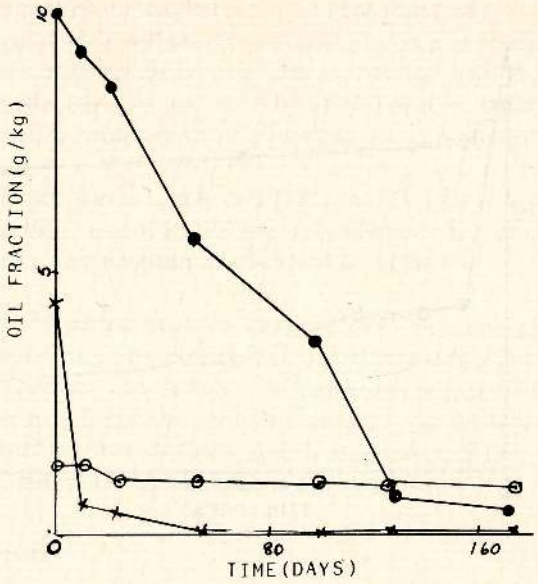

Figure 3 – Loss of oil fractions of ground pepper from 175 μm LDPE For details see Figure 2.

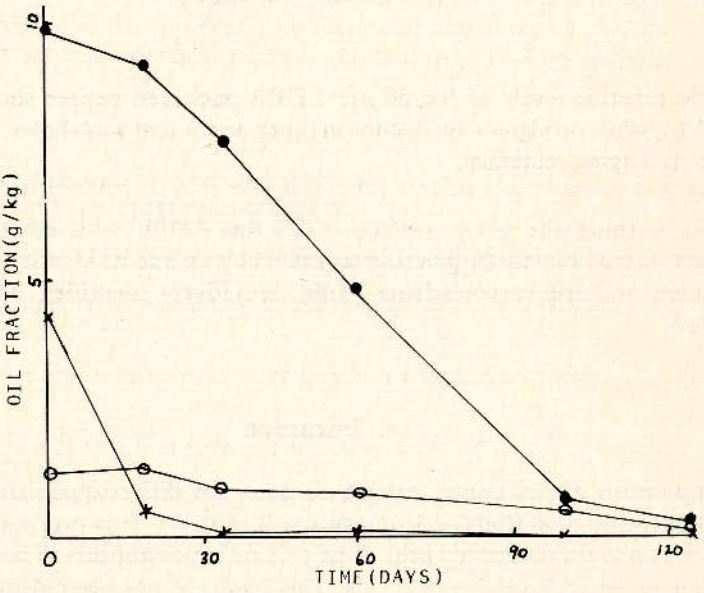

Figure 4 — Loss of oil fraction of ground pepper from 15 μm HDPE For details see Figure 2.

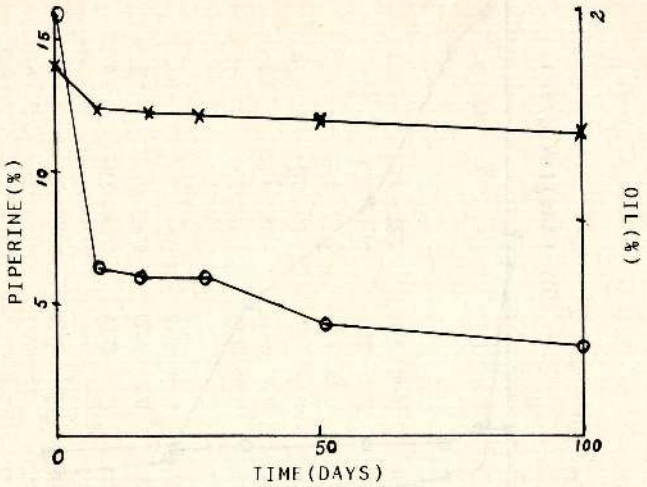

Figure 5 — Loss of oil and piperine from ground pepper on storage in 25 μm LDPE
x ——— x , % piperine ;
O ——— O , % volatile oil

The piperine levels of the 50 μm LDPE packaged pepper showed a small decline (5%), while no significant decline in piperine content was shown in the case of the other packaging materials.

On washing the outer surface of 25 μm LDPE with ether, two major components were isolated: (i) piperine-separated by tlc and its identity verified by its uv spectrum and (ii) caryophyllene oxide (tentatively identified by glc and tlc techniques).

4. Discussion

The composition of Sri Lanka pepper oil does not differ significantly from that reported by the original study of Jennings and Wrolstad.[16] However special attention must be drawn to the additional peak at r.r.t = 3.62 which appears to be characteristic of and unique to Sri Lanka pepper oils. This peak has not been identified.

Results show that milling and packaging conditions markedly affect oil content as well as composition. The absence of volatile constituents in the samples from the open market illustrates two facts viz.: (i) little attention is being paid to the method of packaging of ground pepper and (ii) the absence of volatiles does not appear to be an important consideration in local consumer tastes.

However, this will not be true for products destined for the export market. Here, cold or otherwise controlled milling will be required to minimize heat generation and packaging materials will need to be chosen according to the requirements of shelf-life. This does not necessarily rule out the use of LDPE as preferential loss of monoterpene hydrocarbons and thereby an increase in concentration of oxygenates among the volatiles could result in a product more preferred organoleptically.

The study, confirms that both LDPE and HDPE are poor barriers for essential oils and that the thickness of LDPE has a significant effect on not only the rate of loss of oil but also the composition of the residual volatiles.

The loss of piperine from the 25 micron LDPE is interesting and it is theorised that this compound migrates through the polyethylene facilitated by the movement of oil through the barrier. The detection of caryophyllene oxide on the outer surface of the pouch is not surprising and probably arises by the oxidation of β-caryophyllene; while the less volatile caryophyllene oxide is retained on the outer surface of the pouch to some extent, the other hydrocarbons are volatalised.

Acknowledgements

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Semiconductor to Metal Transition in Ferric Molybdate

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Abstract: Conductivity characteristics of ferric molybdate is studied. It is found that this material undergoes a semiconductor to metal transition at ~139°C.

1. Introduction

The study of insulator to metal and semiconductor to metal transitions in inorganic solids has attracted much attention.[2,8] It is well known that transition metal compounds, notably those of iron exhibits this phenomenon at relatively low temperatures.[2-4,7] In this note we describe our observations on semiconductor to metal transition in ferric molybdate ($Fe_2[MoO_4]_3$).

2. Method

To obtain reproducible results, ferric molybdate is prepared by the following methods. Dilute acetic acid (10% solution) is added to 0.25M ammonium molybdate in ammonium hydroxide (~contaning 2% NH_3) until the pH is $\simeq$ 5. Excess ferric chloride solution containing acetic acid (pH is $\simeq$ 4.5) is added dropwise with vigorous stirring to the molybdate solution and the mixture is boiled. The yellowish brown precipitate of ferric molybdate is washed with deionized water and dried for several hours at 200°C. The dried compound chocolate brown in colour is powdered and compacted between carbon electrodes at a pressure of ~ 5×10^5 Pa in a pyrex glass tube (diameter $\simeq$ 0.5 cm, pellet length $\simeq$ 0.4 cm.). At this pressure the effect of grain boundaries is found to be negligible and further increase of pressure does not reduce the conductivity significantly. The ends of the tube are sealed with epoxy resin, the sample is immersed in a thermostatic bath and V-I characteristics are determined at various temperatures.

3. Results and Discussion

The voltage - current characteristics are found to be highly nonlinear. The plots of current density (J) *vs* potential gradient (E) at different temperatures are indicated in Figure 1. The transition to the highly conducting metallic phase is dependent upon temperature as well as current density. At a given temperature less than T_c ($\simeq$ 139°C), as the voltage is increased from zero, J varies continuously until a point on the curve A is reached. Once this point is passed, there is an abrupt increase in conductivity and

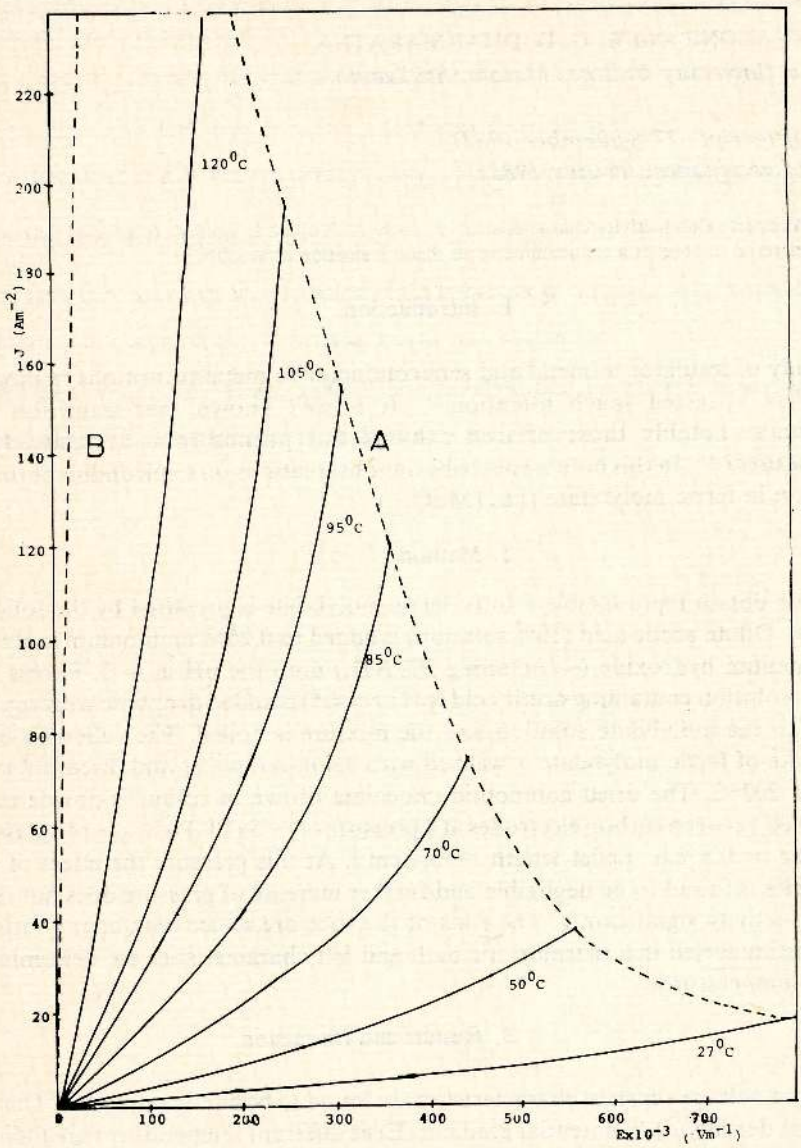

Fig. 1. The plot of J vs E at different temperatures. The dashed curve A gives the points at which the transition to metallic phase takes place abruptly when J is increased. When $T > T_c (\simeq 139^0C)$ the material transforms into the conducting phase and J,E vary along the line B.

further increase of E will change J along the line B, where the conductivity is almost constant ($\simeq 4.5 \times 10^{-2}$ Ωm). No hysteresis is observed before the curve A is intersected, i.e. if the voltage is decreased before crossing this curve, J decreases along the initial path via which it had increased. When the point where the abrupt increase in conductivity is passed, the material remains in the highly conducting metastable phase for several minutes even if the current is discontinued.

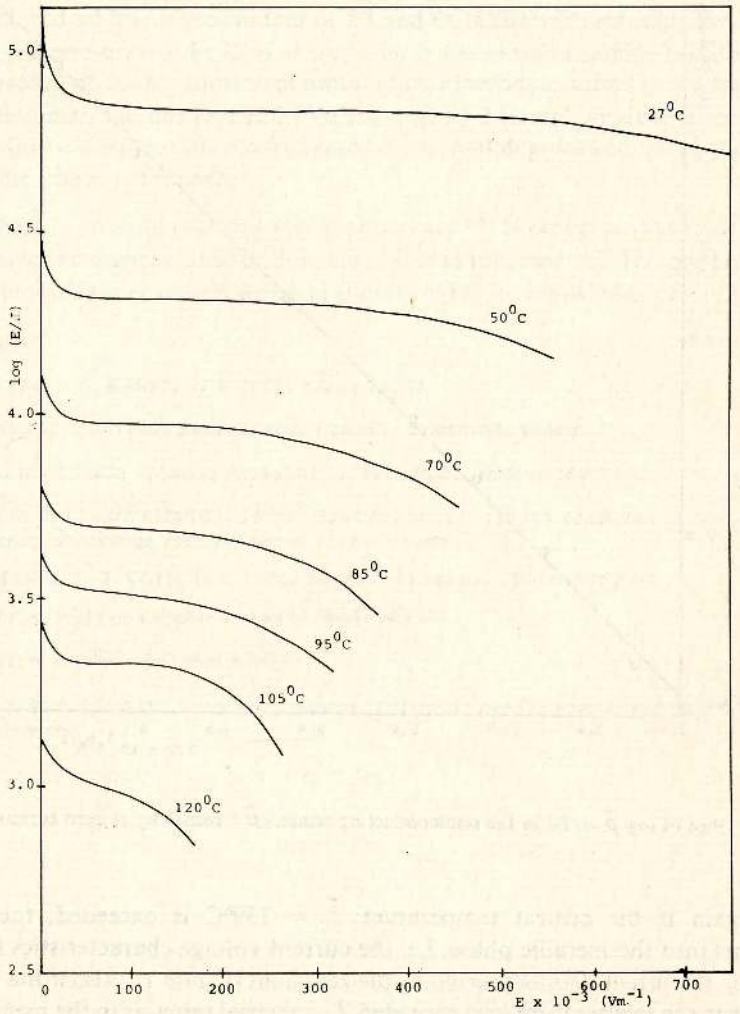

Fig. 2. Plot of log (E / J) vs E at different temperatures.

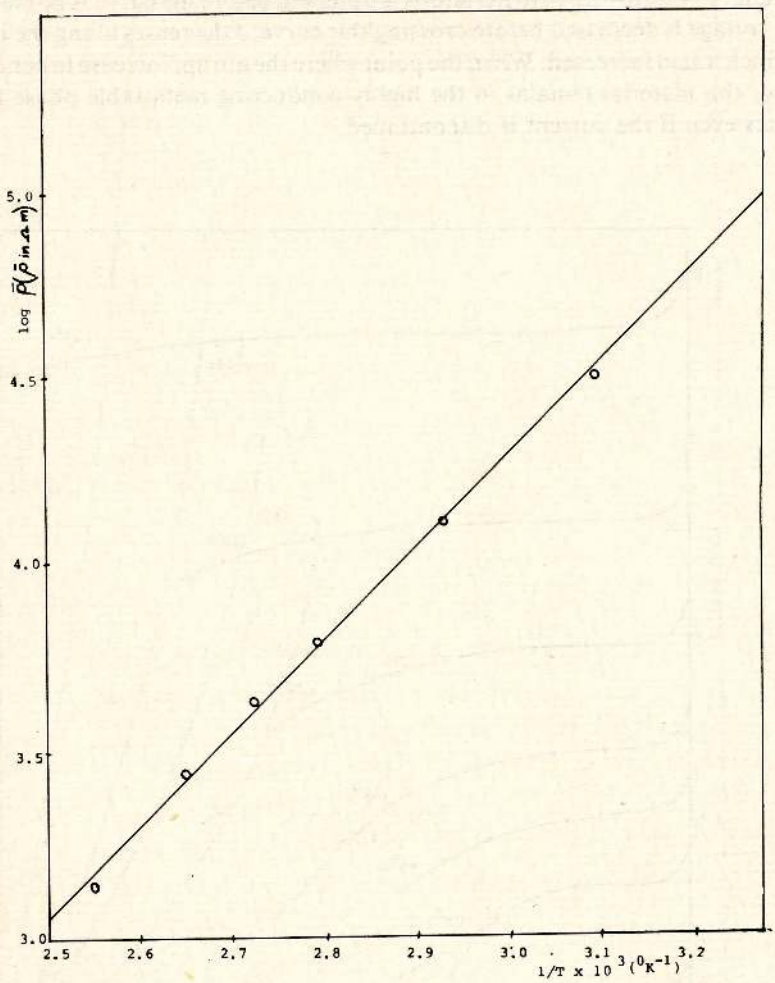

Fig. 3. Plot of log $\bar{\rho}$ vs T^{-1} in the semiconducting phase. ($\bar{\rho}$ = resistivity at zero current density).

Again if the critical temperature $T_C \simeq 139^0C$ is exceeded, the material transforms into the metallic phase, i.e. the current voltage characteristics follow the path B for all current densities including the zero limit (Figure 1). Also if the sample is cooled once the temperature had exceeded T_C, material remains in the metallic phase and complete reversal to the semiconducting phase is observed after several hours.

From a plot of log (E/J) *vs* E (Figure 2) it is possible to determine the resistivity $\bar{\rho}$ of the material at different temperatures as the limit $E \longrightarrow 0$, $J \longrightarrow 0$ is approached in the semiconducting phase. The plot of log $\bar{\rho}$ vs T^{-1} is a straight line (Figure 3) indicating that the relation,

$$\bar{\rho} = \bar{\rho}_0 e^{E/kT} \quad (1)$$

is satisfied with $\bar{\rho}_0 = 6.3 \times 10^{-4} \Omega m$ and activation energy E = 0.50 eV. ($\bar{\rho}$ at 139°C computed from (1) is $\sim 7.1 \times 10^{2} \Omega m$, thus there is $\sim 10^4$ fold increase in conductivity after the transition).

The system is highly sensitive to impurities. The samples of the compound prepared in the manner described above corresponds to stoichimetric $Fe_2(MoO_4)_3$ to an accuracy of ±0.3% in the content of Fe and O. Although reproducible results are obtained, the presence of Fe_2O_3 as an impurity in the samples cannot be ruled out. If a neutral instead of acidic solution of ammonium molybdate is used in the preparation, the resulting material has reproducible but slightly different conductivity properties, i.e. the transition temperature is increased by several degrees and the conductivity in the metallic phase is reduced.

There is no evidence for ionic conductivity [3,5], however we have not been able to determine the electron and/or hole mobilities in the material. The crystal structure of ferric molybdate is not reported in literature to the knowledge of the authors.

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Determination of Piperine in Pepper *(Piper nigrum L)*

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Abstract: This paper introduces a new technique of piperine assay based on tlc-uv densitometry which produces nearly identical results to the already known tlc-uv spectrophotometric method. Results of this study confirms that Sri Lanka pepper has very high piperine content (7-15%); 2-6 fold that of commercial Indian, Malaysian and other varieties. This is the first report containing comprehensive data verifying the high piperine content of Sri Lanka pepper using reliable analytical techniques.

1. Introduction

Pepper *(Piper nigrum L.)* is one of the most important spices grown in Sri Lanka. Traditionally it has been exported as the primary product-black pepper. Sri Lanka pepper has had a reputation for containing high levels of volatile and pungent principles.[6] However, market prices are at present not always dictated by these quality factors. It is clear that proving the presence of these qualities in our pepper is a step in the direction of establishing premium prices for the product. The detailing of acceptable analytical techniques and their application is of special importance in the case of the piperine because this compound is present in our pepper at levels 2-6 fold than found in pepper from other sources judging from our studies and reports contained in the literature.[5,6]

Piperine is responsible for the pungency of black pepper - the contribution from other compounds to the pungency of this material being negligible.[6] The earliest method for determination of piperine in pepper was the Kjeldhal method[20] (for N) which obviously resulted in exaggerated values. An early method established was the spectroscopic method[3] (termed "direct uv method" hereafter) by which quantitation was achieved by measuring optical density at 345 nm. Here again (coloured) impurities could result in exaggerated values.

Several colorimetric methods have been reported eg. using chromatropic acid[11], nitric acid[7], phosphoric acid[8] but generally reproducibility of these methods was considered inadequate.[17]

Labruyere[10] proposed a hydrolytic method to liberate piperidine (from piperine) followed by steam distillation and titrimetric analysis to estimate the former. This method was later modified by substituting a colorimetric step for the titration eg. in methods by Shankaranarayana *et al*[18] and Kap.[9] However, the direct uv method

was still preferred over all these methods and until recently still advocated mainly due to its simplicity and the claim that its error is relatively small - over estimating piperine by only 5-10%. [6,12,16]

Notwithstanding this, analysis of piperine moved in the direction of methods based on thin-layer-chromatography (tlc) and piperine was analysed by Wijesekara *et al* using the tlc-spot area method.[19] here spot area was correlated to concentration. This trend was continued by Mori *et al*[12] advocating the separation of piperine by tlc before estimating it by uv spectrophotometry.

Govindarajan[6] in an exhaustive review stated that a method based on tlc and spectrophotometry at 342 nm (of the eluted spot) gave the best correlation between pungency (by sensory evaluation) and piperine content. However to our knowledge the details of this method (termed "tlc-uv method" hereafter) were not reported. Further, according to this author the error of the "direct uv" method caused by coloured substances was only of the order of 5-10%.[6]

Piperine has also been successfully separated by gas-liquid chromatography but the technique has not been sufficiently studied to merit the status of a good quantitative analytical technique[14,21] for the assay of piperine. HPLC, however has been used successfully to quantify piperine using a variety of systems.[2,4,13]

In this paper we report:—

(a) A "tlc-uv" method which expands on Govindarajan's[6] report and also shows that the error of the "direct-uv" method is not merely 5-10% but varies markedly depending on nature of solvent used for extraction and extraction time rendering the results of the method very suspect.

(b) Data on the tlc-spot area method providing further evidence of its inherent inaccuracies; first pointed out by Govindarajan.[6]

(c) A new method based on tlc-uv densitometry the results of which tally very closely with the tlc-uv spectroscopic method.

2. Materials and Methods

2.1 Standard piperine

Pure piperine (m. pt. 129°C) was purchased from Sigma Chemical Company. Standard curves were prepared using this specimen and also using piperine extracted from pepper (with CH_2Cl_2) recrystallised repeatedly from ethanol. The latter standard had a m. pt. of 129-130°C and purity was verified using mixed melting points.

2.2. Pepper oleoresin

Pepper was sampled from commercial stocks at export dealing points (G.S. Chatoor & Co. Ltd.) as well as at estates (Mahavela and Wariyapola Estates) and other small holdings in Matale and Kandy. The pepper was ground in a mortar and a sample (50g) was extracted in a soxhlet apparatus for 4h using the selected solvent (250 ml). On evaporation of the solvent under reduced pressure, the oleoresin was obtained.

2.3 Direct-uv spectrophotometric method

The oleoresin was dissolved in $CHCl_3$ and an aliquot diluted so that absorbance at 342 nm lay within the limits of a linear standard curve of piperine concentration *vs* absorbance. All manipulations were carried out away from light. $CHCl_3$ proved to be a better solvent than methanol as the use of the latter resulted in a marked decline in optical density with time.

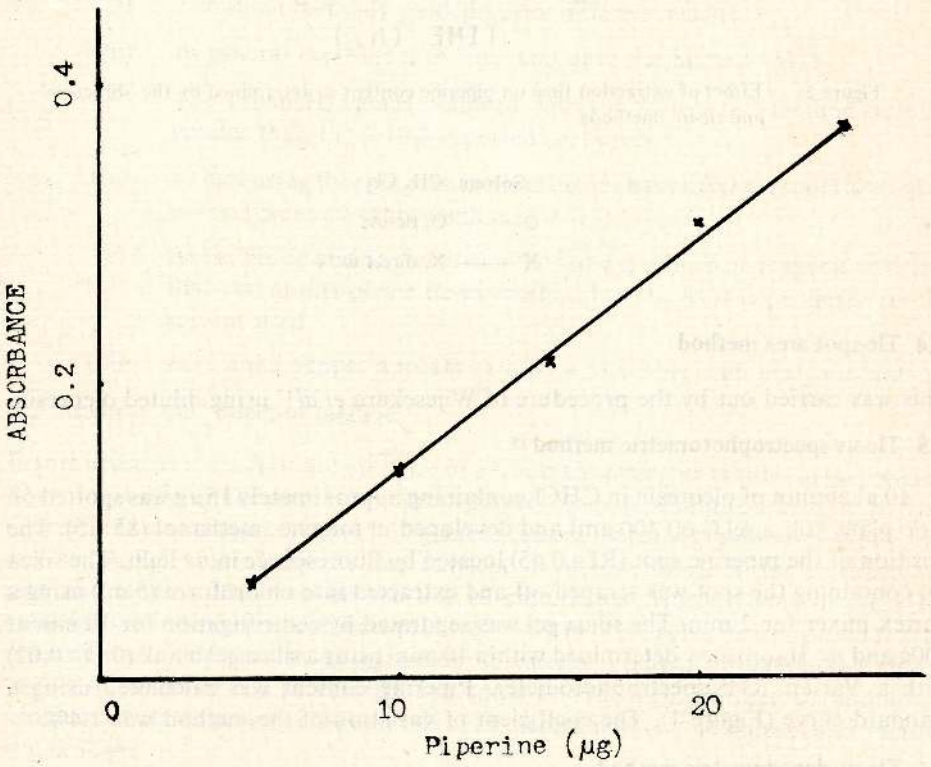

Figure 1 :,Standard curve for piperine using "tlc-uv" method

Piperine (µg) is correlated with absorbance after thin-layer chromatography and uv-spectroscopic analysis at 342 nm.

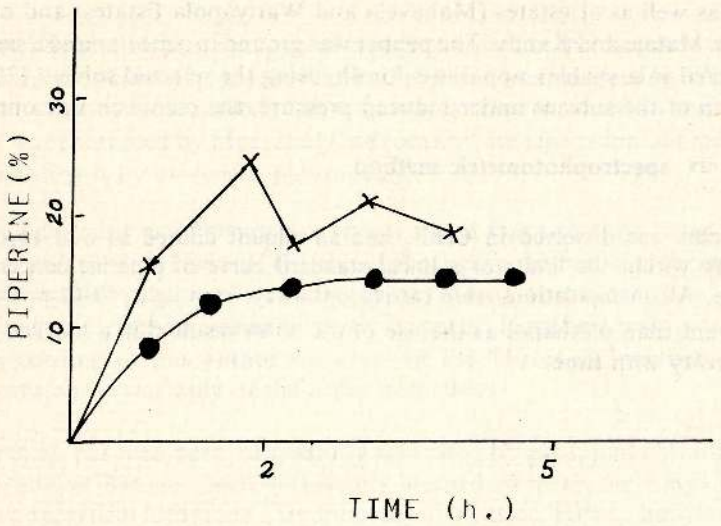

Figure 2: Effect of extraction time on piperine content as determined by the 'direct-*uv*' and *tlc-uv*' methods.

Solvent, CH_2Cl_2

O —— O, tlc-uv;

X —— X, direct uv.

2.4 Tlc-spot area method

This was carried out by the procedure of Wijesekara *et al*[17] using diluted oleoresin.

2.5 Tlc-uv spectrophotometric method[15]

A 10 μl aliquot of oleoresin in $CHCl_3$ containing approximately 15 μg was spotted on a *tlc* plate (silica gel G-60 300 μm) and developed in toluene: methanol (85:15). The position of the piperine spot (Rf = 0.45) located by fluorescence in *uv* light. The silica gel containing the spot was scraped off and extracted into chloroform (5 ml) using a vortex mixer for 2 min. The silica gel was separated by centrifugation for 10 min at 600g and *uv* absorbance determined within 10 min using a silica gel blank (0.D = 0.02) with a Varian 634S spectrophotometer. Piperine content was calculated using a standard curve (Figure 1). The coefficient of variation of the method was 1.4%.

2.6 Tlc-uv densitometric method

Approximately 1.5 μg (in 10 μl) of piperine was spotted on a *tlc* plate (300 μm) and chromatography carried out as in 2.4. The plate was scanned using a Camag automatic scanning variable wavelength densitometer model 7650 (monochromater model).

Scanning was carried out at 342 nm (band width 30 nm) with a slit width of 12 mm and a sensitivity setting of 6 using a Deuterium lamp. Scan speed was 2mm / sec.

A linear standard curve was obtained for aliquots containing 0.5 μg to 2.5 μg when plotting peak area against mass of sample applied. However this standard curve itself was not used for the calculation of the concentration of the unknown as peak area varied slightly from one tlc plate to another. Therefore calculations were made from peak area after running standards on the same plate as the unknown. The coefficient of variation of the technique was 2.4%.

3. Results

3.1 Comparison of analytical techniques

Table 1 shows an analysis of a sample of pepper using different analytical techniques. The solvent used for extraction of oleoresin was also varied.

The results led to the following conclusions:

(i) The three methods yielded vastly different results.

(ii) In general the "direct uv" method gave the highest values.

(iii) The enhanced values obtained with the "direct uv" method were far greater than the 5-10% reported previously.[6]

(iv) Values using the spot area method do not have a fixed trend with respect to the results of other methods.

(v) As 6a, 6b, 6c and 6d were from the same specimen of pepper it was clear that the results of the tlc-uv method has the least dependence on the solvent used.

(vi) Sri Lanka pepper appears to have a relatively high piperine content.

3.2 Errors of the "direct-uv method"

Errors arose as a result of the presence of 342 nm absorbing impurities in the extract. These impurities in the oleoresin (solvent extract) vary depending on the solvent used (Table 2). It is envisaged that the 5-10% enhancement reported previously was possibly due to the fact that methylene and ethylene dichloride were used for extraction in previous studies. The ban on the use of chlorinated hydrocarbons in oleoresin manufacture in some parts of the world will result in other solvents being used for the purpose and therefore the exaggeration of piperine content as determined by the "direct uv" method will be variable and could be very high. Further, an additional problem would be posed in the analysis of an oleoresin where the history of extraction is unknown.

A comparison of the effect of extraction time using CH_2Cl_2 on apparent piperine content by the "direct uv" method and the "tlc-uv method" is shown in Figure 2. It is seen that while the piperine content as estimated by the "uv-tlc method" falls on a smooth hyperbolic curve, the readings of the direct uv method are erratic. This is interpreted as being due to the uv-reading of the extract being a function of not only the extent of extraction of uv absorbing material but also its rate of decomposition during extraction. From this it is inferred that the determination of piperine by the direct-uv method will be subject to errors connected not only with the solvent used but also with extraction time.

Table 1.– Apparent piperine content of pepper with different analytical techniques

Sample	Extraction Solvent	Oleoresin (% dry wt)	Piperine (% dry wt pepper)		
			Spot area	direct-uv	tlc-uv
1. FAQ	CH_2Cl_2	10.6	7.3	—	6.4
2. FAQ	Methanol	27.3	14.1	17.2	11.7
3. Dried green pepper	Methanol	31.7	7.3	13.8	11.4
4. Fresh pepper	Methanol	40.5	12.3	20.3	13.4
5. FAQ	CH_2Cl_2	17.8	—	12.9	8.6
6. Grade I	(a) CH_2Cl_2	14.4	6.9	9.8	7.7
	(b) Methanol	17.3	8.2	14.1	7.3
	(c) Methanol	17.4	10.6	14.9	7.3
	(d) Acetone	11.6	—	8.4	6.3
7. Light berries	CH_2Cl_2	14.4	6.9	9.8	7.7
8. Light berries	CH_2Cl_2	16.3	—	12.5	9.2
9. Off-grade black	CH_2Cl_2	18.0	12.3	14.6	9.1

Graded berries were obtained from the Export trade (G.S.Chatoor & Co,.Ltd) in the course of 1980. Fresh pepper was obtained from Palapathwela, Matale and dried green pepper prepared from fresh pepper in the laboratory.

FAQ – Fair average quality grade.

Extraction time – 4 h.

Table 2.– Effect of using different solvents on piperine content as determined by the 'direct-uv' method

Solvent	Piperine (% dry wt pepper)
CH_2Cl_2	8.8
Acetone	7.6
Methanol (Experiment 1)	12.5
Methanol (Experiment 2)	13.4

Samples of the same lot of pepper were extracted for 4h. using the solvents indicated above.

3.3 Errors of the spot-area method[19]

As indicated by Govindarajan[6] (no details were published by him) the spot area method was found to be not reproducible.

In this study the same sample of oleoresin when applied on different plates led to vast discrepancies leading to a coefficient of variation of the order of 50%. This is largely due to small variations in the characteristics of different *tlc* plates. When the same tlc-plate was used then a reduced coefficient of variation (12%) was observed for multiple determinations. Therefore if the "spot-area method" is used along with standard curves for each tlc plate, then the errors would be infinitely more tolerable.

However the importance of this tlc method lay in the fact that it introduced the concept of separating out 342 nm absorbing impurities by thin-layer chromatography.

The above point was confirmed by measuring the optical density at 342 nm contained in $CHCl_3$ extracts of the silica gel from different parts of the plate. Only approximately 70% of the *uv* absorbance was found to coincide with the piperine spot and a further 25% was found to occur in other parts of the tlc-plate.

3.4 The tlc-uv spectrophotometric method.

Next, an attempt was made to determine the recovery of piperine using the tlc-uv spectrophotometric method. For this purpose a low piperine substrate had to be obtained. The mother liquor of the oleoresin after piperine crystallisation was selected for this purpose. Experiments led to recovery of piperine to the extent of 105%. As the

Table 3.—Piperine content of black pepper by tlc-uv and densitometric methods

Sample No.	Piperine (% dry wt)	
	Tlc-uv	Tlc-densitometric
1. GRADE I	13.3	13.5
2. GRADE I	15.0	14.8
3. GRADE I	13.9	13.8
4. GRADE I	13.3	12.9
5. GRADE I	12.2	12.2
6. LIGHT BERRIES	12.5	12.5
7. LIGHT BERRIES	14.1	13.8
8. LIGHT BERRIES	14.1	14.2
9. ESTATE COLLECTION	13.9	13.8
10. ESTATE COLLECTION	13.5	13.5
11. ESTATE COLLECTION	14.1	14.1
12. ESTATE COLLECTION	13.4	13.3
13. ESTATE COLLECTION	13.8	13.8
14. ESTATE COLLECTION	14.2	14.1
15. ESTATE COLLECTION	13.9	13.9
16. ESTATE COLLECTION	13.8	13.8
17. ESTATE COLLECTION	12.0	11.9

Solvent, CH_2Cl_2; Extraction time, 4h.

Graded pepper (samples 1-8) were obtained from the export trade (G.S. Chatoor & Co., Ltd.) in the course of 1982. Estate collections were obtained from Wariyapola estate (sample 9-12) and small holdings in the Matale district (samples 13-17).

results are calculated from two separate determinations, viz; (i) mother liquor (containing small amounts of piperine) and (ii) mother liquor plus added piperine, this value for recovery is acceptable.

This confirmed the conclusions of Govindarajan[6] and taken together with his sensory evaluation data establishes the credibility of the method.

3.5 Comparison of results of tlc-uv spectrophotometer and tlc-uv densitometric methods

The great disadvantage of the tlc-uv spectrophotometric method is the tedious work involved in scraping out the silica gel, eluting piperine into $CHCl_3$ and centrifuging prior to spectrophotometry. The tlc-uv densitometer obviates the need for these operations and experimental requirements are limited to scanning of the tlc plate at the appropriate wavelength and determination of peak area from the recorded chart. Further the sensitivity of the densitometer method is a great advantage as the quantity of material required is one tenth that of the tlc-uv method thus enhancing separation. Results of both methods tally very closely (Table 3).

4. Discussion

Two methods are now available for the routine analysis of piperine in pepper. The methods are very similar with respect to the separation of the piperine spot but differ in the final quantitative step.

The paper also provides a bank of data illustrating the high levels of piperine in Sri Lanka pepper - generally in the range of 7-15% as against 2–7% for the commercial Indian, Malaysian and other varieties. There appears to be a strong case for the inclusion of piperine content in our certificate of export in order to fully exploit this favourable natural quality of our pepper.

The paper is important at this juncture as the introduction of high yielding Kuching (Malaysian) and Panniyur (Indian) varieties to local plantations is now being advocated,[1] these varieties are not known for high piperine levels. In fact the literature reports the piperine content of the Panniyur variety to be in order of 3-5%.[6] It is foreseen that the replacement of the indigenous variety with the new cultivars although resulting in a significant increase in pepper yield will also result in a decline in oleoresin and piperine yield.

Acknowledgements

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SHORT COMMUNICATION

Coumarins of *Micromelum ceylanicum*

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The presence of a coumarin in *Micromelum ceylanicum* (Sinhalese Walkarapincha) was reported earlier.[3] Previous work[2,3] on *Micromelum* species (Rutaceae) have revealed the presence of coumarins, alkaloids and flavanoids in leaves and stems. In this study, the methanol extract of the fresh leaves yielded four coumarins.

The methanol extract of the fresh leaves was concentrated under reduced pressure. The residue on chromatography on silica gel yielded (a) Fractions 12-14 (Chloroform) containing coumarin I, (b) Fraction 15 (Chloroform) containing coumarin II, (c) Fractions 18-20 (Chloroform/ 2% methyl alcohol) containing coumarin III and (d) Fraction 17 (Chloroform) containing the previously isolated 7-[4'-(4''- methyl -5''- oxo - 2'', 5'' - dihydro - 2'' - furyl) - 3' methyl - 2' - butenyloxy] coumarin (IV).[3] Coumarin I was obtained as a pale yellow crystalline solid m.p. 96-97°C. Its high resolution mass spectrum (MS) showed the molecular ion at m/z 312 corresponding to the molecular formula $C_{19}H_{20}O_4$. The structure was confirmed by comparison of ^1H NMR and mass spectra reported for I.[1] Coumarin II was obtained as white needles m. p. 66-67°C (softens at 63°C). Its high resolution MS showed the molecular ion m/z at 312 corresponding to the molecular formula of I viz. $C_{19}H_{20}O_4$. The structure was confirmed by comparison ^1H NMR and MS reported for II[1]. The two compounds differ in the position of double bonds at 2,3 and 3,4. Coumarins I and II were previously isolated from *Machaeranthera scabrella* (Greene) Shinners (Compositae) by Bohlmann *et al.*[1,7] and from *Ferula diversivittata* (Umbelliferae) by Kieseleva *et al.*[6,7]

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Coumarin III was obtained as a white crystalline solid from water, m.p. 220-224°C. The structure was confirmed by comparison with an authentic sample of umbelliferone[4] (m.m.p., TLC). This is the first occasion that coumarins I and II are reported in the family Rutaceae.

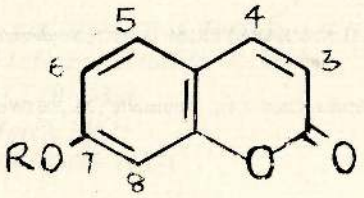
^{1}H NMR spectra were recorded on a HA - 100 MHz spectrometer. Chemical shifts are reported in δ scale relative to TMS as internal standard. MS were recorded on a Varian CH 5 instrument. Plant material was identified by Mr. D. T. Ekanayake, Superintendent, Royal Botanical Gardens, Peradeniya, Sri Lanka.

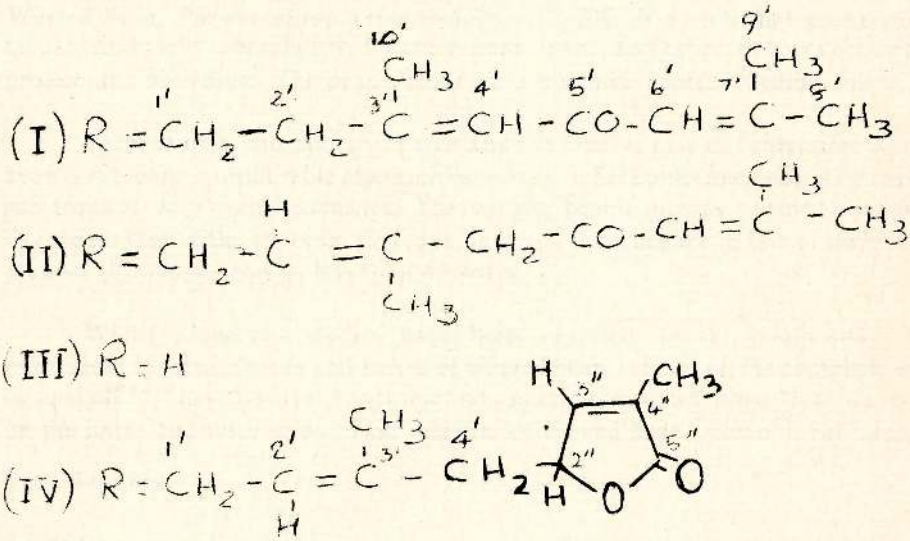
Isolation of Coumarin I. Fresh leaves (700 g) collected in Dambulla, Sri Lanka, in February 1982 were macerated with methanol. After filtering, the residue was extracted with methanol in a soxhlet extractor for 18 hours. The combined extracts were concentrated under reduced pressure. The residue was chromotographed on silica gel 60 (70-230 mesh) ASTM Merck and eluted successively with light petroleum (60-80°C), benzene, chloroform and chloroform / 2% methyl alcohol. Fractions (12-14) after standing for a few hours and trituration with a little methanol yielded a solid. The residue was taken up in acetone/methanol, decolourized with activated charcoal, concentrated and allowed to cool. The solid was collected and recrystallised from methanol/ether to give pale yellow needles (0.5g), m.p. 96-97°C (lit[1,7] m.p. 91°C); MS:m/z 312, 297, 256, 174.9, 161.9, 151, 135, 123, 109, 95, 83, 67, 54.9; high resolution MS:m/z 312.1364 ($C_{19}H_{20}O_4$ requires 312.1362); HNMR ($CDCl_3$); 6.24 (d,3-H,J = 9.5 Hz), 7.58 (d, 4-H,J = 9.5 Hz), 7.37 (d, 5-H,J = 9Hz), 6.85 (m, 8-H), 4.24 (t, I′ -H,J = 6.7), 3.10 (t(br)2′ - H), 6.10 (s(br)6′ - H), 6.17 (s(br)4′ - H), 1.90 (d, 8′ -H,J = 1Hz), 2.20 (d, 9′ -H,J = 1Hz), 2.00 (d, 10 -H,J = 1Hz), IR (KBr) : 1k720, 1610 (coumarin) cm^{-1}.

Isolation of Coumarin II: Fraction 15 crystallized on standing for a long time and triturating with ether. The solid was collected dissolved in ether/methanol, clarified with charcoal and concentrated. The crystalline solid was further recrystallised from chloroform/light petroleum (60-80°C) and acetone/light petroleum (60-80°C) to give a pale yellow solid. The final clarification was effected by dissolving the solid in ether/light petroleum (60-80°C) 1:1 and passing down a column of alumina (I″) BDH. The eluate on concentration yielded white needles (0.6g) m.p. 66-67°C (lit. [1,7] m.p. 63.5°): MS: m/z 312, 297, 256, 244, 162, 150, 134, 121, 107, 95, 83, 67, 55; high resolution MS:m/z 312. 1364 ($C_{19}H_{20}O_4$ requires 312. 1362); ^{1}H NMR ($CDCl_3$); 6.22 (d, 3-H,J = 9.5Hz), 7.62 (d, 4-H,J = 9.5Hz), 7.35 (d, 5-H,J = 9Hz), 6.85 (dd, 6-H), 6.80 (d, 8-H), 4.66 (d(br) I′-H,J = 6.5Hz), 5.60 (t(br)2′ - H), 3.18 (s,4′ - H), 6.1 (m,6′ -H), 1.87 (d, 8′ -H), 2.15 (d, 9′ -H), 1.79 (d, 10′ -H), IR (KBr) : 1722, 1615 (coumarin) cm^{-1}.

Isolation of Coumarin III: Fraction 18-20 solidified on evaporation and standing for a week. This was triturated with ether to give a light brown crystalline solid. This was recrystallised from boiling water as needles (0.5g) m.p. 224°C (lit[7]m.p. 223-224°C).

Isolation of Coumarin IV: Fraction 17 yielded a solid which on recrytallisation from acetone/light petroleum (60-80°C) gave IV as a white crystalline solid (0.5g), m.p. 125°C.[3]





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SHORT COMMUNICATION

Fatty Acids of Winged Bean, *Psophocarpus tetragonolobus* (L.) DC

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(Date of acceptance: 24 March 1983)

Winged bean, *Psophocarpus tetragonolobus* (L.) DC, is a crop that grows easily, quickly and yields abundantly. Its green pods, leaves and tuberous roots are rich in protein and are edible. The bean's seeds are a potential source of edible oil.

Because of its multiplicity of uses and the relative ease of cultivation, winged bean is receiving considerable attention especially in Sri Lanka and other tropical and sub-tropical developing countries. The winged bean's growth potential has been likened to that of the soybean. Soybean has risen from neglect to one of the world's premier protein sources in less than 60 years.

Whilst numerous studies have been reported on the composition and nutritional aspects of pods and leaves of winged bean, reports on the composition of its seed oil[2,3,6,7,9] have been relatively few and sometimes contradictory. Here, we report on the lipids and fatty acids of six varieties of winged bean, grown in Sri Lanka.

Seed Samples

Seeds from six varieties of winged bean, namely TPT-2, S-40, U-53, U-62, U-31 and L-133 were obtained from plants grown on an experimental basis at Angunukolapellesa, Sri Lanka. The seeds were harvested in January 1981.

Extraction of lipid and preparation of methyl esters

Oil was extracted with petroleum ether (b.p. 40-60°C).[1]

To prepare methyl esters the oil (1 g) was refluxed with dry benzene (3 ml) and methanolic sodium methoxide (0.5M. 6 ml) for 45 min. The esters were extracted in the usual way.[4]

Gas chromatography

Gas chromatography was carried out on a Varian Model 2440 chromatograph equipped with a flame ionisation detector and using glass columns (1.8 m x 2 mm i.d)

packed with 10% SP 2340 coated on 100/120 chromosorb W AW. The column was maintained at 190°C. Argon was used as the carrier gas at a flow rate of 30 ml min^{-1}.

Urea crystallisation

Esters (1 g) were crystallised at 0°C, overnight, from a solution of methanol (30 ml) containing urea (5 g). After filtration and washing with methanol saturated with urea, the filtrate was concentrated by heating under reduced pressure, diluted with water (25 ml), and esters extracted thoroughly with diethyl ether (2 x 25 ml). The combined ether extracts were washed with water (10 ml) before final removal of solvent.

The adduct released its esters when mixed with water (50 ml) and these were extracted with ether (2 x 50 ml) as described for the filtrate.

Silver ion chromatography

Silver ion chromatography was carried out on plates (20 x 20 cm) coated with silica gel G (1 mm thick) containing silver nitrate (10%). A mixture of benzene and hexane (70:30) was used as the developing solvent. After development, the plates were dried in a gentle stream of nitrogen and sprayed with an ethanolic solution of 2′, 7′ - dichlorofluorescein (0.2% w/v). The separated components appeared as yellow bands on a purple background when viewed under ultraviolet light. These were scraped off and the esters extracted with ether.

Identification of fatty acids

The structural assignments shown in Table 1 were based mainly on the gas chromatographic behaviour (equivalent chain length) of the methyl esters and comparison with authentic standards. These conclusions were confirmed, in part, by dividing the esters by urea fractionation into an adduct of saturated and monoene esters, and a mother liquor enriched in polyene esters. Further evidence was obtained by hydrogenation results and also by separating the esters according to unsaturation by silver ion thin layer chromatography.

The nature of our gas chromatography column was such that 20:1* overlapped with 18:3 (n-3). We divided this peak between its monoene and triene components on the basis of information obtained in the urea fractionation, where all of the monoene esters and some of the polyene esters is present in the urea adduct and the remainder of polyene esters but none of the monoene esters is present in the mother liquor. This division was supported by the proportion of 20:1 to that of 18:1 in the monoene ester fraction separated by silver ion chromatography.

Component acids of the oil

Table 1 shows that the fatty acid composition of winged bean oil differs from that of other common seed oils in that it has appreciable quantities of the long-chain acids

* Fatty acids are reported in shorthand; the first figure shows the number of carbon atoms in the chain and the figure after the colon shows the number of double bonds.

Table 1 – Oil content and fatty acid composition of winged bean oil

Variety	Oil Content (as a percentage of dry weight of seed)	Fatty Acid Composition (g/100 g of total acids)											
		14:0	16:0	16:1	18:0	18:1	18:2	20:0	20:1	18:3(n-3)	22:0	22:1	24:0
T.P.T-2	17.2	t[a]	6.4	0.1	4.0	33.2	26.9	2.3	2.8	2.0	16.3	1.1	1.9
S—40	16.7	t	7.2	0.1	4.5	35.8	29.7	1.7	3.0	1.2	13.2	0.9	2.7
U—53	20.4	t	5.8	0.1	5.1	32.6	25.9	2.3	2.7	1.5	18.2	1.1	4.7
U—62	16.2	t	6.2	0.1	4.1	32.5	29.4	2.2	2.7	1.4	15.4	1.3	4.7
U—31	19.6	t	7.9	0.1	4.5	35.9	30.8	1.5	2.3	1.0	14.0	0.6	2.3
L—133	20.4	t	6.5	0.1	4.3	35.3	30.7	1.5	2.4	1.1	14.7	0.8	2.6
mean:	18.4	t	6.5	0.1	4.4	34.2	28.9	1.9	2.6	1.4	15.3	1.0	3.6

[a] t denotes quantities less than 0.1%

20:0 (range 1.5-2.3%, mean 1.9%). 22:0 (range 13.2-18.2%, mean 15.3%) and 24:0 (range 2.3-4.9%, mean 3.6%). Groundnut oil contains all three of these, but at much lower levels, the three together making up 4-9%.[11] Occurrence of as much as 18% of behenic acid (22:0) in winged bean oil is interesting, as such high levels of this acid have not been found in any other seed oil. Winged bean oil is also atypical in the presence of the long-chain monoene acids 20:1 (range 2.3-3.0%, mean 2.6%) and 22:1 (range 0.6-1.3%, mean 1.0%).

On the average 68% of the winged bean fatty acids are unsaturated, the major unsaturated acids being oleic acid, 18:1 (range 32.5-35.9%, mean 34.2%); and linoleic acid, 18:2 (range 25.9-30.8% , mean 28.9%). Apart from 20:0, 22:0 and 24:0, the main saturated acids in winged bean are palmitic, 16:0 (range 5.8-7.2%, mean 6.5%) and stearic 18:0 (range 4.0-5.1%, mean 4.4%).

Although Cerny and co-workers[3] previously reported the presence of a 18:4 acid, which they considered to have anti-nutritional properties, we do not find evidence for occurrence of 18:4 acids in any of the six varieties of winged bean examined by us. Gas chromatography of winged bean methyl esters did not show any peaks indicative of 18:4 even after concentrating the polyunsaturated esters by urea crystallisation. Silver ion chromatography too failed to produce a fraction corresponding to tetraenes, confirming the absence of 18:4 acids.

Varietal Differences:

U-53 and L-133 have the highest oil content (20.4% on the weight of dry seed) and appear to be the best winged bean varieties for extraction of oil.

However, the fatty acid compositions of the oils extracted from the different varieties do not show any significant differences.

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ලිපිවල සාරාංශ – සිංහල පරිවර්තන

පොල් රා වල හයිඩ්‍රජන් සල්ෆයිඩ් සෑදීම මර්දනය කිරීම සහ එතනොල් නිෂ්පාදනය වැඩි කිරීම—ක්ෂේත්‍ර පරීක්ෂණ

ඒ. ඩබ්ලිව්. ලියනගේ, ඩී. ජේ. අබේරත්න, එම්. ආර්. හෙට්ටිආරච්චි, කේ. ඩී. එල්. ගුණතිලක, ජී. ජී. විරවන්ස සහ පී. එම්. ජයනිස්ස

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රා වල යීස්ට් පරිවෘත්තීය සඳහා නයිට්‍රජන් ලබා දෙන මූලාශ්‍රයක් වශයෙන් ඇමෝනියම් ලවණ වර්ග එක් කිරීමෙන්, හයිඩ්‍රජන් සල්ෆයිඩ් සෑදීම සම්පූර්ණයෙන් මර්දනයවී එතනොල් නිෂ්පාදනය ඉහල යන බවට කර ඇති සොයා ගැනීම පරීක්ෂා කිරීම පිණිස ක්ෂේත්‍ර අත්හද බැලීම් කරන ලදී. සාමාන්‍ය මැදීම් තත්වයන් යටතේ කරන ලද ක්ෂේත්‍ර අත්හද බැලීම් 4 කදී, රා මැදීමට පෙර, රා එක්රැස් කරන මුට්ටියට NH_4^+ අයන සාන්ද්‍රනය 0.08% (W/V) වූ ඇමෝනියම් ලවණ එක්කිරීමෙන් රා වල එතනොල් අන්තර්ගතය, 12.5% ක සාමාන්‍ය ප්‍රමාණයකින් වැඩිවූ බවද, මුළු එතනොල් නිෂ්පාදනය 26.5% ක සාමාන්‍ය ප්‍රමාණයකින් වැඩිවූ බැවිද පෙනී ගියේය. මෙම NH_4^+ අයන සාන්ද්‍රනයේදී, හයිඩ්‍රජන් සල්ෆයිඩ් සෑදීමද මුළුමනින්ම මර්දනය විය. නිරීක්ෂණය කරන ලද ප්‍රතිඵල වල සංඛ්‍යානමය වැදගත් කම අධික බැව් සංඛ්‍යානමය විශ්ලේෂණයෙන් හෙලි විය.

තල් *(Borassus flabellifer)* L ගසෙහි ධූලක විද්‍යාව පිළිබඳ අධ්‍යයන III. දිගු කාලයක් තල්පිටි වලින් පෝෂණය කිරීමෙන් පසු මීයන් තුළ මාත්සරික ලිම්ෆෝමාවන් හටගැනීම

එස්. එන්. අර්සකුලරත්න සහ ආර්. ජී. පානබොක්කෙ

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ඇතැම් ආසියානු සහ අප්‍රිකානු රටවල මිනිසුන් විසින් අනුභව කරනු ලබන තල්පිටි, මීයන් තුළ දරුණු සහ නිදන්ගත ධූලක බලපෑම් හටගන්වන බැව් මීන් පෙර වාර්තාවී ඇත.

කෙලින්ම 20% ක් තල්පිටි අන්තර්ගත ආහාර කවන ලද මීයන් තුල හෝ තල්පිටි වලින් පෝෂණය කරන ලද මීවිවියන්ගෙන් උපන් මීයන් තුල හටගත් නියෝ ප්ලාස්මයන්හි ලක්ෂණ මෙම වාර්තාවෙන් විස්තර වෙයි. වැඩි වශයෙන්ම දක්නට ලැබුණු අර්බුදය නම් විවිධ ප්‍රමාණයට විවික්තකරණය වූ තනි හෝ බහු මාත්සරික ලිම්ෆෝමාවන්ය. මෙවා ප්‍රධාන වශයෙන්ම පිහිටියේ කුඩා ආන්ත්‍රික අතුණුබහන්හිය. ඇතැම් අවස්ථාවල ප්ලිහාවට සහ වකුගඩුවලට ඇළුණු තයිමීය සහ පුප්ඵුසීය ලිම්ෆෝමාවන් සහ වසා සණ්ඨීකාවන්ද පැවතිණ. ග්‍රෛවීය තන්තුමය සාකෝමාවක්ද අග්න්‍යාශයික ආරම්භයකින් යුක්ත යැයි සිතිය හැකි අන්තර් උදරීය අර්බුදයක්ද මෙම කාණ්ඩයට අයත් විය.

අර්බුද සහිත මීයන් තිදෙනෙකුගේ පසුපස ගාත්‍රවල පක්ෂාඝාතය දක්නට ලැබිණ. ඔවුන් ගෙන් එක් මීයෙක් තුල නිෂ්තර්පන සුසුම්නාවක්ද විය.

මෙම පිටිවල ධූලක බලපෑම් ද, විශේෂයෙන්ම ප්‍රතිශක්ති හැකියාවේ අපේරණයන්ද මෙම අර්බුදයන්ගේ ව්‍යාධි ජනනයන් ආශ්‍රයෙන් සාකච්ඡා කරනු ලැබේ. මෙහිදී C වර්ගයන්ගේ වයිරසයන්ගෙන් ඉටුවිය හැකි නිදානමය කාර්යභාරය කෙරෙහි විශේෂ අවධානය යොමු කෙරේ.

අධික උෂ්ණත්ව සහ ආර්ද්‍රතා තත්වයන් යටතේ ජලභීතය මී ගවයින් වෙත බලපාන අයුරු

එන්. තිලකරත්න, එස්. එස්. ඊ. රණවන සහ ඒ. ශ්‍රී. කන්ද කුමාර්

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තම පැවැත්ම සඳහා සාමාන්‍යයෙන් අන් කෘෂිකාර්මික සතුනට වඩා ජලය අවශ්‍ය වන සතෙකි මී ගවයා. එහෙත් ශ්‍රී ලංකාවේ බොහෝ පෙදෙස් වල, විශේෂයෙන් වියළි කලාපයේ, අවුරුද්දේ වැඩි කාලසීමාවක් තුල ඇතිවන ජල භීතය නිසා මී ගවයින්ට ඉමහත් බාධකයන්ට මුහුණ පෑමට සිදුවේ. මෙම ලිපියෙන් විස්තර කෙරෙන්නේ පරිසර උෂ්ණත්වය සහ ආර්ද්‍රතාවය අධිකවූ වාතාවරණයක් යටතේ බීමට හා ලැගීමට අවශ්‍ය තරම් ජලය නොමැතිවීම මී ගවයින්ට බල පාන ආකාරය පිළිබඳ පරීක්ෂණයක ප්‍රතිඵල වේ. වැඩෙන අවස්ථාවේ (සාමාන්‍ය වයස — මාස 10) වැස්සියන් 5 ක්ද, ගැබ් හා කිරි දෙන අවස්ථා වල පසුවන දෙනුන් පස් දෙනා බැගින්ද පරීක්ෂණයට භාවිතය කරන ලදී. සතුන් සියල්ල පොල් වගාකොට ඇති ඉඩමක නිදැල්ලේ උලා කෑමට ඉඩහැර තිබූ අතර, ජලය සැපයීම අතින් පහත සඳහන් අවස්ථාවනට භාජනය කරන ලදී.

1. අවශ්‍ය තරම් බීමට ජලය සහ දිනකට පැය 1.5 ක් ජලයේ ලැගීමට ඉඩ හැරීම.
2. අවශ්‍ය තරම් බීමට ජලය සැපයූ නමුත් ජලයේ ලැගීමට ඉඩ නොදීම.
3. ජලයේ ලැගීමට ඉඩ නොදීම සහ බීමට ජලය සීමිත ප්‍රමාණයක් සැපයීම.

ඉහත සඳහන් එක් පරීක්ෂණ අවස්ථාවක් සති දෙකකින් සමන්විත වූ අතර, අවස්ථා දෙකක් අතර පරතරය එක් සතියක් විය. අධික ආර්ද්‍රතාවයක් යටතේ අධික උෂ්ණත්වයකට භාජනය වීමෙන් සතුනට ඇතිවන තාප පීඩාව සතුන්ගේ ශරීර මතුපිට සහ අභ්‍යන්තර උෂ්ණත්වය, ස්වසන වේගය, නාඩි වැටීමේ වේගය සහ ඩහදිය ගැලීමේ වේගය මැනීමෙන් නිගමනය කරන ලදී.

ඉහත දක්වෙන සියලුම කාර්යයන් වාතයේ උෂ්ණත්වය හා ආර්ද්‍රතාවය වැඩි වීමට අනුකූලව වැඩිවන බව දක්නා ලදී. සාමාන්‍ය පාළන ක්‍රමය යටතේ අධික උෂ්ණත්වය හා ආර්ද්‍රතාවය මගින්, වැඩෙන වයසේ සතුන් වැඩි ලෙස පීඩාවට පත්වන බව පෙනුණි. ජලයෙහි ලැගීමට නොහැරීම සහ බීමට ජලය සීමා කිරීමෙන් කාණ්ඩ තුනේම සතුන් වඩාත් තාප පීඩනයට ගොදුරු විය. තාප පීඩනයෙන් මිදීම සඳහා වැඩෙන සතුන් ස්වසන වේගය වැඩි කිරීමෙන් (හති දැමීමෙන්) තාපය පිට කිරීමට උත්සාහ කරන අතර, වැඩුණු සතුන්ගේ අමතර තාපය ඉවත් කිරීම කෙරෙනුයේ ඩහදිය හැලීමේ වේගය වැඩිවීමෙන් බව දක්නා ලදී.

fපිලරයිසියාව පිළිබඳ ගණිත ආදර්ශය

කේ. තෙන්නකෝන්

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fපිලරයිසියාවේදී මිනිසා — පරපෝෂිතයා — මදුරුවා අතර ඇති වන අන්තර් ක්‍රියාකාරිත්වය පිළිබඳ ආදර්ශයක්, අවකල සහ අනු-අවකල සමීකරණ පද්ධතියක් මගින් සූත්‍රකරණය කර ඇත. මානව සහ මදුරු සංගහනයන්හි ගුණිතය, අවධි අගයක් ඉක්මවූ විට, පද්ධතිය අස්ථායී වී කාලය ගතවීමත් සමග ආසාදක සංඛ්‍යාව සාතීය වශයෙන් වැඩිවී ස්පර්ශෝන්මුඛ ස්ථායී සමතුලිත තාවක් කරා ලඟාවන බැව් ආකෘතියෙන් පෙන්නුම් කෙරෙයි. මෙම ගුණිතය අවධි අගයට වඩා අඩුවූ විට, මූල ලක්ෂ්‍යය ස්පර්ශෝන්මුඛ වශයෙන් ස්ථායී වන අතර කාලයත් සමග ආසාදක සංඛ්‍යාව සාතීය වශයෙන් අඩු වෙයි. වෙනස්වන කාලගුණික තත්වයන් නිසා මෙකී ස්පර් ශෝන්මුඛ සමතුලිතතා දිශා දෙකින් කවර දිශාවකට හෝ රෝගය වැඩිදුර නොයන බව දක්වේ. ආදර්ශය සනාථ කිරීම සඳහා ශ්‍රී ලංකාවේ දකුණු වෙරළබඩ තීරයේ fපිලරයිසියාව වැළඳීම් පිළිබඳ දත්තයන් ඉදිරිපත් කර ඇත. fපිලරයිසියාව දුරුකරලීම කෙරෙහි ආදර්ශයෙන් ඇතිවන බලපෑම් සාකච්ඡාවට භාජනය කර ඇත.

ශ්‍රී ලංකාවේ, මධ්‍යම පළාතේ, ස්ත්‍රීපුර ගුහාවෙහි වායුගෝලයේ කාබන් ඩයොක්සයිඩ් සාන්ද්‍රණය

වී. බස්නායක

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ශ්‍රී ලංකාවේ ස්ත්‍රීපුරහි පිහිටි බොහෝ දුරට තිරස් C හැඩයෙන් යුත් හුණුගල් ගුහාවක වායු ගෝලයේ CO_2 සාන්ද්‍රණය, ගුහාවෙහි වැසුනු කෙළවරෙහි 3% කට ආසන්නවූ ප්‍රමාණයක සිට විවරවූ කෙළවරෙහි 0% ක් දක්වාවූ අනුක්‍රමණයක් පෙන්වීය. සෑම ස්ථානයකම O_2 සාන්ද්‍රණයන් 18% ට වැඩි විය. ගුහාව ඇතුලතදී ඇතිවන දෘශ්වසනය එක්තරා දුරකට හයිපර්කැප්නියාව නිසා ඇතිවන්නක් බැව් පෙනී යයි. ගුහාවෙහි ඇතැම් ස්ථානයන්හි දැඩි දෘශ්වසනය ඇතිවීමට සම්පූර්ණ හේතු තවමත් සොයාගත යුතුව ඇත.

එජ්පාවල ඇපටයිට්වල ප්‍රයෝජ්‍ය කරගත හැකි ෆොස්ෆරස් ප්‍රමාණය වැඩි කිරීම පිළිබඳ මූලික පරීක්ෂණාගාර අධ්‍යයනය

සි. එස්. වීරරත්න

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එජ්පාවල ඇපටයිට්වල ප්‍රයෝජ්‍ය කරගත හැකි ෆොස්ෆරස් ප්‍රමාණය වැඩි කිරීම පිණිස මූලික පරීක්ෂණ පවත්වන ලදී. 2% ක් සත්ව පොහොර හෝ පිදුරු හෝ ගෙන්දගම් මිශ්‍රකළ ඇල්ටි සොල් (රතුවන් දුඹුරු ලැටසොලික් පස්) වර්ගයක සහ ඇල්ෆිසොල් (රතුවන් දුඹුරු පස්) වර්ගයක නියැදි වෙන වෙනම ගෙන 50% ක ක්ෂේත්‍ර ධාරිතාවයේදී හෝ ජලයේ ගිල්වූ තත්වය යටතේ බීජෝෂණය කරන ලදී. ජලයේ නොගිලුනු තත්වයන් යටතේ, පිදුරු සහ සත්ව පොහොර වලින් ඇපටයිට්වල ෆොස්ෆරස් මුක්තිය වැඩිවන බැව්, බීජෝෂණය කළ නියැදි වල ඔල්සන් ගේ ෆොස්ෆරස් හෙවත් සෝඩියම් බයිකාබනේට් නිස්සාරණය කරගත හැකි ෆොස්ෆරස් ප්‍රමාණය සති දෙකින් දෙකට මැණිමෙන් පෙනී ගියේය. ජලයේ ගිල්වූ තත්වයන් යටතේ ඵලදායී වූයේ සත්ව පොහොර පමණකි. පිදුරු වලින් කිසිදු සැලකිය යුතු බලපෑමක් ඇති නොවීය.

ශ්‍රී ලංකාවේ *Pseudomonas Solanacearum* **වල සනාල මැලවුම් රෝග කාරකයන්ගේ ජීවදර්ශ ව්‍යාප්තිය**

ජේ. එම්. ආර්. එස්. බණ්ඩාර

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ශ්‍රී ලංකාවේ විවිධ කෘෂි පාරිසරික කලාපයන්ගෙන් *Pseudomonas Solanacearum* විශේෂයේ රෝගකාරක වර්ග එකතුකර ගන ලදී. මෙහිදී හඳුනාගත්තේ ෆේජ්ටයිපින් ජීව දර්ශ අංක 2 හා 3 යනුවෙන් නම් කරන ලද ජීව දර්ශ දෙක පමණි. මධ්‍යම කඳුකරයේ වගා කරන ලද අර්තාපල් ශාක වලින් 2 වන ජීව දර්ශය වෙන් කරගන්නා ලද අතර, එය සෙල්සියස් අංශක 16° ට සීමා වූ බැව් පෙණින. සියළුම සොලනේසි කුලයේ හෝගයන්ට රෝග කාරකවූ 3 වන ජීව දර්ශය දිවයින පුරා විහිදි සැම් නියැදීම් ස්ථානයකදීම පාහේ වෙන් කර ගන්නා ලදී. තෙත් සහ වියළි කලාපීය දේශගුණික ප්‍රදේශයන් ජීව දර්ශනයන්ගේ ව්‍යාප්තිය කෙරෙහි කිසිදු බලපෑමක් ඇති නොකරන බැව් පෙණින.

කඳුරට වියළි කලාපයෙන් ලැබුණු *P. solanacearum* නියැදි රාශියකට මැලවුම් රෝගය ඇති කිරීම කෙරෙහි සහජගික බලපෑමක් ඇති කළ *P. marginalis* පැවති බැව් පෙනී ගියේය. *P. solanacearum* වල 4 වන ජීව දර්ශය හා සමාන ජීව රසායනික ප්‍රතික්‍රියාවන් *P. marginalis* මගින්ද පෙන්නුම් කෙරිණ.

ශ්‍රී ලංකාවේ ප්‍රාග් කේම්බ්‍රීය විජයන් සංකීර්ණයේ ඇතැම් ග්‍රැනයිට් සහ නයිස් වර්ගයන්ගේ වයනය පිළිබඳ අධ්‍යයනයන්

කේ. දහනායක සහ එච්. ඒ. එච්. ජයසේන

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ශ්‍රී ලංකාවේ ප්‍රාග් කේම්බ්‍රීය විජයන් සංකීර්ණයේ, මයික්‍රොක්ලයින් බොහෝ සෙයින් අන්තර්ගත වූ ග්‍රැනයිට් සහ නයිස් පාෂාණ වර්ග බහුලව පවතී. නිමජ්ජන ශිඛරයන්ගේ සහ නැමී වියුහ යන්ගේ හරය වශයෙන් පවතින මෙම පාෂාණ දේහයන්, පිහිටි පාෂාණ හා ආකස්මික වූත් අනුක්‍රමිකවූත් ස්පර්ශයන් පෙන්නුම් කරයි. මෙම ග්‍රැනයිට් සහ නයිස් පාෂාණ දේහයන්, මැග්මැටික සහ දේහාන්තරණ මූලාරම්භයන්ගෙන් යුක්ත වන බැව් ඒවායේ වයනය පිළිබඳව කළ අධ්‍යයනයන්ගෙන් හෙළි වෙයි.

ශ්‍රී ලංකාවේ ඇති විවිධ වර්ගයේ දහයියාවල භෞතික හා රසායනික ගුණාංග පිළිබඳ අධ්‍යයනයන්

එම්. ජී. එම්. යූ. ඉස්මායිල්, ඩී. ආර්. කේ. ලොකුලියන සහ ආර්. පී. ගුණවර්ධන

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වී කෙටීමේ අතුරු නිෂ්පාදනයක් වශයෙන් බිහිවන දහයියා බොහෝ දුරට අපතේ යන ද්‍රව්‍යයකි. මෙම දහයියා කර්මාන්ත රාශියක් සඳහා අමු ද්‍රව්‍යයක් වශයෙන් භාවිතා කළහැකි බැව් පෙනී ගොස් ඇත. දහයියා උපයෝගීකරණය වැඩි දියුණු කිරීමට, එහි භෞතික සහ රසායනික ගුණාංග අධ්‍යයනය කිරීම අත්‍යාවශ්‍ය වෙයි. මෙහි වාර්තා වන අධ්‍යයනයේදී එකිනෙකට වෙනස් දහයියා වර්ග හයක, භෞතික සහ රසායනික ගුණාංග පරීක්ෂාවට භාජනය කර ඇත.

විවිධ වී ඇට වර්ග හඳුනා ගැනීම් සඳහා, ඇටයේ බාහිර පෙනුම, ප්‍රමාණය සහ බර මෙහෙවින් වැදගත් වෙයි. දහයියා ග්‍රෑම් එකක කැලරි අගය, කැලරි 4127 ක් වන බැවින් එය ඉන්ධන වර්ගයක් වශයෙන් භාවිතා කිරීමේ හැකියාව ඇත. දහයියාවල විශිෂ්ඨ ගුරුත්වය සහ තොග ඝනත්වය පිළිවෙලින් 1.32 සහ ඝන සෙ. මීටරයට ග්‍රෑම් 165.3 කි. එහි බරින් 9.94% ක් එහි ප්‍රධාන අතෙනෙන්ද්‍රිය සංරචකය වන සිලිකා වෙයි. විවිධ දහයියා වර්ගවල තෙතමනය, ජෛවද්‍රව්‍ය K_2O, Na_2O, CAO, MgO, Al_2O_3, Fe_2O_3, MnO, P_2O_5, SO_3 සහ Cl පිළිවෙලින් 9.4% 87.8%, 0.69%, 0.027%, 0.081%, 0.09%, 0.183%, 0.014, 0.034%, 0.24%, 0.082% සහ 0.007% වෙයි. විවිධ දහයියා වර්ගවල මෙම සංරචකයන් අතර වෙනස්කම් ඇති බැව් නිරීක්ෂණය කර ඇත. පසෙහි තත්වය, භාවිතා වන පොහොර වර්ගය, දේශගුණික තත්වය යනාදිය මෙම වෙනස්කම් වලට හේතු වේ යයි සලකනු ලැබේ. දහයියාවල ස්ඵටික සිලිකා අන්තර්ගත වන බව, ඉලෙක්ට්‍රෝන අපික්‍රොස්කොපික පරිලෝකනයෙන් සහ අන්තර් තාප විශ්ලේෂණයෙන් සොයා ගන්නා ලදී. එහෙයින් පොසොලැනික සිමෙන්ති වර්ග සැදීම් සඳහා දහයියා පාවිච්චි කළහැක. එහි ඇති අස්ඵටික සිලිකා, අධික උෂ්ණත්වයන්හිදී ස්ඵටිකමය ස්වරූපයකට පත්වෙයි. සක්‍රිය දහයියා ලබාගැනීම පිණිස, දහයියා සෙ. 700° උෂ්ණත්වයක් යටතේ දැවිය යුතු බැව් මෙයින් පෙන්නුම් කෙරෙයි.

ශ්‍රී ලංකාවේ තෝරියම් බහුල මොනසයිට් අගමි නිධි වල ජානය

එම්. එස්. රූපසිංහ, වී. ගොට් සහ සී. බී. දිසානායක

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ශ්‍රී ලංකාවේ මොනසයිට් අගමි නිධි, ලෝකයේ වැඩි වශයෙන්ම තෝරියම් අන්තර්ගත අවසාදිත අතරට ගැනෙයි. ශ්‍රී ලංකාවේ ගිණිකොනදිග ප්‍රදේශයක ගංගා අවසාදිත සහ පාෂාණ පිළිබඳව කරන ලද මෙම අධ්‍යයනයෙන් තෝරියම් බහුල මොනසයිට් වලට ප්‍රභව පාෂාණ වන්නට ඇත්තේ ශ්‍රී ලංකාවේ ප්‍රාග් කේම්බ්‍රිය සංකීර්ණයේ උස්බිම් සහ ගිණිකොනදිග කාණ්ඩ වල බෙහෙවින් විපරිතවූ ඇලුමිනිය සිස්ට සහ නයිස් වර්ගත් ග්‍රැනයිටාභ පාෂාණ වර්ගත් බැව් පෙනී යයි. ග්‍රැනියුලයිට් පරිදර්ශී තත්වයන් යටතේ හටගත් තියුණු වැලිවැටීමේදී සහ විපර්යාසයන්හිදී පැතිරුණාවූ ඇලුමිනිධර මැග්මැටික තරලවල, තෝරියම් බහුලවී යයි සැළකේ. විපර්යාසයේ P—T තත්වයන්, මැණික්, මොනසයිට් සහ ඒ ආශ්‍රිත බර බනිජ වර්ග ඇතුළු විවිධ මැණික් බනිජ වර්ග රාශියක් සෑදීම සඳහා ඉතාම යෝග්‍ය බැව් ඔප්පු විය.

කුඩු කරන ලද කළු ගම්මිරිස් ගබඩාකර (කුඩා ඇසුරුම්වල) තැබීමෙන් ඒවායේ අන්තර්ගත දුස්ස්‍රාවී තෙල් සහ පිපරින් ප්‍රමාණය කෙරෙහි ඇතිවන බලපෑම්

ඊ. වී. පාකෘසෝනි, එස්. බාලචන්ද්‍රන් සහ ඊ. ආර්. ජෑන්ස්

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ශ්‍රී ලංකාවේ කළු ගම්මිරිස් වල සගන්ධ තෙලෙහි සංයුතිය සහ ගම්මිරිස් කුඩුකර විවිධ ද්‍රව්‍යයන් ගෙන් තැනූ ඇසුරුම් වල අසුරා ගබඩා කර තැබීමේදී සංයුතියෙහි සිදුවන වෙනස්වීම් මෙයින් විමර්ශනා වෙයි.

ෆිපරික් මොලිබ්ඩේට් වල, අර්ධ සන්නායකයක සිට ලෝහයක් දක්වා ඇතිවන සංක්‍රමණය

කේ. තෙන්නකෝන් සහ ඩබ්ලිව්. ජී. ඩී. ධර්මරත්න

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මෙම ලිපියෙන් ෆිපරික් මොලිබ්ඩේට්වල සන්නායකතා ලක්ෂණ අධ්‍යයනය කෙරෙයි. සෙ. ග්‍රෙ. 139° දී මෙම ද්‍රව්‍යය, අර්ධ සන්නායකයක සිට ලෝහ දක්වාවූ සංක්‍රමණයකට භාජනය වන බව පෙනී යයි.

ගම්මිරිස් *(Piper nigrum L.)* වල අන්තර් ගත පිපරින් ප්‍රමාණය නිර්ණය කිරීම

ඊ. ආර්. ජෑන්ස්, අයි. සී. පතිරණ සහ ඊ. වී. පාක්‍යසෝති

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පිපරීන් අන්තර්ගතය නිර්ණය කිරීම සඳහා දැනට ප්‍රචලිතව ඇති වර්ණාවලි දීප්තිමාන ක්‍රමයෙන් ලැබෙන ප්‍රතිඵල වලට බෙහෙවින් සමාන ප්‍රතිඵල ගෙන දෙන්නාවූ, tlc—uv සනත්වමිතිය පදනම් කරගත් නව ක්‍රමයක් මෙම නිබන්ධනයෙන් ඉදිරිපත් කරනු ලැබේ. වෙළඳාම් පිණිස ඇති ඉන්දීය, මලයාසියානු සහ වෙනත් වර්ගවල ගම්මිරිස් වලට වඩා 2 - 6 ගුණයකින් පමණ වැඩිවූ අධික පිපරින් ප්‍රමාණයක් (7 - 15%) ශ්‍රී ලංකාවේ ගම්මිරිස් වල අන්තර්ගතවන බව මෙම අධ්‍යයනයේ ප්‍රතිඵල වලින් සනාථ වේ. විශ්වාසදායී විශ්ලේෂණාත්මක ක්‍රම උපයෝගී කර ගනිමින් ශ්‍රී ලංකාවේ ගම්මිරිස් වල අධික පිපරින් අන්තර්ගතය පිරික්සෙන පර්යේෂක අන්තර්ගත ප්‍රථම වාර්තාව මෙයයි.

1. தென்னங் கள்ளில் ஐதரசன் சல்பைட்டு உருவாதலைக் கட்டுப்படுத்தி எத்தனோல் விளைச்சல் அதிகரித்தல் — களப் பரிசோதனைகள்

ஏ. டபிள்யூ. லியனகே, டீ. ஜே. அபேரத்தினை, எம். ஆர். ஹெட்டி ஆராச்சி, கே. டீ. எல். குணதிலக்கா, ஜீ. ஜீ. வீரவன்சா, பீ. எம். ஜயதிஸ்ஸ

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கள் நொதி அனுசேபத்துக்கான நைதரசன் மூலம் என்ற வகையில் அமோனியம் உப்பு சேர்க்கப்படுவதன் காரணமாக ஐதரசன் சல்பைட்டு உருவாதல் முற்றுகவே பாதிக்கப்பெற்று எத்தனோல் விளைச்சல் அதிகரிக்குமென்ற காண்பு முடிவினை பரீட்சிப்பதற்குக் களநிலை ஆய்வுகள் மேற்கொள்ளப்பட்டன, சாதாரணக் கள் இறக்கல் நிலைகளின் கீழ் நான்கு களப் பரிசோதனைகள், மேற்கொள்ளப்பட்டன. கள் இறக்க முன்னர் சேகரிப்புப் பாத்திரத்துக்குள் NH_4^+ அயன் 0.08% (W/V) செறிவுகொண்ட அமோனியம் உப்பு சேர்க்கப்பட்டதன் பின்னர் கள்ளின் எத்தனோல், உள்ளடக்கம் 12.5% ஆலும் மொத்த எத்தனோல் விளைச்சல் 26.5% சராசரியாலும் அதிகரிக்குமென்பது கண்டறியப்பட்டது. இந்த NH_4^+ அயன் செறிவு நிலையில் ஐதரசன் சல்பைட்டு உருவாதலும் முற்றுகவே பாதிப்புற்றிருந்தது இப்பெறுபேறுகள் அதியுயர் புள்ளிவிவரச் சிறப்புடையனவென்பது புள்ளி விவர ஆய்வினால் புலனாகியது.

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2. பனைமர (*Borassus flabellifer*) நச்சியல்பு பற்றிய ஆய்வுகள்

III கொட்டைக் கிழங்கு மா நெடுதூட்டப்பெற்ற எலிகளில் திங்கிழை நிணயக் கட்டிகள் உருவாதல்

எஸ். என். அரசகுலரத்தினை, ஆர். ஜீ. பானபொக்கே

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சில ஆசிய, ஆப்பிரிக்க நாடுகளில் மக்கள் உணவாக அருந்தப் பெறுகின்ற கொட்டைக் கிழங்கு மா எலிகளுக்கு ஊட்டப்பெற்றால் தீவிர, நாட்பட்ட நச்சுத் தன்மைகளை ஏற்படுத்துகிறதென இதற்கு முன் அறிக்கையிடப் பெற்றுள்ளது.

நேரடியாக 20% மா கலக்கப்பெற்ற உணவினை ஊட்டிய அல்லது பனைமா ஊட்டப் பெற்ற பெண் எலிகளின் வழித்தோன்றிய எலிகளில் ஏற்பட்ட புது விளைசல்களின் (neoplasins) சிறப்புக் கூறுகள்பற்றி இந்த அறிக்கையில் விளக்கம் கொடுக்கப்பட்டுள்ளது. பல்வேறு அளவுகளைக்கொண்ட தனிநிலை

அல்லது பல்நிலைத் தீங்கிழை நிணயக் கட்டிகள் பெரும்பாலும் ஏற்பட்டிருந்தன, அவை பொதுவாகச் சிறுகுடல் நடுமடிப்புகளில் தோன்றியிருந்தன. எலிகள் சிலவீற்றில் தைமசு, நுரையீரல் நிணயக் கட்டிகள் ஏற்பட்டிருந்தன. இன்னும் சில எலிகளில் மண்ணீரல், ஊறுநீரிகளைச் சேர்ந்த கணுக்களில் நிணயக் கட்டிகள் ஏற்பட்டிருந்தன. கழுத்து பைப்புரோ - சாக்கோமா நோய்வாய்ப்பட்ட எலி யொன்றும் சதையின் மூலமாக ஏற்பட்டதெனக் கருதத்தக்க உள் வயிற்றுக் கழலையம் கொண்ட எலியொன்றும் இவைகளுட் காணப்பட்டன.

கழலையம் ஏற்பட்டிருந்த மூன்று எலிகளின் பின் உறுப்புக்கள் பாரிசவாதத் தினால் செயலற்றுக்கிடந்தன. ஓர் எலியின் முண்ணுண் நலிவுற்றிருந்தது.

கொட்டைக் கிழங்கு மாவின் நச்சுத் தன்மைகள், குறிப்பாக, பாதியாதாக் கத் திறன் சார் நிலை மாறல்கள் ஆகியவை சி—வகை வயிரசுக்களின் நோய்காரணச் செல்வாக்கோடு ஒப்புநோக்கி இக்கழலையங்களின் நோய்த் தோற்றுவியலுடன் அலசி ஆராயப்பட்டுள்ளன.

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3. வெப்பப் புழுக்கமுள்ள சூழலில் மேய்க்கப்பெற்ற வளர்ப்பருவ, பால் கொடுப்பருவ, சூல்ப்பருவ எருமை மாடுகள் நீர்த்தடை வரம்புக்கு ஆளாக்கப்பட்டதன் விளைவுகள்

என். திலகரத்தினை, எஸ். எஸ். ஈ. ரணவனை, ஏ. ஸ்ரீ கந்தகுமார்

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காற்று, வெப்பநிலை = 27.6 - 32.8°C ஆக அமைந்த வெப்பத்தையும் சார்பு ஈரப்பதன் = 62 - 84% ஆக அமைந்த ஈரத்தன்மையையும் கொண்ட சூழலில் குடி நீர்த் தடை வரம்புக்கு ஆளாக்கப்பெற்ற எருமை மாடுகளின் வெப்ப அழுத்த உடலியல் சுட்டிகள் சிலவற்றின் விளைவுகளை சோதிப்பதற்குப் பரிசோதனையொன்று மேற்கொள்ளப்பட்டது. சூர்தி எருமை இனம் சார்ந்த வளர்ப் பருவத்தைச் சேர்ந்த (சராசரி, வயது 10 மாதங்கள்) ஐந்து பசுக்கன்றுகளும் பால்கொடுப் ட்ருவத்தைச் சேர்ந்த (சராசரி பால் விளைச்சல் 5 லீட்டர்/நாள் ஒன்றுக்கு) ஐந்து பால் மாடுகளும் சூல்ப்பருவத்தைச் சேர்ந்த (கருக்கொண்டு 8-9 மாதங் கள் சென்ற) ஐந்து பசுக்களும் இளந் தென்னை மரங்களின் கீழ் மேயவிடப்பெற்று அடுத்தடுத்து வரும் மூன்று வாரகால வரையறைகொண்ட காலப் பகுதிகளில் மூன்று தொழிற்படவிடல்களுக்கு ஆளாக்கப்பட்டன. ஒவ்வொரு தொழிற்பட விடலும் எல்லாத் தொகுதிகளைச் சேர்ந்த விலங்குகளுக்கும் ஏக காலத்தில் மேற் கொள்ளப்பட்டது. பொதுப் பண்ணை முகாமிப்பு எனப் பெயரிய I ஆம் தொழிற் படவிடலின்போது விலங்குகளுக்கு விருப்பம்போல நீர் குடிக்கும் வசதியும் நாள்தோறும் 1.5 மணிவரை சேற்றில் புரளும் வசதியும் அளிக்கப்பட்டன. II ஆம் தொழிற்படவிடலின்போது சேற்றில் புரள இடம் கொடுக்கப்படவில்லை. III ஆம் தொழிற்படவிடலின்போது குடிநீருக்குத் தடை வரம்பு விதிக்கப்

பட்டதுடன் சேற்றில் புரளவும் இடம் கொடுக்கப்படவில்லை. நாளில் பல முறை ஒவ்வொரு விலங்கினதும் நேர்குடல் மற்றும் தோல் வெப்பநிலை, சுவாசம், நாடித்துடிப்பு, தோல் ஆவியாகல் ஆகிய விகிதங்களை அளவிட்டு வெப்ப அழுத்தம் குறிக்கப்பட்டது.

ஆயப்பட்ட எல்லா உடலியல் மாறல்களும் 0700 மணி முதல் 1400 மணி வரை படிப்படியாக அதிகரித்துக்கொண்டுபோய் 1800 மணியளவில் குறைதல் உற்றன. நேர வினைவானது உயர் தனிச் சிறப்புடையதே (PL 0.001). பொதுப் பண்ணை முகாமிப்பின் கீழ், வளர்ப்பருவ ஈனுப்பெற்றங்கள் வளர்ந்த பசுக்களிலும் பார்க்க அதிக அழுத்தத்திற்கு உள்ளானவைகளாகக் காணப்பட்டன. சேற்றில் புரளல் மறுக்கப்பட்டமை காரணமாகவும் குடிநீர்த் தடை வரம்பு விதிக்கப் பட்டமை காரணமாகவும் வெப்ப அழுத்தம் பெரிதும் மாற்றமுற்றது. நேர்குடல் வெப்ப நிலை அதன் மூல நிலையிலிருந்து 0.9 - 12. °C சராசரி உயர்ச்சி கண்டது. நண்பகல் ஒரு நிமிடத்துக்கான சுவாச வீதம் அதன் மூல நிலையிலிருந்து 16-18 வரை உயர்ச்சியுற்றது. பின்னைய இரண்டு தொழிற்படவிடல்களின்போது குறிப்பிடத்தக்க தொகுதி வேறுபாடுகள் அவதானிக்கப்படவில்லை. I ஆம் தொழிற்படவிடலின்போது 310 ± 15 ஆக விருந்த சராசரி தோல் ஆவியாகல் வீதம் II, III ஆகிய தொழிற்படவிடல்களின்போது 271/15 g/m² ± மணி வரை குறைதலுற்றது. ஈனுப்பெற்றங்கள், பொதுவாக, குறைந்த தோல் ஆவியாகல் வீதத்தினையும் உயர் சுவாசித்தல் வீதத்தினையும் கொண்டனவாகக் காணப்பட்டன.

நிழலார் இடங்களில் இருந்தாலும் சூழ்ந்துள்ள வெப்பநிலை அதிகரிக்கும் போது எருமை மாடுகள் வெப்ப அழுத்தத்திற்கு ஆளாவனவென்பது இப்பெறு பேறுகளின்படி புலனுகும். சேற்றில் புரளும் வசதிகள் இன்மையாலும் குடி நீர்த் தடை வரம்பு விதிப்பதனுலும் இந்த அழுத்தம் தீவிர நிலை அடைகிறது. இளம் மாடுகள் சிலபோது நுரையீரலின் உதவியைக் கொண்டு ஆவியாக்கக் குளிர் நலத்தைப் பெறுகின்றன. வளர்ந்த எருமை மாடுகள் சேபு கால்நடைகளுக்கு ஒத்த வீதங்களில் தோலினூடாக ஈரப்பதன் இழக்கும் திறன்கொண்டனவாகக் காணப்பட்டன.

பிலேரியாசிசு கணித மாதிரியுரு

கே. தென்னகோன்

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பிலேரியாசிசு நோய் தொடர்பில் மனிதர் ஒட்டுண்ணி - கொசு இடைத் தாக்கத்துக்கான மாதிரியுருவொன்றுவகையீட்டு, தொகைவகையீட்டு சமன்பாடு களின் தொகுதியை ஆதாரமாகக்கொண்டு சூத்திரிக்கப்பட்டுள்ளது. மனித வினத்தினதும் கொசுவினத்தினதும் குடிநிலை அடர்த்திகளின் பெருக்கம் குறிப் பிட்டவொரு மாறுநிலைப் பெறுமானத்தைத் தாண்டிச்செல்லும்போது இத்

தொகுதி உறுதியில்லா நிலை அடைகிறது. அத்துடன் காலப்போக்கில், தொற்றுணிகளின் (infectives) எண்ணிக்கை அணுகு கோட்டுடனியலும் உறுதிச் சம நிலையை நோக்கியவாறு அடுக்குக் குறிமுறைக்கேற்ப அதிகரிக்கத் தொடங்குகிறது. இப்பெருக்கம் மாறுநிலைப் பெறுமானத்தைத் தாண்டிச் செல்லாமல் இருக்குமிடத்து ஆரம்பப் புள்ளி அணுகு கோட்டு முறையில் உறுதியான நிலையில் இருக்கும். அத்துடன் காலப் போக்கில் தொற்றுணிகளின் எண்ணிக்கை அடுக்குக் குறி முறைக்கேற்பக் குறைந்து செல்கிறது. மாற்றமடையுங் கால நிலையின் காரணமாக இவ்விரண்டு அணுகு கோட்டு சமநிலைகளை நோக்கி, அந்த நோய் அவ்வளவு தூரம் செல்லமாட்டாதென்பதை ஊகித்துணர முடிகிறது. இம் மாதிரியுருக்கு ஆதாரமாகக்கொண்டு இலங்கையின் தென்கரையோரப் பகுதியில் பிலேரியாசிசு நோய் வாய்க்கப்பெற்றவர்களின் தரவுகள் பயன்படுத்தப் பட்டுள்ளன. பிலேரியாசிசு நோய் ஒழிப்புக்கு இம்மாதிரியுரு எங்ஙனம் பயன் படுத்திக்கொள்ளலாமென்பது இக்கட்டுரையில் ஆராயப்பட்டுள்ளது.

இஸ்திரிபுரக் குகை வளிமண்டலத்தில் காணப்படும் காபன் ஈரொட்சைட்டுச் செறிவு—மத்திய மாகாணம், இலங்கை

வீ. பஸ்நாயக்கா

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இலங்கையில் இஸ்திரிபுரத்தில் அமைந்துள்ள பெரும்பாலும் கிடை C வடிவங் கொண்ட சுண்ணும்புக் கற்குகையின் உட்புற வளிமண்டலம் (குகையின் மூடப் பெற்ற பகுதி சுமார் 3% அளவில் இருந்து திறந்த பகுதி 0% அளவு வரை செல்லும்) CO_2 செறிவுப் படித்திறன் கொண்டுள்ளதெனத் தெரிகிறது. எல்லாப் பகுதிகளிலும் O_2 செறிவுகள் 18% க்கு மேற்பட்டனவாகக் காணப்பட்டன. குகையின் உட்புறத்தில் ஏற்படுகின்ற இடர்மூச்சுயா (மூச்சுத்திணரல்) அதிபர புகையுயா (Hyprocapnia) காரணமாகவும் ஏற்படலாமெனக் கூறலாம். ஆனால் குகையின் சிற்சில பகுதிகளில் நேருகின்ற தீவிர இடர்முச்சுயா எக்காரணம் கொண்டு ஏற்படுகிறதென்பது மேலும் ஆராயப்பட வேண்டியதாகும்.

எப்பாவலை அப்பரைற்றுக் கல்லில் இருந்து அதிகப் பொசுபரசைப் பெறுவது பற்றிய ஆரம்ப நிலை ஆய்வுகூடப் பரீட்சைகள்

சி. எஸ். வீரரத்தினை

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எப்பாவலை அப்பரைற்றுக் கல்லிலிருந்து அதிகப் பொசுபரசைப் பெறுவதுபற்றிய ஆரம்ப நிலை நுண்ணாய்வுகள் மேற்கொள்ளப்பெற்றன. செம்பூரான்கல் மணலான அல்டிசொல் மாதிரிகளும் செம்மண்ணிலான அல்டிசொல் மாதிரிகளும்

2% கால்நடை உரம் அல்லது வைக்கோல் அல்லது சல்பர் ஆகியவற்றுடன் கலக்கப்பெற்று 50% மென்மைபட அரைக்கப்பட்ட அப்பரைற்றுடன் கள உறிஞ்சல் நிலையில் அல்லது நீரில் மூழ்கடிக்கப்பட்ட நிலையில் வெவ்வேறுக நுண்மப் பெருக்கத்திற்கு உட்படுத்தப்பட்டன. இரண்டு வார இடைவெளிகளில் தீர் மாணிக்கப்பெற்ற நுண்மப்பெருக்கத்திற்காளான மண் மாதிரிகளின் ஒல்சன் P யின்படி நோக்குமிடத்து நீரில் மூழ்கடிக்கப்பட்ட நிலையில் வைக்கோல், கால்நடை உரம் ஆகியவை அதிக பொசுபேற்று விடுவிப்பிற்குக் காரணமாயின வெனத் தெரிந்தது. நீரில் மூழ்க்கடிக்கப்பட்ட சூழலில் கால்நடை உரம் மாத் திரம் பயன் விளைவித்தது. வைக்கோல் அவ்வளவு செல்வாக்குடையதெனத் தெரியவில்லை.

இலங்கையில் "சூடோமோனஸ் சொலனேசீரும்" *(Pseudomonas solanacearum)* என்னும் கலனவாடல் நோய் ஈனியின் உயிரின வகைப் பரம்பல்

ஜே. எம். ஆர். எஸ். பண்டாரா

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இலங்கையின் பல்வேறு கமச்சூழல் பிராந்தியங்களிலிருந்து — சூடோமோனஸ் சொலனேசீரும் கிமிது — எனப் பெயரிய நோய் ஈனி (Pathogen) யின் வகைகள் சேகரிக்கப்பட்டன. சென்சு. ஹேவர்ட் — அஃதாவது உயிரினவகை 2, உயிரின வகை 3 ஆகிய இரண்டு மட்டுமே கண்டுபிடிக்கப்பட்டன.

மத்திய மலைப் பிரதேசத்தில் வளர்க்கப்பெறும் உருளைக் கிழங்குத் தாவரத்தில் இருந்து உயிரினவகை 2 பிரித்தெடுக்கப்பட்டது. 16°C சம வெப்ப நிலையில் மாத்திரம் அது இருக்கிறது. உயிரின வகை 3 எல்லா சொலனேசஸ் இனப் பயிர் களிலும் நோய்களை உண்டுபண்ணுகிறது. தீவின் எல்லா மாதிரியெடுத்தல் இடங் களிலும் அது பிரித்தெடுக்கப்பட முடிந்தது. ஈர வலயம் மற்றும் உலர் வலயம் ஆகியவை உயிரினவகைகளின் பரம்பலுக்கு அவ்வளவு உதவவில்லை எனத் தெரி கிறது.

மலைநாட்டு உலர் வலயத்தில் இருந்த பல *P. solanacearum* மாதிரிகளில் *Pseudomonas marginalis* எனப் பெயரிய நோயீனிகள் இருந்தன. வாடல் நோய் உண்டுபண்ணுவதற்கு இவை ஒத்துழைக்கின்றன. *P. solanacearum* என்ற 4 வது உயிரின வகையின் உயிர் இரசாயனத் தாக்கத்திற்கு சமமான தாக்கம் *P. Marginalis* என்னும் நோயீனியும் கொண்டுள்ளது.

இலங்கையின் முற்கேம்பிரிய விசயன் பாறைச் சிக்கலைச் சேர்ந்த சில கருங்கல், நைசுப் பாறைகளின் இழைமை ஆய்வு

கபில தகநாயக்கா, எச். ஏ. எச். ஜயசேனு

J. Natn. Sci. Coun. Sri Lanka 1983 **11 (1):** 77 – 86

இலங்கையின் முற்கேம்பிரிய விசயன் பாறைச் சிக்கலில் மைக்குரோகிளீன் வள முள்ள கருங்கற்பாறைகளும் நைசுப் பாறைகளும் நிறையக் காணப்படுகின்றன. அமுங்கு குமிழ்களினதும் மடிப்புற்ற அமைப்புகளினதும் அகடுகளாக விளங்கு கின்ற இப்பாறைகள் சடுதியாகவும் படிமுறையாகவும் நாட்டுக் கற்பாறைகளுடன் ஒட்டிக்கொண்டுள்ளனவெனத் தெரிகிறது. கருங்கற்பாறை, நைசுப் பாறை ஆகியவற்றின் இழைமைகளை ஆராயுமிடத்து அவை மசினேத்தன்மயமாக்கல், அனுமூர்த்தத் திரிபு என்பவற்றின் காரணமாகத் தோன்றியுள்ளனவெனத் தெரிகிறது.

இலங்கையில் பெறுகின்ற பல்வேறு நெல் உமி வகைகளின் பௌதிக, இரசாயன இயல்புக்கூறுகள் பற்றிய ஆய்வு

எம். ஜீ. எம். யூ. இஸ்மயில், டீ. ஆர். கே. லொக்குலியனு, ஆர்.பி. குணவர்த்தனு

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அரிசி ஆலைத் தொழிலின் பக்க வினைவாகக் கிடைக்கும் நெல் உமியானது பெரும் பாலும் கழிவுப் பொருளாய்க் கொள்ளப்படுகிறது. ஆனால் பல கைத்தொழில்களுக் கான மூலப் பொருளாக நெல் உமி பயன்படுத்தப்படலாமென்பது கண்டறியப் பட்டுள்ளது. நெல் உமியின் உபயோகங்களைக் கண்டுபிடிக்க முன்னர் அதன் பௌதிக மற்றும் இரசாயன உடைமைகளை உய்த்துணரல் வேண்டும். ஆறு இனங் களைச் சேர்ந்த நெல் உமிகளின் பௌதிக மற்றும் இரசாயன இயல்புக் கூறுகள் இந்த பரிசோதனையின்போது ஆராயப்பட்டுள்ளன.

வெளித் தோற்ற அளவுகள், கூலமணிசார் நிறை ஆகியன பல்வேறு நெல் மணிகளை இனங்காண்பதற்குத் துணைபுரிகின்றன. நெல் உமியின் கலோரிப் பெறு மானம் 4127 cal/g ஆக இருப்பதனால் அது எரிபொருளாகப் பயன்படுத்தப் படலாம். அரிசி உமியின் தன்னீர்ப்பும் பருமை அடர்த்தியும் முறையே 1.32 ஆக வும் 165.3 g/..... ஆகவும் இருக்கின்றன. நெல் உமியின் பிரதான அசேதன வுறுப்புக் கூறு சிலிக்காவாகும். அதன் எடை 9.94% ஆகும். ஈரலிப்பு, சேதன வுறுப்புப் பொருள், K_2O, Na_2O, CaO, MgO, Al_2O_3, Fe_2O_3, MnO, P_2O_5, SO_3, Cl ஆகிய நெல் உமியிலுள்ள பல்வேறு பதார்த்தங்களின் எண்ணிக்கைகள் முறையே 9.4%, 87.8%, 0.69%, 0.027, 0.81%, 0.09%, 0.183%, 0.014%, 0.34%, 0.34%, 0.24% 0.082%, 0.007% ஆகும். வேறுபட்ட நெல் உமிவகைகளில் மேற்கூறிய கூறுகளும்

சிற்சில அளவு வேறுபாட்டுடன் அமைவதைக் காணலாம். இவ்வித்தியாசத்திற்குக் காரணம் மண்ணின் தன்மை, இடப்படும் உர வகைகளின் இயல்பு, காலநிலை மாற்றம் முதலியன ஆகும். அலகிடல் இலத்திரன் நுணுக்குக்காட்டி, வகையீட்டு வெப்பப் பகுப்பு ஆகியவற்றின் மூலம் நெல் உமியில் உருவமற்ற சிலிக்கா அடங்குவது கண்டறியப்பட்டுள்ளது. எனவே, பொசோலானிக் வகை சீமெந்துகளை உற்பத்தி செய்வதற்கு நெல் உமி பயன்படுத்தப்படலாம். உயர் வெப்பநிலைகளில் நெல் உமியின் உருவமற்ற சிலிக்கா பளிங்கு உருவம் அடைகிறது. செயல்திறமுடைய நெல் உமியைப் பெற்றுக்கொள்ள அது 700°C வெப்பத்தில் எரிக்கப்படல் வேண்டுமென்பது இதன் தாற்பரியம் ஆகும்.

இலங்கையில் தோரியம் வளமிக்க மொனசைற்றுப் படிவக அடையல்களின் தோற்றம்

எம். எஸ். ரூபசிங்கா, டபிள்யு. கோக்ட்; சி. பீ. திசாநாயக்கா

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இலங்கையிலுள்ள மொனசைற்றுப் படிவகங்கள் உலகில் முதற்தரமான தோரியம் வளமிக்க அடையல்களாகும், இலங்கையில் தென் மேற்குப் பகுதியொன்றில் உள்ள ஆற்று அடையல்களையும் பாறைகளையும் சோதித்துச் செய்த இந்த ஆய்வின்படி., இலங்கைப் புவிதளத்தின் முற்கேம்பிரியத் தொகுதி சார் மலைநாட்டுத் தென் மேற்குப் பகுதியைச் சேர்ந்த மிகுந்து உருமாற்றமடைந்த அலுமினிய சிசுற்றுப் பாறைகள், நைசுப் பாறைகள், கருங்கற் போலிப் பாறைகள் ஆகியவை தோரியம் வளமிக்க மொனசைற்று மூலப் பாறைகளாக அமைந்து இருக்கலாம், தீவிர மடிப்புகள் ஏற்பட்ட காலத்திலும் மணிப்பாறை முகவணிகள் உருமாற்ற மடைந்த காலத்திலும் அலுமினிய அடையல்களை ஊடுருவிச்சென்ற மசினை நீர்மங்கள் தோரியம் வளமிக்கனவாகக் கருதப்படுகின்றன. உருமாற்றத்துடன் தொடர்பு கொண்ட P-T சூழமைதிகள், மணிக்கல் மொனசைற்றும் ஏனைய பிற பாரமான கனிசங்களும் உட்பட்ட பல்வேறு மணிக் கனிசங்கள் உருவாதலுக்குப் பெரிதும் உகந்தனவென நிரூபிக்கப்பெற்றுள்ளன.

அரைத்த கறுப்பு மிளகின் ஆவிப்புறப்புள்ள எண்ணெய், பிபரின் உள்ளடக்கத்தின் மீது களஞ்சியத்திடுகை (சிறு கட்டுகளில்) யால் ஏற்படும் விளைவுகள்

ஈ. வி. பாக்கியசோதி, எஸ். பாலச்சந்திரன், ஈ. ஆர். ஜான்ஸ்

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இலங்கை கறுப்பு மிளகு ஆவிப்புறப்புள்ள எண்ணெயின் அமைப்பும் அரைத்தலின் பின்பும் பல்வேறு பொதி கட்டும் பொருள்களில் இட்டுவைக்கப்படுவதன் பின்னரும் அவ்வமைப்புக்கு ஏற்படுகின்ற மாற்றங்களும் இக்கட்டுரையில் விளக்கப்பட்டுள்ளன.

உலோகத் தாண்டல் குறைகடத்தியாக பெரிக்கு மொலித்தேற்று

கே. தென்னகோன், டபிள்யு. ஜீ. டீ. தர்மரத்தினே

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பெரிக்கு மொலித்தேற்றின் கடத்துதிறன் இயல்புக்கூறுகள் ஆராயப்பெற்றுள்ளன. 139C° வெப்பத்தில் இப்பொருள் உலோகத் தாண்டல் குறைகடத்தியாக மாற்றம் பெறுகிறதெனத் தெரிகிறது.

மிளகின் (*Piper Nigrum I*) பிபரின் துணிதல்

ஈ. ஆர். ஜான்ஸ், ஐ. கி. பத்திரன, ஈ. வி. பாக்கியசோதி

J. Natn. Sci. Coun. Sri Lanka 1983 **11 (1):** 129 – 138

இந்தக் கட்டுரையில் t/c-uv செறிவுமானி முறை அடிப்படையாகக்கொண்ட பிபரின் பரீட்சிக்கும் புதிய தொழினுட்பமுறையொன்று விளக்கப்பட்டுள்ளது. முன்னர் பயன்பாட்டிலிருந்த t/c-uv நிறமாலையொளிமானி முறையின் கீழ் பெறுகின்ற அதே தரவுகளை இப்புதிய தொழினுட்பமும் அளிக்கிறது. இவ்வாராய்ச்சி முடிவுகளின்படி இலங்கை மிளகு மிக்க பிபரின் உள்ளடக்கம் (7-15%) கொண்டதெனத் தெரிகிறது. அது இந்திய, மலேசிய மற்றும் பிற மிளகு வகைகளின் உள்ளடக்கத்தை விட 2-6 மடங்கு ஆகும். நம்பத்தகு பகுப்புத் தொழினுட்பத்தின் மூலம் இலங்கை மிளகின் உயர் பிபரின் உள்ளடக்கத்தை ஆய்ந்து கூறும் முழு நிறைவான தரவுகளைச் சமர்ப்பிக்கும் முதலாவது அறிக்கை இதுவாகும்.

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Research papers, Papers read at Symposia and Reviews may be submitted to the Editorial Board. Research papers should describe original investigations or technological achievements. Reviews should be critical evaluations of existing knowledge in a specialised field. The Journal also accepts short communications. They should be submitted if the results are of sufficient importance to merit publication in advance of a full paper.

Languages of Publication: Sinhala, Tamil and English.

Refereeing and Editing: All material submitted is examined by two or more referees prior to publication. Papers are edited to increase clarity and ease of communication. In preparation for the press, particular attention is paid to grammar and the conventions of the Journal with regard to symbols, illustrations, tables, references and nomenclature.

Manuscripts submitted for editorial consideration can be processed expeditiously if they conform from the outset to the style of the Journal. Authors are therefore advised to follow closely the form described in these instructions.

PRESENTATION OF MANUSCRIPTS

No maximum length contribution is prescribed but papers should be written clearly and concisely. All unnecessary textual matter, figures and tables must be eliminated. In general, the impersonal form should be used.

Supplementary material of a detailed nature, which is not essential in the printed paper, but may be useful to other workers, may be deposited with the Secretary. Such material will be made available to other scientists on request and a note to this effect should be included in the paper.

The paper should be reasonably subdivided into sections, and if necessary, sub-sections. The following pattern is suggested for Research Papers: (a) Introduction (b) Experimental (c) Results (d) Discussion (e) Conclusions (f) Acknowledgements (g) References. In many cases, two of sections (b), (c) and (d) can be combined. When a separate Discussion is used, it should not recapitulate the results but discuss their significance and relation to the object of the work and to the work of other people. Conclusions should not merely repeat preceding sections.

Special care must be taken in citing references correctly. Responsibility for the accuracy of these rests entirely with the authors. It is the author's responsibility to obtain written permission to reproduce material which has appeared in another publication.

FORM OF MANUSCRIPTS

Manuscripts should be submitted in **triplicate**—including the original typewritten copy — typed throughout in double spacing on one side of the paper only. Adequate margins should be left (4 cm) with liberal spacing at the top and bottom of each page. The typescript should be free of corrections.

Headings of major sections should be centred and sub-section headings should be placed on the left of the page. The complete set of headings and sub-headings in an article should be numbered following the style adopted in this Journal and the set should reflect the logical development of ideas.

Paging: Each page of the manuscript should be numbered and the name of the first author and page number indicated in the upper right-hand corner of the page.

The *first* page should contain the article title, the name(s) of the author(s) and name and address of the establishment where the work was carried out. In the case of co-authors, respective addresses should be clearly indicated. Female authors should include one of their given names. The title should be concise but informative. The first word of the title should preferably be one useful in indexing and information retrieval. Where a series of related papers is submitted, each individual paper should have the same general heading, followed by a series number and title of the part. Any footnote to the title should be given at the bottom of this page.

The *second* page should contain an abstract (of not more than 250 words) which should be a summary of the entire paper, not of the conclusions alone and intelligible without reference to the paper itself. The text should begin on page three and each subsequent major section—references, figure legends and table legends should begin on a new sheet.

The *last* page should contain (a) a note as to the number of manuscript pages, figures and tables, (b) proposed running title of less than 42 characters (letters and spaces) and (c) the name and mailing address of the person to whom the proofs should be sent.

Illustrations: All illustrations are considered as figures and each graph, drawing or photograph should be numbered in sequence with Arabic numerals. Authors must submit the original and two duplicates of each figure. Figure should be planned to fit the proportions of the printed page (12 x 17 cm).

Figures must be drawn in Indian ink on plain white paper or board or tracing paper, not larger than 20 x 30 cm. Drawings should be lettered with a lettering set; lettering should be kept large enough to be legible after a reduction of 50 to 60%. If this is not possible, all letters and numerals must be inserted clearly and lightly in blue pencil and not in ink.

Each figure should carry a legend so written that the general meaning of each illustration can be understood without reference to the text. The amount of lettering on a drawing should be reduced as far as possible by transferring it to the legend. Figure legends should be typed on a separate sheet and placed at the end of the manuscript.

Graphs should be plotted on white or blue-lined graph paper or tracing cloth; grid lines that are to be shown in the engraving should be inked in black. The caption of each axis should be lettered parallel to its axis. Each figure should be identified in the margin with author's name and figure number. The preferred position of all illustrations should be indicated in pencil in the manuscript.

Photographs: Half-tone illustrations should be included only when essential. Good glossy prints with sharp contrasts between black and white areas should accompany the manuscripts; they should not be attached to manuscript pages. The size should be such that when the print is reduced to the normal size for reproduction (12 × 17 cm maximum), the detail is still clear. Magnification should be indicated with a scale line on the photograph. The author's name and figure number should be given on the back of each photograph.

Tables should not repeat data which are available elsewhere in the paper. Each table should be typed on a separate sheet with due regard for the proportions of the printed page. They should be numbered consecutively with Arabic numerals. Tabulated matter should be clearly set out and the number of columns in each table should be kept as low as possible. Tables should have legends which make their general meaning clear without reference of the text and all table columns should have explanatory headings. Units of measure should be indicated in parentheses in the heading of each column. Vertical lines should not be used and horizontal rules used only in the heading and at the bottom. A one-column table may be up to 42 characters (letters and spaces) wide. A two-column table may be 90 characters wide. Footnotes to the tables are to be placed directly below the table and should be indicated by superscript lower-case italic letters (*a, b, c,* etc). Each table should carry on the back of the sheet the author's name and figure number. The preferred position of tables should be indicated in pencil in the manuscript.

References to the literature must be indicated in the text by a small superior number referring to the list of references which must be inserted on a separate sheet at the end of the paper. The list should be arranged in alphabetical order by author and numbered in Arabic numerals. All author's initials must be given after surnames. The year of publication should follow in parentheses. When journal articles are listed, the journal name should be abbreviated in accordance with the *World List of Scientific Periodicals* 1900-1960, 1972, 4th edn. London: Butterworths Scientific Publications. If the journal is not in the list, the name should be given in full. The abbreviated journal title should be underlined to indicate italic type, and followed by the volume number underlined with a wavy line to indicate bold type, the issue number in parentheses and then the inclusive pages. When books are listed, the order should be: author(s), year, book title, volume number, edition, pagination/inclusive pages, place of publication and publisher. When sections of a book are listed, the order should be: author (s) of section, year, the word *In* followed by author of book, book title, volume number, edition, inclusive pages, place of publication and publisher. The series title of a book should be given in parentheses after the publisher.

Examples:

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Book - SCHOKMAN, D. (1966) *Vegetable growing: local and exotic varieties,* 29 p. Colombo: Agriculture Department.

Section of Book - ZITNAK, A. (1973) *In Chronic cassava toxicity: proceedings of an interdisciplinary workshop, London, England,* 29-30 *January* **1973,** pp. 89-95. Ottawa: International Development Research Centre. (IDRC-00e).

Footnotes which are *indispensable* should be indicated in the text by small superior figures and listed on a separate page in the manuscript.

Abbreviations and Symbols recommended in the various parts of British Standard 1991: *Letter symbols, signs and abbreviations* should be used. Authors are encouraged to use the S. I. System of units (see description in British Standard PD 5686: *The use of S. I. Units).*

Authors whose papers contain mathematical expressions should submit a list of the symbol used carefully and clearly indicated for the guidance of the printer. This list will not appear in print.

Foumulae and Equations: Equations should be typewritten and *quadruple* spaced. They should be started on the left margin and the number placed in parentheses to the right of the equation.

Nomenclature: Scientific names of plants and animals will be printed in italics, and should be underlined in the manuscript. In the first citation, genus, species and authority must be given e.g. *Tylenchorhynchus claytoni* Steiner. In later citations, the generic name may be abbreviated to its initial letter. e.g. *T. claytoni.*

Special instructions in the fields of Physical, Chemical and Medical Sciences are available on applications to the Secretary.

Short Communications: The Journal may include a limited number of short communications. Authors should submit short communications only when they believe that rapid publication of their results is of the utmost importance. A short communication must not exceed 1,200 words, i.e. 4 pages of copy inclusive of illustrations and tables. Short communications should be complete in their own right and suitable for citation. The title should indicate the content clearly as these papers do not carry abstracts.

Proofs: Corrected galley proofs must be returned to the Secretary without delay as directed. Failure to do so will result in delay in publication. Correction of proofs by authors must be restricted to printer's and similar errors. They should be marked in pencil. Any modification of the original text is to be avoided. Responsibility for correcting proofs rests entirely on the authors though editorial assistance will be provided.

Reprints: 20 reprints will be supplied free of charge for each article. Additional reprints can be ordered on the reprint order form which will accompany the proofs.

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